DC Facility Consultation and Planning Guide

Foreword

- A data center (DC) is large in scale and complex in system structure. Based on service and management requirements, each related department will raise requirements on how to build a DC, where to build the DC, how much to invest, and how much to gain from the DC. Therefore, it becomes a very important issue for DC users to figure out how to sort out these different requirements scientifically, ensure the economical efficiency and reliability of the subsequent operation, and finally obtain the most appropriate overall solution.

Objectives

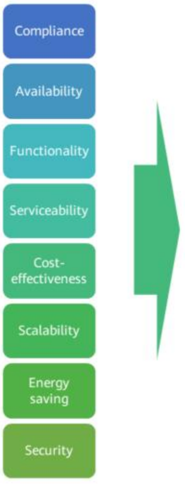
On completion of this course, you will be able to:

- Understand the overall DC planning and consultation service process.
- Know how to use the three DC assessment models.
- Be familiar with the approach for producing the DC site selection report and feasibility research report.

Contents

- Google DC at Hamina port, Finland.The low-temperature seawater is transported from the Gulf of Finland to the cooling station of the DC through the circulating pump. The heat exchanger exchanges heat between the seawater and the chilled water in the DC. The temperature of the seawater increases after the seawater absorbs heat
- Facebook DC in Oregon: It is located in the desert of Oregon in the US.The DC adopts various energy saving technologies, such as direct ventilation for free cooling, equipment room temperature improvement, double-layer ventilation structure, customized power modules unique battery rack and equipment rack design, power supply voltage improvement, and server virtualization technologies, to achieve a PUE of 1.07.
- The Apple Maiden DC is located in North Carolina, where a long sunshine duration, a preferential policy for environmental protection, and cheap land are available. The DC uses PV power generation as the main energy source, to achieve zero emission and earn LEED Platinum.
- Alibaba Cloud DC beside Qiandao Lake: The annual average temperature of the Qiandao Lake area is 17° C. The temperature of the deep water lake is constant all year round. The DC uses lake water cooling instead of air conditioner cooling for 90% of the year. The estimated annual average PUE of the DC is 1.3.
- Tencent Guizhou Qixing DC: The DC will be used to store Tencent's core big data in the future. The DC features high concealment, high protection, and high security. Five caves were cut in a hillside about hundreds meter long, with two square shafts at the top of each cave.

Factors to Be Considered in Requirement Analysis



External conditions

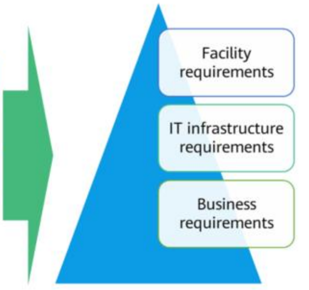
- Area, floor, and bearing capacity of each functional area in the equipment room
- Power supply and water supply environment
- Weather, transportation, geology...

Service requirements

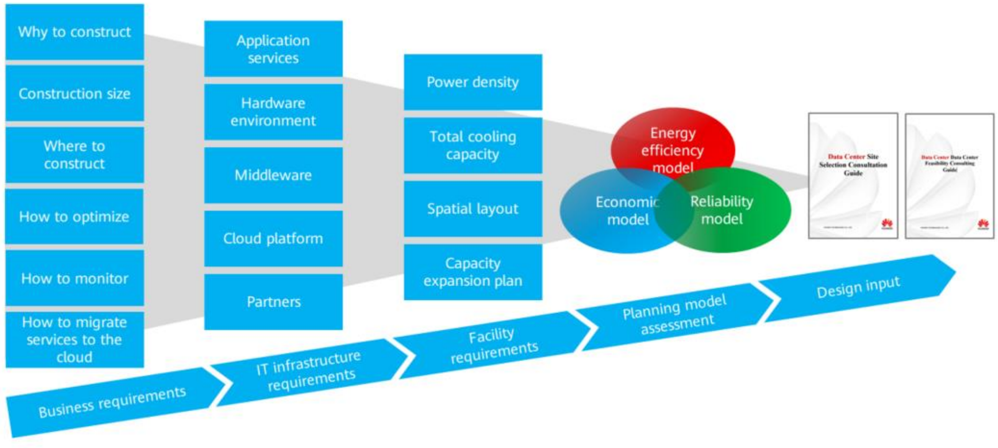
- Power density (equipment information)
- Business growth rate...

Customer expectations

- Energy saving objective (PUE)
- Construction level (Tier I–Tier IV, Class A/B/C)
- Initial scale, reservation for capacity expansion
- Resource usage (surface usage and cabinet space usage)
- Management requirements (management objects, linkage requirements, and proactive management)
- Display function (visualized O&M)...

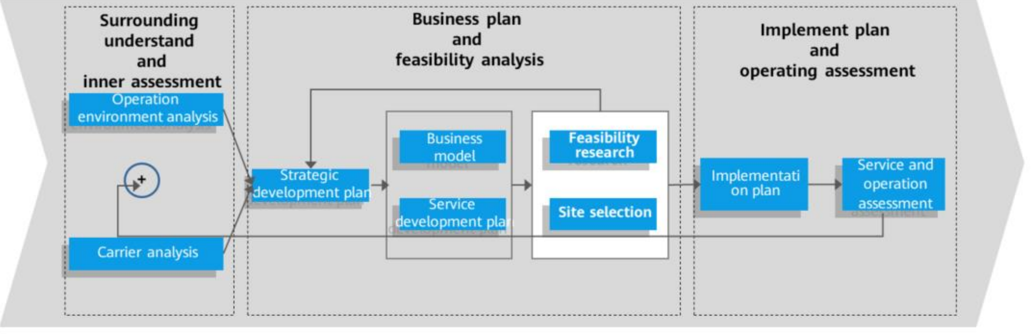


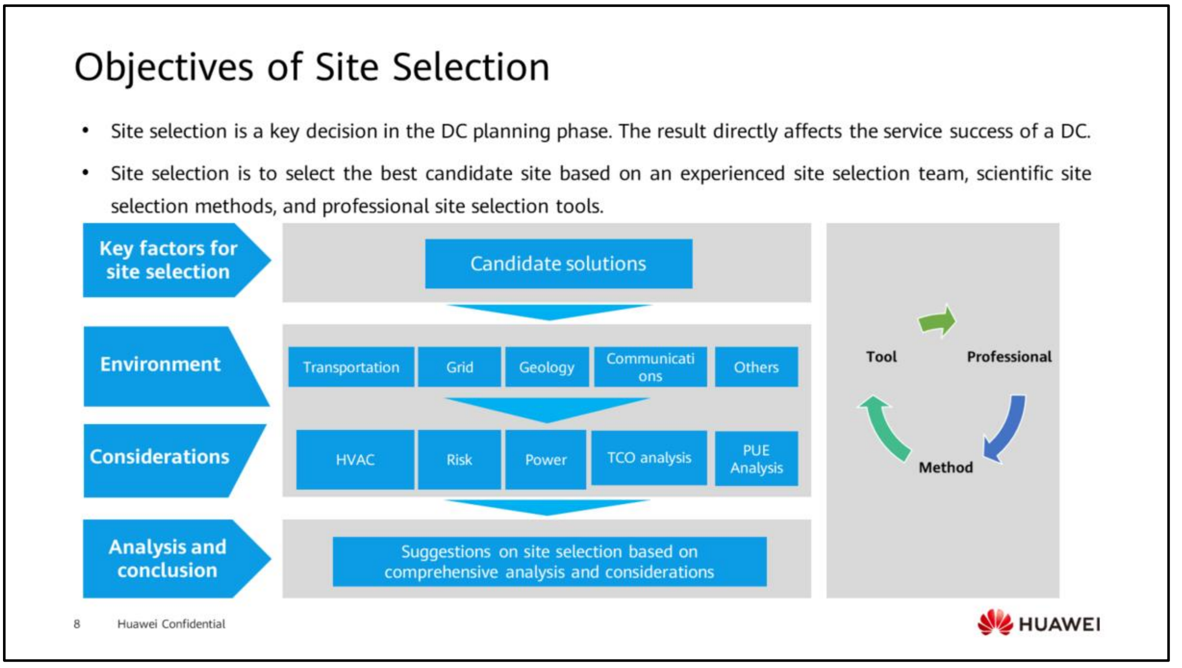
DC Requirement Analysis Methodology



DC Consultation and Planning Process

- The process from launch to project initiation for a DC involves a series of analysis and research, which is called the consultation phase. The feasibility research of the DC is also a task to be completed in this phase. Feasibility research is usually conducted after business consultation. The site selection and feasibility research are usually conducted in parallel and staggered. On one hand, the site selection result directly affects the technical solution of the DC. On the other hand, the requirements of the technical solution also affect the site selection.

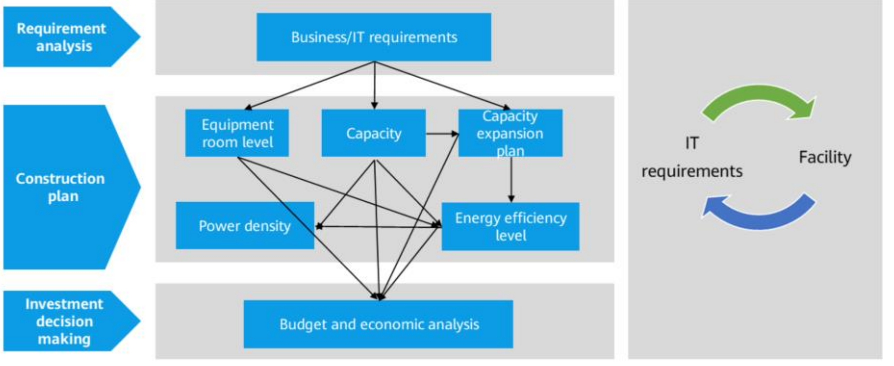




- Method
    - Process and methods for site selection consultation
    - Assessment standards for site selection consultation
    - Assessment system for site selection consultation
- Professional
    - Experienced site selection consultation team
    - Heating, ventilation and air conditioning (HVAC), heavy current, and weak current research team
- Tool
    - Global climate database
    - Other databases
    - Site selection consultation checklist

Objectives of Feasibility Research

- Feasibility research is the source of DC planning, design, and integration implementation. It analyzes factors that affect the project, such as technologies, laws, and regulations, determines whether the project is necessary and feasible, determines the technical solution to be used, and evaluates the economic and social benefits of the project, providing decision-making suggestions for project investors.



Contents

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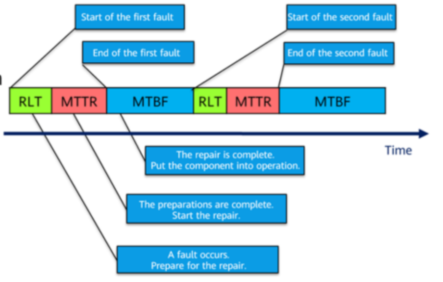
Reliability and Availability

- Failure rate: indicates the conditional probability that a component works normally before time t and becomes faulty after time t.
  - $\lambda = 1/MTBF$
- Reliability: indicates the probability that specified functions can be performed under specified conditions.
  - $R = e^{-\lambda}$
  - Serial system: $R(t) = R(1) \times R(2) = e^{-(\lambda 1 + \lambda 2)t}$
  - Parallel system: $R(t) = R(1) + R(2) - [R(1) \times R(2)]$,

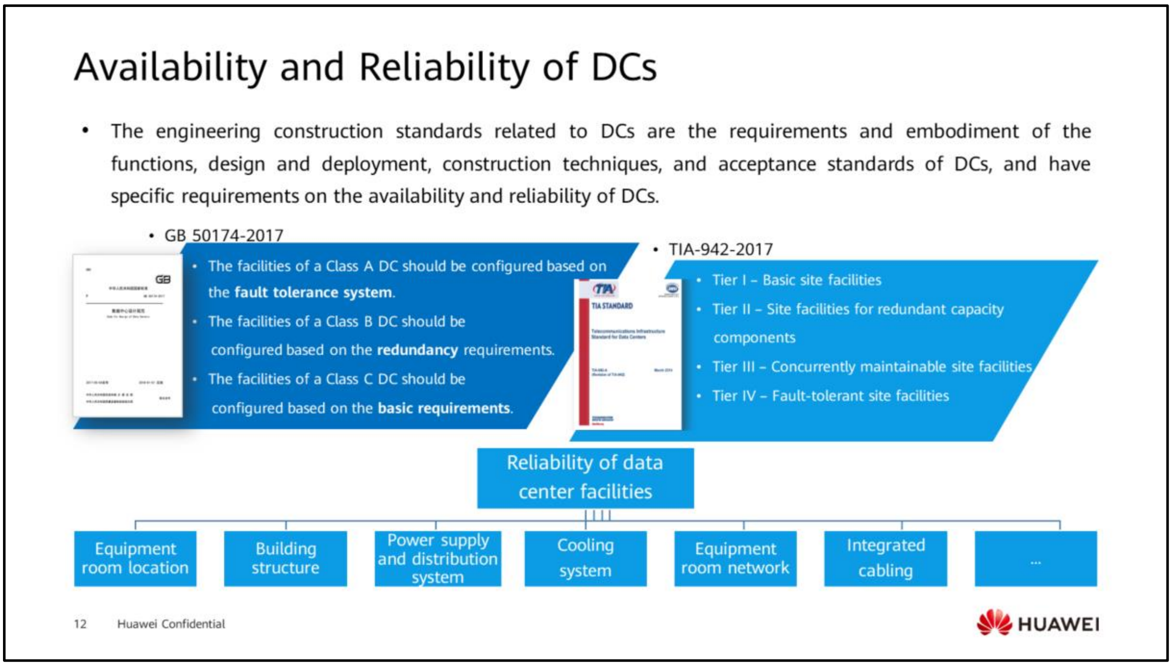
    $R(t) = e^{-\lambda 1t} + e^{-\lambda 2t} - [e^{-(\lambda 1 + \lambda 2)t}]$



- Availability: indicates the capability of performing specified functions under specified conditions at specified time or in a specified time range. It reflects the system reliability, repairability, and maintainability. Availability is usually represented by letter A.

$$\text{Availability} = \left(\frac{MTBF}{MTBF + RLT + MTTR}\right) \times 100\%$$

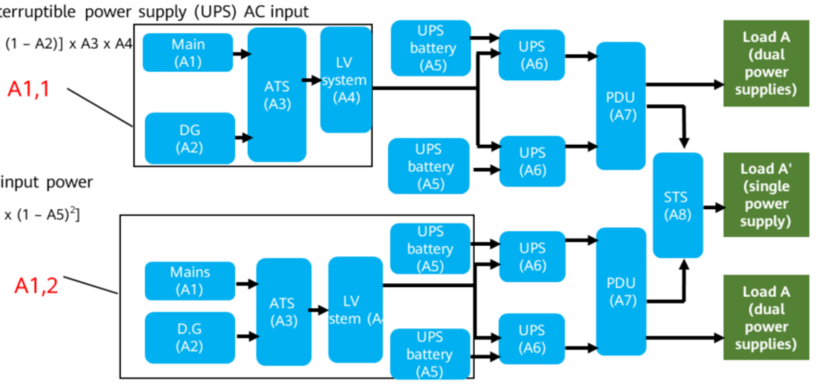
MTBF: Mean Time Between Failures
MTTR: Mean Time To Repair
RLT: Repair Logistics Time



- In this course, only the reliability models of the power supply and distribution system and cooling system are discussed.

Reliability Model of the Power Supply and Distribution System (1)

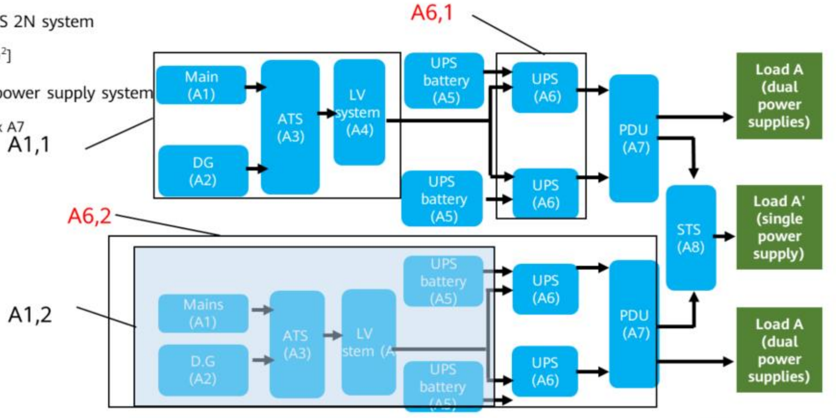
- The following uses the typical architecture of the power supply and distribution system in a Tier IV disaster recovery (DR) DC as an example.
- Availability of the uninterruptible power supply (UPS) AC input
  - $A_{1,1} = [1 - (1 - A1) \times (1 - A2)] \times A3 \times A4$
- Availability of the UPS input power
  - $A_{1,2} = [1 - (1 - A_{1,1}) \times (1 - A5)^2]$



- The Uptime class A DC power supply system consists of two mains power supplies, two backup power supplies, two LV power distribution systems, a UPS 2N system, and two PDU power distribution systems.

Reliability Model of the Power Supply and Distribution System (2)

- The following uses the typical architecture of the power supply and distribution system in a Tier IV DR DC as an example.
- Availability of the UPS 2N system
  - A6,1 = [1 – (1 – A6)^2]
- Availability of a bus power supply system
  - A6,2 = A1,2 x A6,1 x A7



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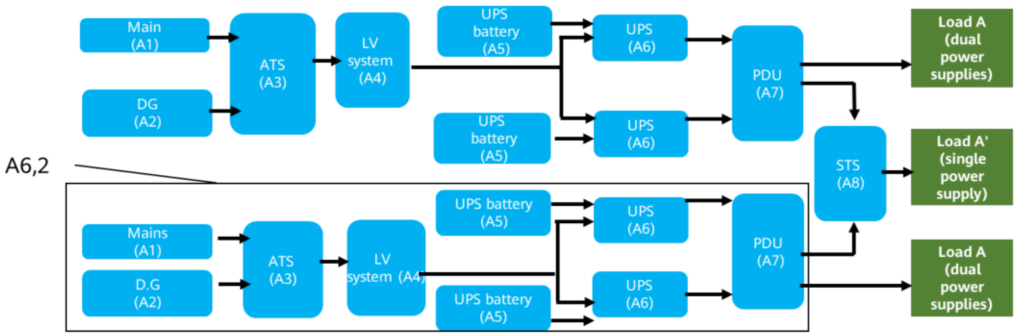
- A bus power supply system consists of the UPS input power supply, UPS 2N system, and PDU power distribution system.

Reliability Model of the Power Supply and Distribution System (3)

- The following uses the typical architecture of the power supply and distribution system in a Tier IV DR DC as an example.
- Therefore, the availability of the power supply system for key loads is as follows:
  - $A = [1 - (1 - A6,2)^2]$ (dual power supplies), A' = [1 – (1 – A6,2)2] x A8 (single power supply)



- The Uptime class A DC power supply system consists of two mains power supplies, two backup power supplies, two LV power distribution systems, a UPS 2N system, and two PDU power distribution systems.

Reliability Model of the Power Supply and Distribution System (4)

- Refer to the related data in the table. The following can be obtained through calculation:
  - Availability of the AC input power A1,1 = 0.9999 4144 6225 299
  - Availability of the UPS input power A1,2 = 0.9999 9999 9999 983
  - Availability of the UPS 2N system A6,1 = 0.9999 9999 7382 582
  - Availability of a bus power supply system A6,2 = 0.9999 9876 0808 568
  - Availability of key loads A = 0.9999 9999 9998 464 (dual power supplies), A' = 0.9999 9360 5155 464 (single power supply)

Reference values for the availability of major power supply subsystems and components

Subsystem	Power grid (A1)	Generator (A2)	ATS (A3)	LV power distribution system (A4)
Availability	0.9988 1458 3841	0.9999 3202 0398	0.9999 4378 0437	0.9999 9774 6241
Subsystem	UPS battery (A5)	Single UPS system (A6)	PDU power distribution system (A7)	STS (A8)
Availability	0.9999 8303 0881	0.9999 4883 9291	0.9999 9876 3426	0.9999 9360 5157

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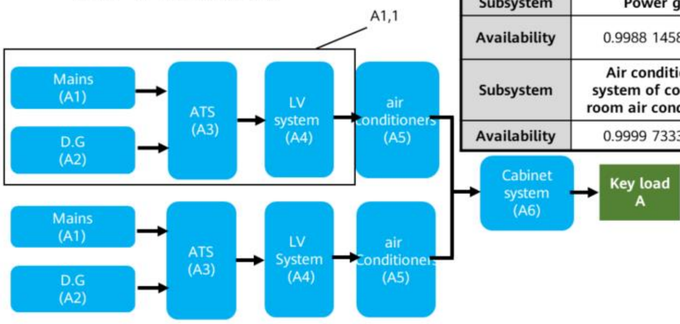
- The Uptime class A DC power supply system consists of two mains power supplies, two backup power supplies, two LV power distribution systems, a UPS 2N system, and two PDU power distribution systems.

Reliability Model of the Cooling System

- The following uses the typical architecture of the cooling system in a Tier IV DR DC as an example.
- Availability of the AC input power for each air conditioning system in the equipment room
  - A1,1 = [1 – (1 – A1) x (1 – A2)] x A3 x A4
- Therefore, the availability of the cooling system for key loads is as follows:
  - A = [1 – (1 – A1,1 x A5)^2] x A6

Reference values for the availability of major cooling subsystems and components

Subsystem	Power grid	Generator	High-power ATS
Availability	0.9988 1458 3841	0.9999 3202 0398	0.9999 4378 0437
Subsystem	Air conditioning system of computer room air conditioners	LV power distribution system	Cabinet system
Availability	0.9999 7333 4044	0.9999 9912 1013	1



- The cooling system (N+N fault tolerance configuration) of a Uptime class A DC consists of two mains power supplies, two backup power supplies, two LV power distribution systems, and two redundant cooling systems consisting of the air conditioning system dedicated for N+N redundancy equipment rooms and cabinet system.

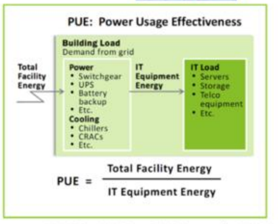
Contents

Quantitative Assessment Indicators for DC Energy Efficiency – PUE

- In 2006, Christian Belady put forward the concept of DC power usage effectiveness (PUE). In 2007, The Green Grid (TGG) developed and improved the concept of PUE. In February, TGG proposed the following PUE definition in Green Grid Metrics:

$$PUE = \frac{\text{Total facility energy}}{\text{IT infrastructure energy}}$$

- On October 29, 2009, TGG released the PUE white paper 2.1, that is, PUE v2, which is frequently referenced. PUE v2 provides a method to report more accurate PUE. PUE V2 defines different types of PUE measurement methods. TGG divides these methods into three levels: basic, intermediate, and advanced.

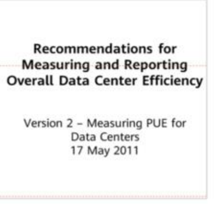


- In 2011, the DC Efficiency Task Force (DCETF) published a paper outlining the recommended methods for measuring and reporting PUE. DCETF adds a 4th level that is more basis. From PUE0 to PUE3, a higher level indicates stricter requirements. Next, I will focus on PUE0, PUE1, PUE2, and PUE3 defined by DCETF.

Four Levels of PUE V2

- The following table lists the PUE levels in the Recommendations for Measuring and Reporting Overall DCs Efficiency released by DCETF.

	PUE0	PUE1	PUE2	PUE3
Energy Consumption Measurement Position of IT Infrastructures	UPS output power	UPS output energy	PDU output energy	Input energy of IT equipment
Definition of IT Infrastructure Energy Consumption	Peak power of IT equipment	Annual energy consumption of IT equipment	Annual energy consumption of IT equipment	Annual energy consumption of IT equipment
Definition of Total Facility Energy Consumption	Peak power of total facilities	Annual energy consumption of total facilities	Annual energy consumption of total facilities	Annual energy consumption of total facilities


Recommendations for Measuring and Reporting Overall Data Center Efficiency

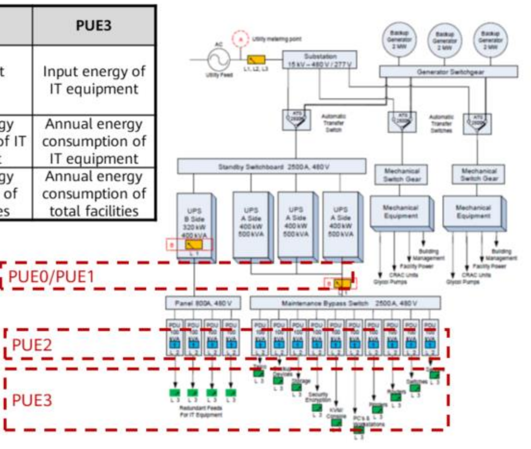
Version 2 – Measuring PUE for Data Centers
17 May 2011

- Except for PUE0, all measurement results must be converted into energy, which means that time components must be introduced. An example is as follows: if kilowatts per hour is used to replace kilowatts, all input energy must be included. For example, heat generated by gas combustion must be converted into kilowatts per hour.
- In addition, all measurement results must be measured at the specified time point for at least one year.

Measuring Positions of IT Equipment Energy Consumption for Different Levels of PUE V2

	PUE0	PUE1	PUE2	PUE3
Measuring Positions of IT Equipment Energy Consumption	UPS output power	UPS output energy	PDU output energy	Input energy of IT equipment
Definition of IT Equipment Energy Consumption	Peak power of IT equipment	Annual energy consumption of IT equipment	Annual energy consumption of IT equipment	Annual energy consumption of IT equipment
Definition of Total Facility Energy Consumption	Peak power of total facilities	Annual energy consumption of total facilities	Annual energy consumption of total facilities	Annual energy consumption of total facilities

- According to PUE V2, the energy consumed by offices and network operations centers (NOCs) must be included in the PUE calculation formula.
- PUE V2 also clarifies that renewable energy, such as wind and solar energy, has no impact on the PUE, and that the PUE is irrelevant to the energy source and type.
- The four levels of PUE V2 are designed for new or reconstructed DCs. All-round measurement should be included in the design so that the DCs can become facilities with high energy efficiency.



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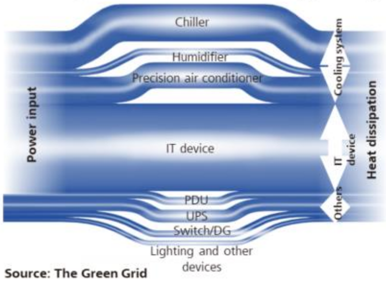
Energy Efficiency Model – DC Energy Consumption Structure

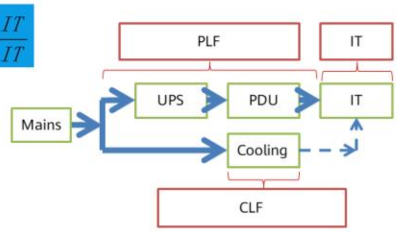
- DC energy consumption structure: includes IT equipment energy consumption, power supply and distribution energy consumption, and cooling energy consumption.
  - Power load factor (PLF) = Energy consumption of the power supply and distribution system/Energy consumption of IT equipment
  - Cooling load factor (CLF) = Energy consumption of the cooling system/Energy consumption of IT equipment
  - IT/IT indicates the ratio of the energy consumption of IT equipment to its own, that is, the value of IT/IT is 1.



Source: The Green Grid

Energy efficiency model

$$PUE = PLF + CLF + \frac{IT}{IT}$$



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- The PUE of some DCs is calculated as follows: PUE = PLF + CLF + ALF + 1. The auxiliary load factor (ALF) is the energy efficiency factor of auxiliary systems such as the lighting system and office system. This part is not discussed in this course.

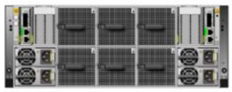
Energy Consumption of IT Equipment

- IT equipment in a DC includes servers, storage equipment, and LAN switches. The number of servers is the largest, occupying the majority. The energy consumption features of IT equipment are similar. Therefore, servers are used as an example.
  - Rack servers are still the mainstream. Some high-end DCs use large servers such as midrange servers and mainframes.

*The Huawei RH1288 V server is a 1 U 2-socket rack server. Its maximum power consumption is about 500 W (with 8 drives, 2 CPUs, and high load). If 40 U cabinets are fully configured, the power density **can reach 20 kW**.*

*Huawei E9000 blade server is 12 U high. Three servers can be deployed in one single rack. The rated power of the rack is 27 kW to 45 kW, and the actual operating power is about **17 kW**.*

  - Mainstream public clouds, such as HUAWEI CLOUD, Alibaba Cloud, Baidu Cloud, Tencent Cloud, AWS, Microsoft, and Google, have provided GPU-based computing services.



  - Huawei GPU server is 4 U high. The power of a single server is 4.4 kW. A maximum of 10 servers can be installed in a rack. The rated power density of the rack is 44 kW, and the actual power is about 30 kW.
  - The rated power of HPE, SuperMicro, and NVIDIA products ranges from 3.2 kW to 4 kW, and the rack power can be greater than 30 kW.

- Huawei RH1288 V3 server (RH1288 V3 for short) is a general-purpose 1 U 2-socket rack server launched to meet customer requirements for the Internet, Internet DC (IDC), cloud computing, enterprise, and telecom service applications.

IT Equipment Energy Consumption – Annual Energy Consumption

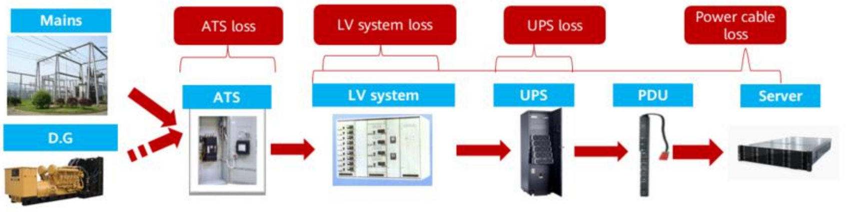
- Single server: Assume that the maximum output power of a 2 U server is 500 W and the AC/DC conversion efficiency is 85% (average value). The maximum input power Pserver of the server is calculated as follows:
  - Pserver = Pmax/0.85 = 500 W/0.85 = 588.23 W, which indicates the maximum power consumption of the server under full configuration and 100% load.
- Overall servers: The actual operating energy consumption is not the same. Designing a medium-sized DC usually involves thousands of servers. Assume that a DC requires 2000 rack servers based on service requirements. The redundancy coefficient C is 0.8, and the utilization coefficient K is 0.8.
  - Pactual = Pserver x C x K x 2000 = 588.23 W x 0.8 x 0.8 x 2000 = 752.93 kW, which indicates the actual total power of servers in a medium-sized DC. If high-density blade servers or integrated cabinet servers are used, the total power will be lower and the equipment power density will be higher. However, the actual total power must be considered based on actual service conditions.
- Annual energy consumption (based on PUE3): Based on the industry attributes of DC services (such as finance, ISP, and government), assume that the actual annual usage efficiency is 0.7 and the efficiency of the UPS and whole set of power distribution equipment is 0.9. The annual energy consumption is calculated as follows:
  - E = (752.93 kW x 365 x 24 x 0.7)/0.9 = 5,129,963.06 kWh, which is the denominator in the PUE calculation of the energy efficiency model.

- Annual electricity price: The annual electricity price varies according to the electricity price and policy environment in different regions, which is also an important factor in the energy efficiency model. Assume that the annual average electricity price of area 1 is CNY0.5 per kWh and that of area 2 is CNY0.6 per kWh. The annual electricity price difference between the two areas can reach CNY51.3 million.

Energy Consumption of the Power Supply and Distribution System

- PLF = ATS switching loss rate + LV power distribution system loss rate + UPS system loss rate + Power cable loss rate
  - The ATS switching loss, LV power distribution system loss, and power cable loss are small, which are basically the cable metal voltage drop, cable contact point loss, and heat loss. The statistical data shows that the value ranges from 1% to 3%. The median value is 2%, that is, 0.02.

    PLF = UPS system loss rate + 0.02
  - In the DC design, the UPS system loss varies according to the UPS power supply solution.



Power Supply and Distribution Energy Consumption – UPS System Loss (1)

- For details, see the (1+1) solutions of DC UPS actual power supply in ANSI/TIA-942–2017. The UPS efficiency varies depending on the load rate in different configuration modes. The following uses the (1+1) parallel system power supply solution as an example to discuss the loss rate of the UPS system in a DC.

$$PLF = \text{UPS system loss rate} + 0.02$$

Power Supply and Distribution Energy Consumption – UPS System Loss (2)

- Assume that the actual total power of IT loads such as servers in a DC is 1000 kW and there are 10 smart modules of 100 kW. Each smart module is configured with two UPSs to form a （1+1） parallel system, and each UPS bears 50 kW load. The power supply time is set to 15 minutes based on the standard power supply time of the DC.
  - In solution A, two 160 kVA UPSs of a certain model are used, and the output power factor is 0.9. The load rate is 34%, which is in the range of 25%–50%. Use the digital interpolation method to calculate the UPS loss rate. The calculated result is H = 0.0877.

Solution A UPS efficiency table

Load Rate	0	25%	50%	75%	100%
Loss Rate-H	-	9.50%	7.48%	5.93%	7.63%

  - In solution B, two 200 kVA UPSs of a certain model are used, and the output power factor is 0.9. The load rate is 27%, which is in the range of 25%–50%. Use the digital interpolation method to calculate the UPS loss rate. The calculated result is H = 0.0937.

Solution B UPS efficiency table

Load Rate	0	25%	50%	75%	100%
Loss Rate-H	-	9.63%	6.37%	5.88%	7.17%

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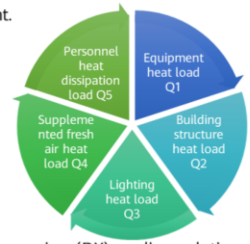
- The UPS efficiency tables of solution A and solution B are actually measured by UPS manufacturer.
- Interpolation calculation:
  - A: When the load rate is 34%, the UPS loss rate is in the range of 25%-50%, H=(7.48%-9.50%)/(50%-25%) × (34%-25%)+9.50% =8.77%
  - B: When the load rate is 27%, the UPS loss rate is in the range of 25%-50%, H=(6.37%-9.63%)/(50%-25%) × (27%-25%)+9.63% =9.37%

Power Supply and Distribution Energy Consumption – UPS System Loss (3)

- PLF = UPS system loss rate + 0.02
  - Solution A (160 kVA, 1+1): PLF = （UPS system loss rate + 0.02）×2 = 0.216
  - Solution B (200 kVA, 1+1): PLF = （UPS system loss rate + 0.02）×2 = 0.228
- Therefore, in the 1+1 UPS power supply solution, the PLF change is only 0.006 due to the load rate of UPSs with different capacities, which has little impact on the PUE. In addition, the following information must be clarified:
  - Compared with the configuration solution of two UPSs in this case, if one UPS is configured or the modular UPS solution is used to improve the UPS load rate, the UPS system loss will be smaller.
  - If a large-capacity STS is installed on each UPS output bus, the PLF increases by 0.01–0.02.
  - If a power distribution output cabinet with an output isolation transformer is configured, the PLF increases by 0.03–0.05 each time a transformer is added to the power supply loop.
  - This calculation model does not include the conversion efficiency of mains input, that is, the conversion loss of 35 kV/0.4 kV or 10 kV/0.4 kV is not included.

Energy Consumption of the Cooling System

- The CLF focuses on the heat load in a DC. The main sources are shown in the figure on the right.



- Equipment heat loads: $Q1 = P_{IT} \times \eta1 \times \eta2$ (kW)
  - $\eta1$ is the number of systems in use at the same time, and $\eta2$ is the comprehensive coefficient.
  - Generally, the cooling capacity redundancy is considered. The value of $\eta1 \times \eta2$ is 0.8.
- Other heat loads: $Q' = \Sigma (Q2–Q5) = Q1 \times 15\% = P_{IT} \times \eta1 \times \eta2 \times 15\%$
  - The heat loads (Q2, Q3, Q4, and Q5) except Q1 account for a small proportion of the cooling energy consumption of the entire DC. The heat loads can be estimated based on 15% of the equipment heat loads.
- The power of IT equipment in a DC is 1000 kW and remains unchanged annually. The direct expansion (DX) cooling solution and chilled water (CW) cooling solution are used for comparison. Assume that COP of the DX cooling solution is 3 and COP of the CW cooling solution is 5.8.
  - DX cooling solution: $CLP = P_{DX}/P_{IT} = (Q1 + Q2 + Q3 + Q4 + Q5)/COP_{DX}/P_{IT} = (\eta1 \times \eta2 + \eta1 \times \eta2 \times 15\%)/COP_{DX} = 0.32$
  - CW cooling solution: $CLP = P_{CW}/P_{IT} = (Q1 + Q2 + Q3 + Q4 + Q5)/COP_{CW}/P_{IT} = (\eta1 \times \eta2 + \eta1 \times \eta2 \times 20\%)/COP_{CW} = 0.166$
- Therefore, in different cooling solutions with the same heat load, the CLF change in the PUE indicator is 0.154, which has a great impact on the PUE.

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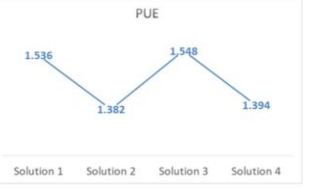
- Q2 is 10% of the IT equipment load in the equipment room, and Q3 to Q5 is 5% of the IT equipment load. Therefore, the load coefficient of Q2 to Q5 is 15%.

Quantitative Assessment Indicators of DC Energy Efficiency

- Based on the preceding calculation results, the quantitative assessment indicators of DC energy efficiency can be obtained.
  - Solution 1 [UPS (160 kVA) + DX cooling] PUEcase 1 = 0.216+0.320+1=1.536
  - Solution 2 [UPS (160 kVA) + CW cooling] PUEcase 2 = 0.216+0.166+1=1.382
  - Solution 3 [UPS (200 kVA) + DX cooling] PUEcase 3 = 0.228+0.320+1=1.548
  - Solution 4 [UPS (200 kVA) + CW cooling] PUEcase 4 = 0.228+0.166+1=1.394

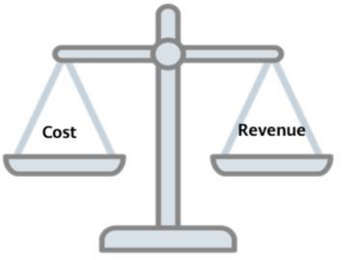


- In this way, a DC with good design and operation can be obtained. When the cooling system is correctly configured, the power supply and distribution system is stable, and the impact of fresh air units and office energy consumption is not considered, the energy efficiency ratio should be less than 1.5. Based on the configuration combination of different solutions and the balance between DC services and other assessment models, an important basis is provided for subsequent DC design and implementation.

Contents

Economic Model of Data Center Facilitiy

- The investment in Data Center Facilitiy is a considerable expenditure. The purpose of using the economic model is to minimize risks and improve economic benefits. The economic model here is not a macro-economic or micro-economic model, but a model for investment economic analysis and economic assessment in DC projects. Based on model analysis and assessment, an optimal solution is selected from multiple dimensions including comprehensive availability, energy efficiency, and other factors. It is an important basis for making decisions on the DC site selection report and feasibility research report.
- The economic model tool is used to comprehensively analyze the cost and revenue of the DC.



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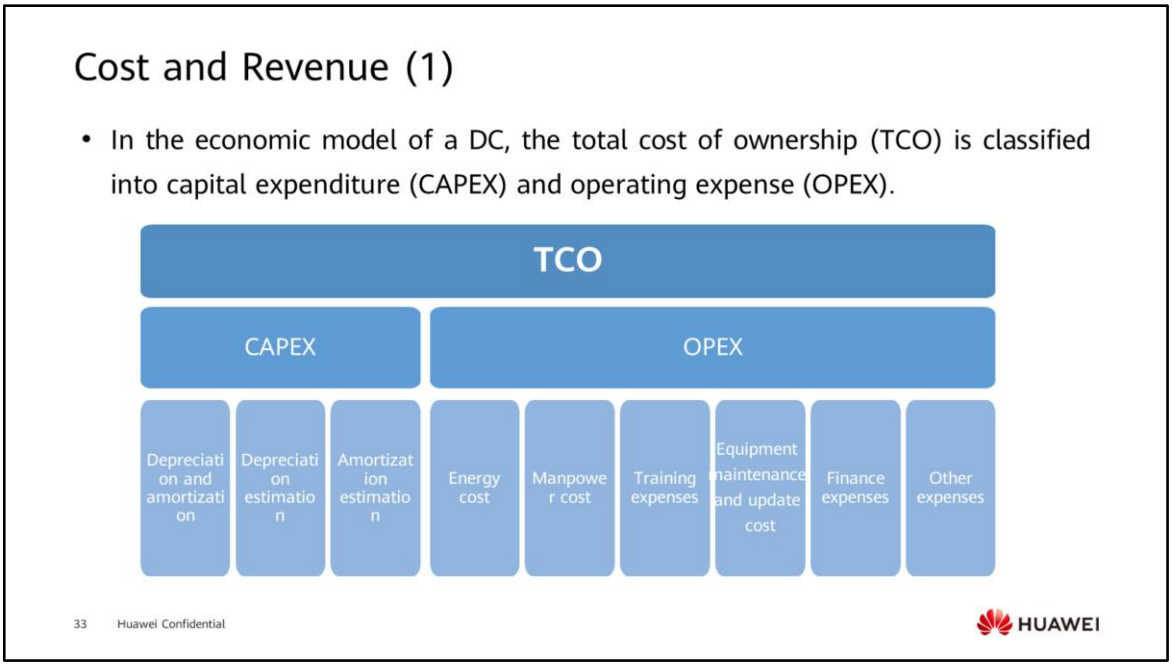
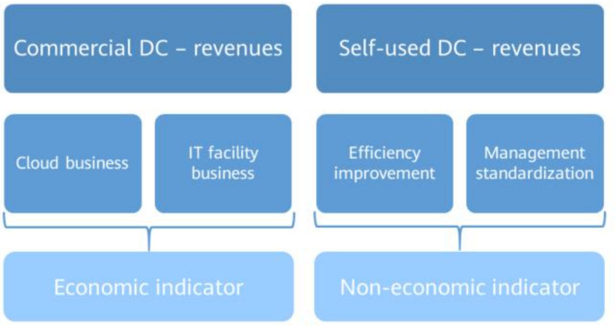


- Depreciation and amortization: Depreciation and amortization indicate that the assets among the years of the production and operation periods are allocated to account for the income tax payable and distributable revenues in the current year.
- Depreciation estimation: Annual depreciation = (Original value of fixed assets – Estimated net residual value)/Depreciation period
- Amortization estimation: Amortization refers to the allocation of one-time input expenses such as intangible assets and deferred assets. The nature of amortization is the same as that of depreciation of fixed assets. Annual amortization = Expenses to be amortized/Valid period of use
- Energy cost: Servers, LAN switches, and computer room air conditioners are energy-consuming equipment. The energy load density of DCs is much higher than that of common office buildings and factories. Therefore, energy cost is a major part of the DC cost.
- Manpower cost: DC personnel include information technology personnel and technical management personnel. The number of personnel depends on the scale of the project, the size of the information system, and the nature of the work. The cost includes salaries, bonuses, benefits, and various insurances.
- Training fees: Training includes professional training for technical personnel and operation training for users, both of which require funds.
- Equipment maintenance and update cost: The maintenance cost includes the cost of computer consumables, machine maintenance, accessory replacement, and purchase of small tools and software.

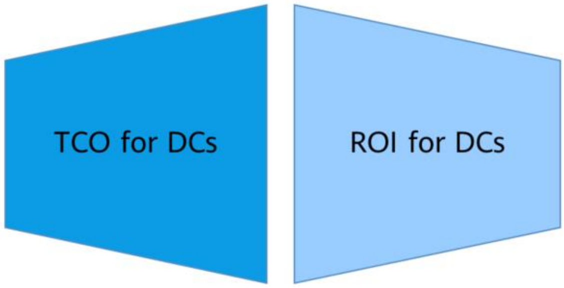
Cost and Revenue (2)

- Revenues in the economic model of a DC are relative to the operation mode of the DC. According to operation modes, DCs are classified into commercial DCs and self-used DCs.



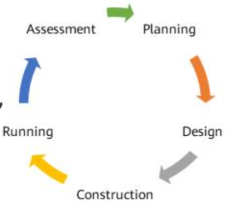
Economic Assessment Methods for DCs (1)

- Based on the characteristics and operation modes of DCs, there are two methods for economic analysis and assessment.



Economic Assessment Methods for DCs (2)

- TCO for DCs
  - The TCO is proposed by Gartner Group in 1987 to analyze the direct and indirect costs of information technology or the entire lifecycle of a DC.
  - A DC project is regarded as a service or product with a lifecycle. The cost (hardware, software, energy consumption, and O&M management) of the entire lifecycle can be calculated based on different planning solutions to obtain different TCO models. Then, a proper and minimum solution can be selected.
  - The TCO is used to calculate the cost of a DC. The revenues of the DC and the impact of uncertainty in the future are not considered. Therefore, the TCO is not applicable to economic assessment of commercial DCs.



Economic Assessment Methods for DCs (3)

- ROI for DCs
  - Facing the huge market of commercial DCs, such as cloud service providers and hosting DCs, and the developed management, the accounting of the ROI is becoming more and more refined. The ROI qualitative analysis is to quantitatively analyze the profitability and development prospect of DCs. Based on the TCO, the ROI takes into account the analysis and assessment of economic revenues and non-economic revenues.
  - In the actual application, the ROI can use the static assessment indicators and dynamic assessment indicators based on project characteristics.
  - The static assessment indicator is a quick and common financial judgment method. The specific indicators include the payback period and ROI. This course will focus on this part.
  - The dynamic assessment indicator takes into account the time value of the fund and all the economic data in the whole lifecycle of the project. The specific indicators include net present value, dynamic investment payback period, internal rate of return, net present value method, and internal rate of return method.

ROI for DCs (1)

- The static assessment indicator is one of the simplest financial judgment methods, including the payback period and ROI.
- The payback period is the time it takes for the cash flow of an investment project to be equal to the initial investment of the project. The unit of the payback period is usually year. The shorter the payback period, the higher the feasibility of the project, and this indicator is applicable to a short-term recovery investment plan.
    - Payback period Pt: the period required for the net income of the project in each year to equal to the investments. C1: cash inflow
    - C0: cash outflow

$$\sum_{t=0}^{Pt} (C_1 - C_0) = 0$$

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- The ROI for DCs can be classified into static assessment indicators and dynamic assessment indicators.
    - The static assessment indicator is one of the simplest financial judgment methods.
    - The dynamic assessment indicator takes into account the time value of the fund and all the economic data in the whole lifecycle of the project. The direct indicator includes the net present value.

ROI for DCs (2)

- The payback period can be calculated in two ways:
  - When the net revenue of each year is the same after the project is completed, the calculation formula is as follows:
  - I:the total amount of funds invested in the project, A:the net cash flow of each year, and the investment recovery is completed in t year.

$$Pt = \frac{I}{A}$$

  - When the net revenues of a project vary from year to year, the calculation formula is as follows:

$$Pt = \text{Year when the accumulated net cash flow starts to be positive} - 1 + \frac{\text{Absolute value of the accumulated net cash flow of the previous year}}{\text{Net cash flow of the current year}}$$

- The assessment standard is $Pt \leq Pc$, indicating that the project is feasible. Otherwise, this project is infeasible. Pc is the expected payback period.

- Characteristics of the payback period: It features a clear and simple concept, and can reflect the risk of the project. However, the economic data after the payback period is not involved.

ROI for DCs (3)

- The ROI is an indicator of profitability. It is the ratio of the net income M of a project in the normal production year to the total investment K.

$$E = \frac{M}{K} \times 100\%$$

- The assessment standard is $E \geq Ec$, indicating that the project is feasible. Otherwise, this project is infeasible. Ec is the benchmark value of the ROI.

- Characteristics of the ROI: the economic data within the project cycle is not involved.

Contents

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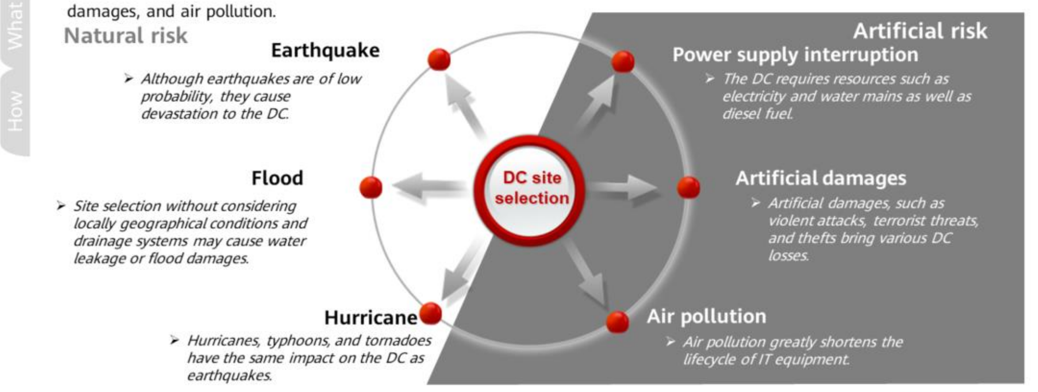
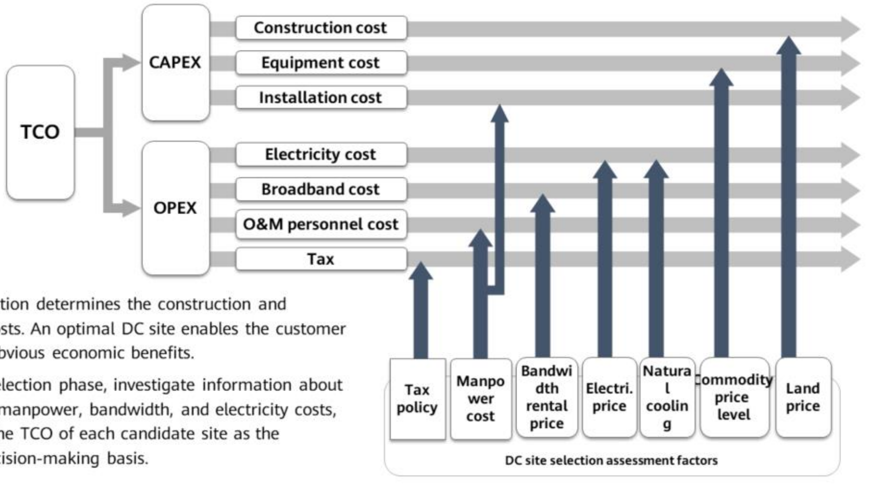
Site Selection Contributing to Availability

- DC services are affected by locally natural and facility conditions. Therefore, external risks must be prevented during site selection to minimize the probability of equipment failures.
- The external risks that affect DC availability include earthquakes, floods, hurricanes, power supply interruption, artificial damages, and air pollution.



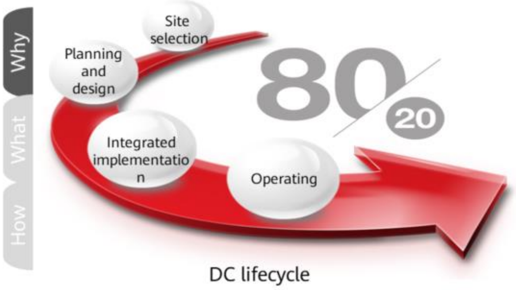
Site Selection Contributing to Lowering down the TCO

Why
What
How



- DC site selection determines the construction and operating costs. An optimal DC site enables the customer to achieve obvious economic benefits.
- In the site selection phase, investigate information about the tax and manpower, bandwidth, and electricity costs, and assess the TCO of each candidate site as the essential decision-making basis.

Importance of Site Selection Consultation



DC lifecycle

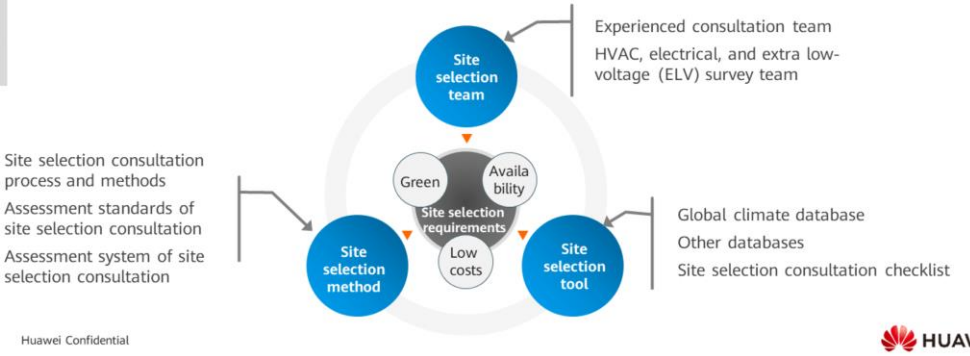
- Site selection is the initial phase of the DC lifecycle. Therefore, incorrect site selection will cause increasing losses in the following phases of the lifecycle.
- Why not increasing investment by 20% in the site selection phase to prevent 80% of losses?

- DC site selection affects costs, profits, service continuity, and risks of a DC. To select a proper site, experienced site selection consultants must perform objective analysis using scientific consultation methods and professional site selection tools.

Three Elements of Site Selection Consultation

Why | What | How

- The site selection team, site selection method, and site selection tool are the three key elements of the site selection consultation service.
- Consultation services are not delivered based on standardized operations, but largely depend on consultants' personal capabilities.
- Methods and tools are also important to make assessment results more scientific and objective.



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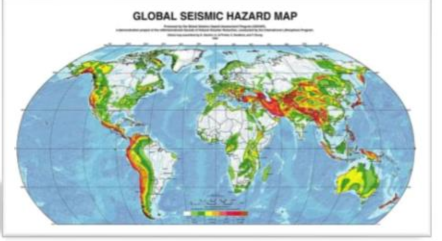
International Standard – ANSI/TIA-942 (1)

Why
What
How

1. The local utility company should be able to provide adequate power to supply all initial and future power requirements for the DC.
2. The site should not be located in a 100-year flood plain, near an earthquake fault, on a hill subject to slide risk, or downstream from a dam or water tower. Additionally there should be no nearby sites that could create falling debris during an earthquake.
3. The site should not be in the flight path of any nearby airports.
4. The site should be no closer than 0.8 km (1/2 mile) from a railroad or major interstate highway to minimize risk of chemical spills.
5. The site should not be within 0.4 km (1/4 mile) of an airport, research lab, chemical plant, landfill, river, coastline, or dam.
6. The site should not be within 0.8 km (1/2 mile) of a military base.



Source: ANSI/TIA-942-2017
Telecommunications Infrastructure Standard for DCs

International Standard – ANSI/TIA-942 (2)

Why

What

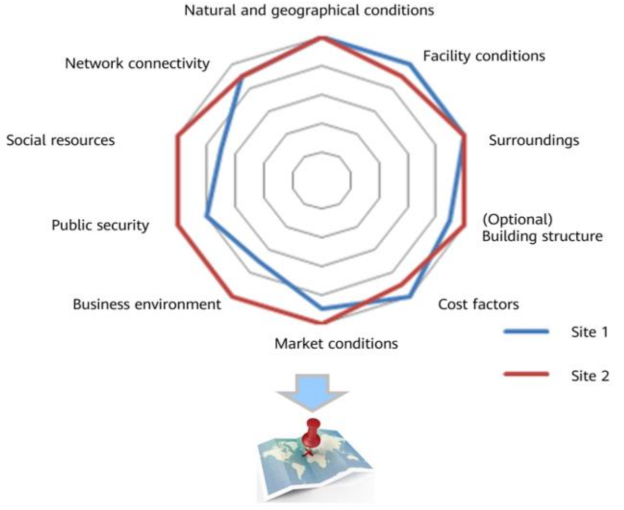
How

7. The site should not be within 1.6 km (1 mile) of nuclear, munitions, or defense plants.
8. The site should not be located adjacent to a foreign embassy.
9. The site should not be located in high danger and pollution areas.
10. The DC should be located below 3050 m (10,000 ft.) elevation.
11. Consideration should be given to zoning ordinances and environmental laws governing land use, fuel storage, sound generation, and hydrocarbon emissions that may restrict fuel storage and generator operation.

Source: ANSI/TIA-942-2017 Telecommunications Infrastructure Standard for DCs

DC Site Selection Assessment System (1)

Why
What
How



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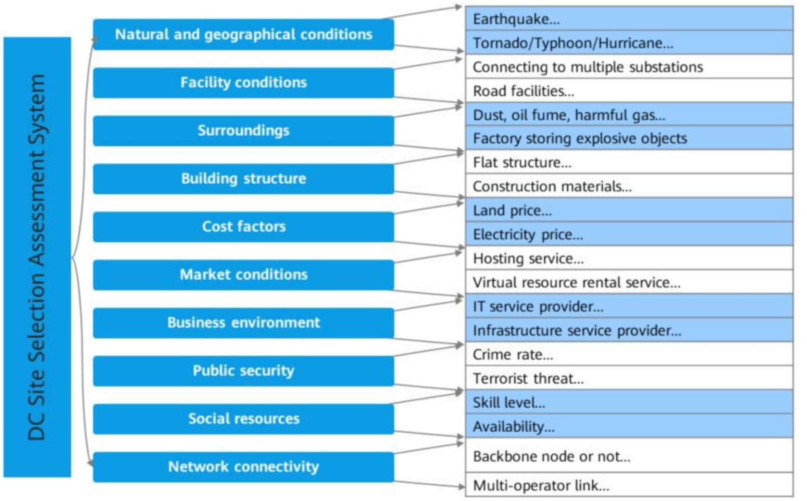
DC Site Selection Assessment System (2)



How to Set Weights of Assessment Factors

Why

What

How

- Weights of factors in the assessment system are set based on customer's requirements. Do not apply the same factor weight configuration to all projects.
- For example, the customer focuses on the availability, cost, and energy conservation of the DC in a project. Therefore, the association between each factor in the assessment system and the three features must be analyzed. Higher score indicates closer association, and then the weight of each assessment factor is obtained based on the score.

	Association with Availability	Association with Costs and Profits	Association with Energy Conservation	Total Score	Weight
Natural and geographical condition	High	Low	High	4	13.3
Facility condition	High	Medium	High	5	16.7
Surroundings	High	Medium	High	5	16.7
(Optional) Building structure	Medium	Low	Medium	2	6.7
Cost factor	Low	High	Low	2	6.7
Market condition	Low	High	Low	2	6.7
Business environment	Medium	High	Low	3	9.9
Public security	High	Low	Low	2	6.7
Social resource	Low	High	Low	2	6.7
Network connectivity	High	Medium	Low	3	9.9

Correlation: High, medium, and low
Score: High = 2, medium = 1, low = 0

Site Selection Factor – Natural and Geographical Conditions (1)

Why

What

How

- A DC must be located in areas with less natural disasters, such as earthquakes, typhoons, and floods, to avoid devastation to the DC.
- A DC should be located in cold and dry areas to minimize energy consumption.

Site Selection Factor – Natural and Geographical Conditions (2)

Why
What
How

Natural Condition Assessment Factors	Assessment Standard
Earthquake	• The site should be far away from seismic belts. • According to the global seismic hazard map, the site should be located in areas where the seismic hazard degree is less than 4.0. • The site should be far away from volcanoes. • The site should be far away from sites that could create falling debris during an earthquake
Flood and tsunami	• The site should be far away from areas where floods or tsunamis ever occurred within last 100 years. • According to the global flood hazard distribution, the site should be located in areas where the flood hazard frequency is below 1st to 4th deciles, that is, the site is located in the white areas.
Mudflow	• The site should be far away from a hill subject to slide risk, or downstream from a dam or water tower.
Hurricane, typhoon, and tornado	• The site should be located in areas where the Saffir-Simpson hurricane intensity scale (SSHS) level is lower than SS1.
Altitude	• The site should be located below 3050 m (10,000 ft.) elevation.
Climate	• The site should be located in areas where the annual average temperature is below 20°C to achieve energy conservation using natural cooling sources.

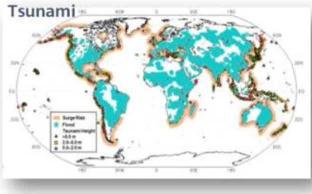
Reference Data of Other Natural Conditions

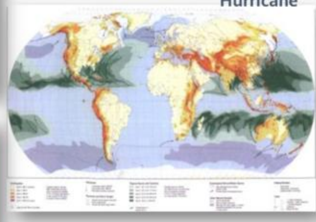
Why

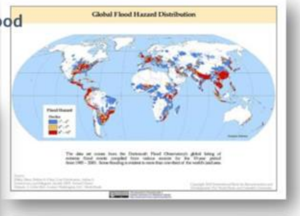
What

How

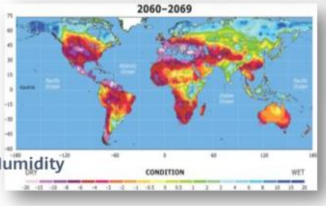
- Besides earthquakes, other natural disasters, such as hurricanes, mudflows, and tsunamis, must be considered. A DC should be **far away from areas where these natural disasters are frequent**.
- In addition, **climate conditions** must be prioritized during DC site selection.


Tsunami

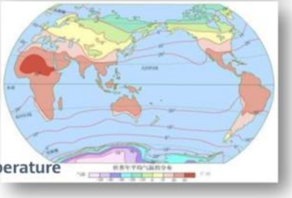

Hurricane



Flood



Humidity


Temperature

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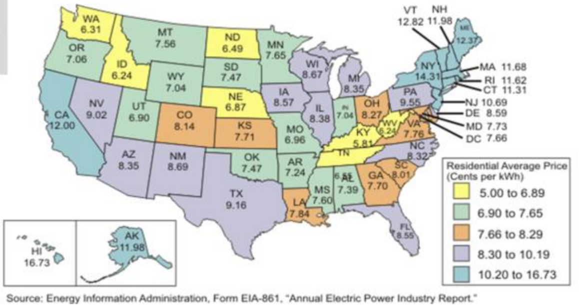
Site Selection Factor – Facilities (1)

- DC's requirements for local power supply capability depend on the DC service characteristics, quality, and capacity. The power supply must be stable and sufficient.
- The power quality affects DC operating. Frequent power outage, harmonic interference, and voltage peak may cause DC equipment failures
- The power cost accounts for over 50% of the total DC operating cost, and therefore the mains price is important for DC site selection.
- To ensure reliable DC operating and reduce the OPEX, a DC should be located in areas with sufficient and stable power supply, as well as low power cost.



Source: Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

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Site Selection Factor – Facilities (2)

Why

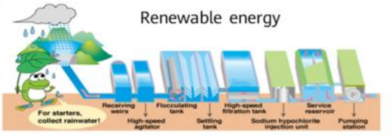
What

How

- Besides power supply facilities, infrastructure such as **water, road, and drainage facilities** must be included in the DC site selection plan. Lack of any preceding facilities may cause problems in the maintenance phase.

Facility Assessment Factor	Assessment Standard
Mains introduction	The site should be located in areas where power is sufficient and can be obtained from two or more substations. The power supply is not rationed even in peak hours in summer.
Road facilities	There are more than two separate roads routed through the site.
Water supply assurance	Water supply is sufficient.
Diesel fuel supply	The site should be within 20 km of diesel stations
Drainage facilities	Water leakage should be prevented in rainy days.

Renewable energy



Traffic road

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Site Selection Factor – Surroundings (1)

Why

What

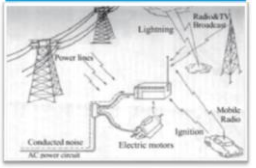
How

- Air pollution, electromagnetic interference (EMI), and flammable and explosive objects are key elements to be focused in the surroundings of a DC.

Air pollution

- Hazard materials such as particles and sulfur in the air corrode equipment in the DC, which result in equipment failures and shorten the equipment service life. Therefore, air quality is a key element for site selection.

EMI



- Severe EMI affects internal communications of the DC. It is recommended that a DC be located in a MICE $M_1I_1C_1E_1$ environment (according to ANSI/TIA-568-C.0).

Flammable and explosive objects

- A DC should be far away from factories and plants manufacturing or storing flammable and explosive objects.

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Site Selection Factor – Surroundings (2)

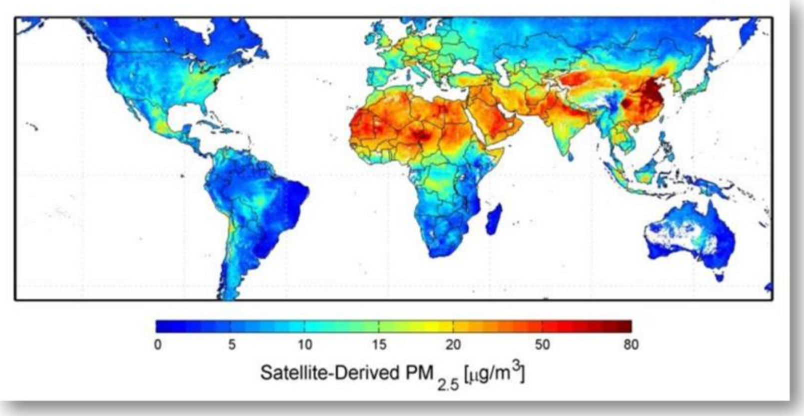
Why
What
How

Ambient Environment Assessment Factor	Assessment Standard
Air pollution	The air corrosiveness of the DC surroundings should meet the G1-level requirements specified in ANSI/ISA-71.04. The air cleanliness of the DC surroundings should meet the level-8 requirements specified in ISO 14644-1. The site should be far away from a heavily polluted source, such as a chemical plant, power station, coal mine, or electroplate factory. The site should be no closer than 0.8 km (1/2 mile) from a railroad or major interstate highway to minimize risk of chemical spills.
Factory with explosive materials	The site should not be within 1.6 km (1 mile) of nuclear, munitions, or defense plants.
EMI	It is recommended that a DC be located in a MICE $M_1I_1C_1E_1$ environment (according to ANSI/TIA-568-C.0).
Other risky factors	The site should not be in the flight path of any nearby airports. The site should not be within 0.4 km (1/4 mile) of an airport, research lab, chemical plant, landfill, river, coastline, or dam. The site should not be within 0.8 km (1/2 mile) of a military base. The site should not be located adjacent to a foreign embassy.

Site Selection Factor – Surroundings (3)

Why
What
How

Air particle



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Site Selection Factor – Building Structure

Why
What
How

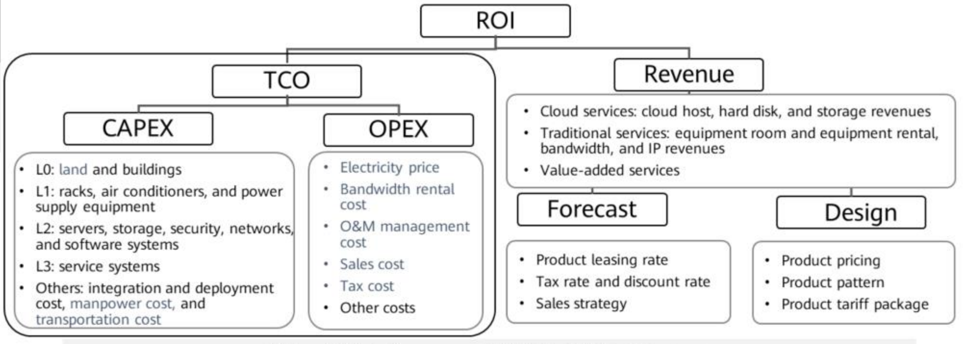
- Compared with commercial buildings, DC buildings have requirements on the story height, bearing capacity, span, and materials.

Large-span steel buildings are more suitable for DC equipment rooms.

1. Large-span buildings are recommended to facilitate equipment arrangement.
2. The bearing capacity of the building should meet requirements of the TIA-942 standards.
3. If a DC is located on the top floor of a multi-tenant building, sufficient vertical shaft and pipeline space should be reserved for power cables, ground cables, and air conditioners.
4. The building should meet the bearing requirements of equipment.
5. Building materials should be incombustible. The external wall should be constructed using concrete or ashlar masonry to ensure safety.

Site Selection Factor – Costs (1)

- Site selection affects the DC operating costs. Therefore, during site selection, consider impact of the land price, electricity price, broadband cost, manpower cost, and tax on the TCO.
- The electricity cost occupies a high proportion of the total cost. The mains prices outside China are provided in the following slide for reference. The land price and manpower cost must be surveyed locally.



ROI = TCO + Revenue = CAPEX + OPEX + Revenue

Site Selection Factor – Costs (2)

Why / What / How

Table 5.6.A. Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State, October 2013 and 2012 (Cents per Kilowatthour)

Global electricity prices

Census Division and State	Residential		Commercial		Industrial		Transportation		All Sectors	
	October 2013	October 2012	October 2013	October 2012	October 2013	October 2012	October 2013	October 2012	October 2013	October 2012
New England	16.37	15.61	13.58	13.25	11.50	11.43	12.40	6.90	14.06	13.62
Connecticut	18.61	18.08	14.57	14.73	12.67	12.92	9.90	9.34	15.83	15.77
Maine	14.45	14.76	11.25	11.19	7.57	8.09	–	–	11.33	11.61
Massachusetts	15.63	14.38	13.89	13.05	12.40	11.95	13.73	5.07	14.01	13.09
New Hampshire	16.73	16.03	13.38	13.21	11.00	11.95	–	–	14.16	14.02
Rhode Island	14.55	13.66	11.04	11.01	10.04	10.14	13.68	12.76	12.22	11.92
Vermont	17.66	17.51	15.00	14.62	10.01	9.83	–	–	14.64	14.46
Middle Atlantic	15.91	15.54	12.87	12.83	7.17	7.25	12.02	12.23	12.66	12.53
New Jersey	15.54	15.17	12.43	12.13	10.31	9.98	10.54	10.09	13.21	12.90
New York	18.89	18.44	15.19	15.14	6.43	6.09	13.24	14.07	15.49	15.21
Pennsylvania	13.14	12.80	9.13	9.34	6.87	7.17	8.06	7.83	9.58	9.66
East North Central	12.43	12.42	9.58	9.41	6.61	6.51	5.55	5.77	9.29	9.14
Illinois	10.86	11.91	7.98	7.79	5.84	5.69	5.24	5.49	8.09	8.21
Indiana	11.55	11.09	9.67	8.99	6.64	6.21	9.86	9.16	8.74	8.16
Michigan	14.99	14.22	11.11	10.90	7.58	7.46	9.83	8.89	11.06	10.68
Ohio	11.99	12.06	9.36	9.59	6.20	6.53	6.92	7.48	9.01	9.12
Wisconsin	13.92	13.43	10.88	10.49	7.46	7.29	–	–	10.47	10.15
West North Central	11.05	10.67	8.70	8.33	6.38	6.07	8.06	7.09	8.66	8.25
Iowa	11.70	10.99	8.53	7.88	5.69	5.12	–	–	8.03	7.34
Kansas	11.62	11.29	9.47	9.36	6.80	6.95	–	–	9.27	9.19
Minnesota	12.20	11.54	9.38	8.93	6.95	6.55	9.47	8.53	9.33	8.81
Missouri	10.15	9.89	7.96	7.55	5.44	5.42	6.93	5.84	8.19	7.83
Nebraska	10.47	10.43	8.57	8.52	6.96	6.60	–	–	8.54	8.23
North Dakota	9.72	9.42	8.55	8.14	7.20	6.62	–	–	8.37	7.93
South Dakota	10.90	10.66	8.57	8.24	6.97	6.70	–	–	8.98	8.65
South Atlantic	11.56	11.48	9.39	9.35	6.41	6.39	8.33	8.55	9.68	9.60
Delaware	14.04	14.53	10.10	10.36	8.29	8.40	–	–	10.93	10.96
District of Columbia	13.03	12.35	11.89	12.10	6.08	5.66	9.32	9.44	11.86	11.93
Florida	11.33	11.53	9.44	9.69	7.53	7.85	8.55	8.70	10.27	10.49
Georgia	11.02	10.89	9.65	9.56	5.81	5.78	6.84	6.62	9.13	9.04

Source: eia U.S. Energy Information Administration

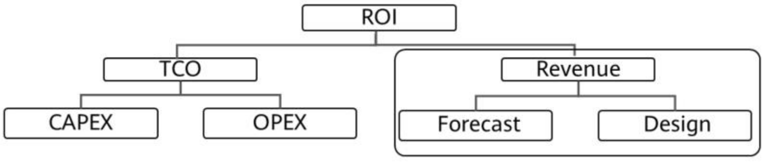
Site Selection Factor – Market Conditions (1)

Why

What

How

- Besides cost factors, local market conditions affect DC profits.
- A survey on the local market conditions of various DC services is required to predict the market growth rate.
  - Market conditions of the hosting service
  - Market conditions of the virtual resource rental service
  - Market conditions of value-added cloud services
  - Market conditions of other cloud services



ROI = TCO + Revenue = CAPEX + OPEX + Revenue

Site Selection Factor – Market Conditions (2)

Why
What
How

- Market requirement analysis

Enterprise status

- Industry
- Area
- Enterprise scale (employee quantity)
- Main service
- Service scale (or data scale)

+

DC status

- Infrastructure
  - Area and equipment room idleness rate
  - Equipment room level
  - Total rated power
  - Telecom operator connection status
- DC application
  - Purpose (for production or DR)
- DC overview
  - Construction time
  - Construction mode (self-built or outsourcing)
  - Investment scale

+

Future requirements

- Investment estimation (time and expected scale)
- Expected investment field (for production or DR)
- Outsourcing probability
- Reason for outsourcing or not
- Factors for selecting an outsourcing supplier: hardware conditions, service level, quality certification, and brand awareness

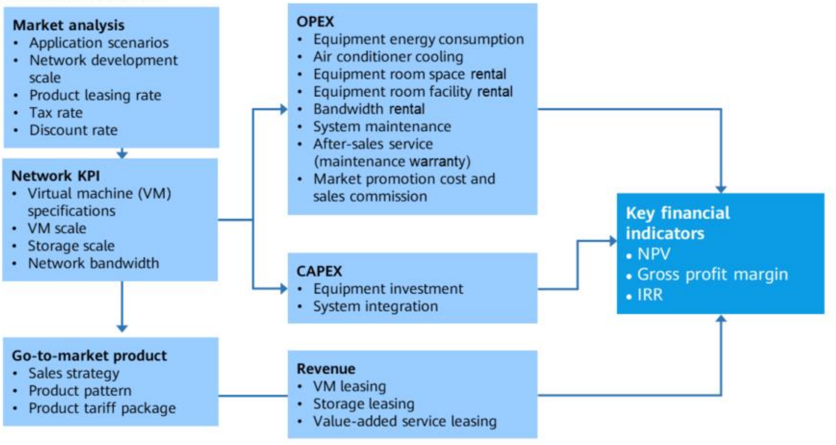
Survey content

Survey conclusion

- Requirement scale, time, and purpose analysis
- Customer group analysis
- Required product and price
- Local geographical conditions and policy advantages

Site Selection Factor – Market Conditions (3)

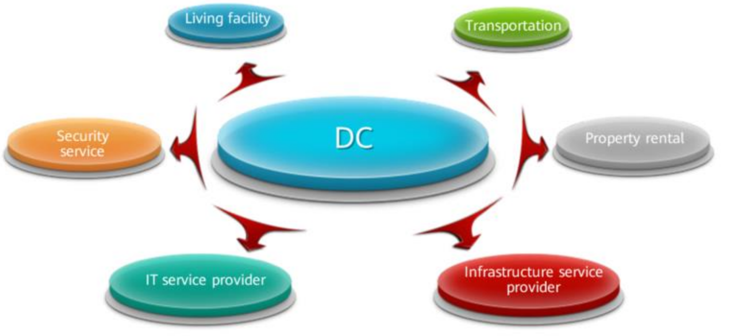
- The costs and market conditions are analyzed to estimate the ROI of the project. The following describes a typical ROI analysis model for reference.



Site Selection Factor – Business Environment

Why What How

- DCs are not isolated, and must be located in areas with suitable business environments.
- To select a site, investigate local IT service providers, infrastructure service providers, security services, property rental resources, living facilities, and transportation resources.



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Site Selection Factor – Network Connectivity

- Network connectivity determines the DC reliability. To ensure smooth DC data output, a DC should be located in areas with network coverage of multiple operators.
- The network bandwidth affects the customer experience. The output bandwidth of existing IDCs is generally 100 Gbit/s or above, and the bandwidth requirements will be increased gradually.

Site Selection Consultation Service Process (1)

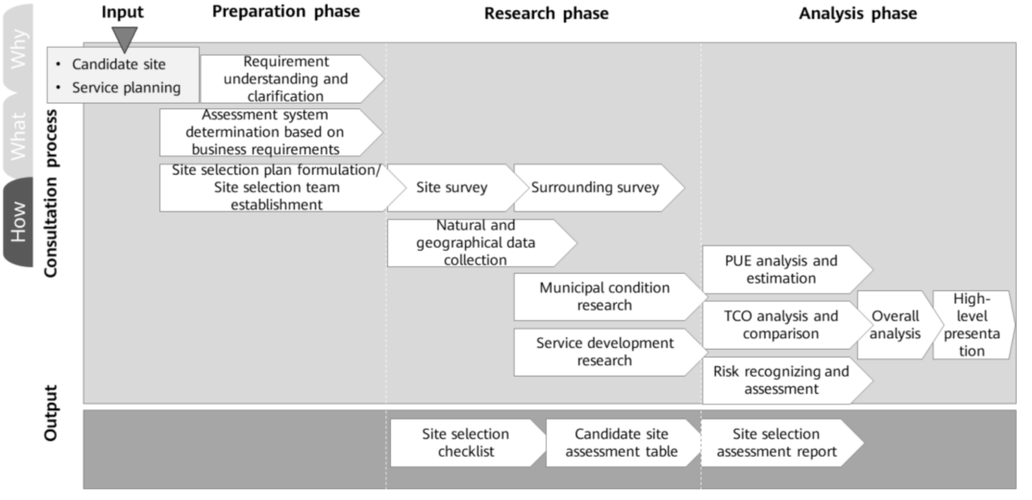
Why

What

How

- The service process of DC site selection consultation varies with projects. However, the service process mainly includes the following three phases based on summarized site selection consultation experience:
- Preparation phase: Understand requirements and formulate plans.
- Research phase: Perform survey and research and collect information.
- Analysis phase: Analyze and output assessment results.

Site Selection Consultation Service Process (2)



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Service Contents in the Preparation Phase

Why

What

How

- Fully understand service requirements, formulate site selection assessment systems and plans, and assign task owners.

Requirement understanding and clarification → **Assessment system determination** → **Site selection plan formulation/Site selection team establishment**

Requirement understanding and clarification

Get familiar with customer's services and (IDC) development plans:

- Project budget
- Potential user groups and user requirements
- Project business mode
- PUE of the existing IDC
- Operating difficulties of the existing IDC
- ...

Assessment system determination

Determine the site selection assessment system that meets customer's requirements:

- Natural and geographical conditions
- Facility conditions
- Surroundings
- Cost factors
- Market conditions
- ...

Site selection plan formulation/Site selection team establishment

Formulate the site selection consultation plan, prepare required resources, and assign responsible personnel:

- Organization of the team for site selection consultation
- Site selection implementation plan
- Consultation tool preparations

Service Contents in the Research Phase

- Perform survey and research on candidate sites against the checklist based on requirements of the project assessment system.

Site survey → **Social research** → **Data collection**

Site survey

Investigate local conditions and surroundings of the candidate site:

- Location and geography
- Ground resistance, load-bearing capability, and water quality
- Transportation, mains, drainage, and broadband
- Air pollution, noise, and EMI
- Natural cooling source
- ...

Social research

Get familiar with information about local policies, prices, and social resources:

- Land price
- Prices of the mains, water, fuel, and natural gas
- Tax policy
- IDC market conditions
- Business environment
- ...

Data collection

Collect climate data and historical data of natural disasters:

- Detailed climate data
- Sunshine data
- Historical data of natural disasters, such as earthquakes, floods, and hurricanes
- Crime rate
- ...

Service Contents in the Analysis Phase

Why | What | How

- Analyze the survey and research data, score candidate sites, and output the assessment report to support decision making on DC site selection.

PUE analysis and estimation → TCO analysis and comparison → Risk recognizing and assessment

PUE analysis and estimation

Analyze factors impacting PUE and PUE comparison results of each candidate site, and select a candidate site with the optimal PUE status:

- Climate comparison for candidate sites
- Impact of local climate conditions on the PUE
- PUE analysis and comparison
- ...

TCO analysis and comparison

Analyze the CAPEX and OPEX of candidate sites and select a candidate site with the optimal TCO:

- CAPEX comparison for candidate sites
- OPEX comparison for candidate sites

Risk recognizing and assessment

Recognize potential risks of candidate sites and select a candidate site with minimal risks during the construction and operating phases:

- Damage risks caused by natural disasters
- Equipment failure risks caused by air pollution
- Tier-level recommendations
- ...

Deliverable of the Site Selection Consultation Report

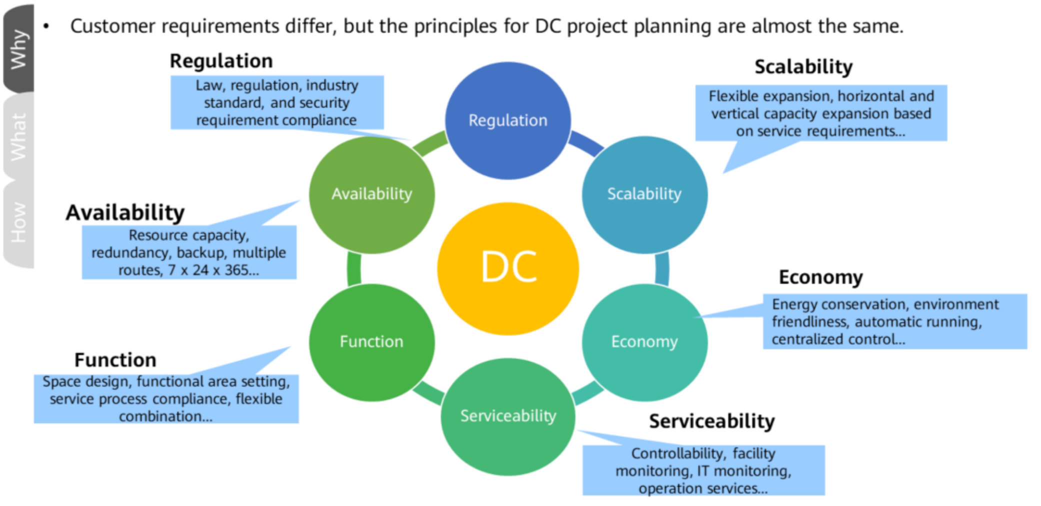
Why
What
How

Site Selection Consultation Report Deliverable

Contents

Principles and Contents of Feasibility Research

- Customer requirements differ, but the principles for DC project planning are almost the same.



Feasibility Research Plan Formulation

Why

What

How

- Feasibility research plan formulation: project progress and work breakdown of feasibility research consultation services

	Project Preparation		Project Delivery				
	W-4 W-3	W-2 W-1	W1 W2 W3	W4 W5	W6 W7 W8	W9 W10	W11 W12
	Executive communication	Consultation preparation	Project initiation	Survey and research	Requirement analysis	Solution verification	Feasibility research report
Key project activities	1. Executive seminar 2. Project principle and direction confirmation 3. Assessment range and framework communication 4. Assessment schedule communication 5. Project direction determination by the management layer	. Project resource preparation 2. Project team establishment 3. Project scope (details) definition determination 4. Communication and determination of the project scope 5. Requirement research plan customization 6. Definition of the feasibility research plan	1. Customer resource preparation and confirmation 2. Project kick-off meeting 3. Research material preparation	. Onsite survey . Customer interview . Information research and collection (IDC situation, customer typ sales type, and IDC O&M situation) . Key problem discussioı and clarification . Customer expectation research	1. Requirement analysis 2. Long-term objective communication and confirmation 3. Gap analysis 4. Preliminary analysis results	. Preliminary solution conclusions, suggestions, and economic analysis 2. Customer communication and confirmation 3. Report drafting 4. Feasibility research report presentation tı middle-layer leaders	1. Feasibility research report presentation to executives 2. Final report submitting
Key achievements	• Principle and direction	• Project plan	• Project kick-off meeting	• Research result • Research report	objectives confirmed by customers • Consultation report draft	• Consultation report draft review (presentation to middle-layer leaders)	• Final feasibility report (presentation to executives)

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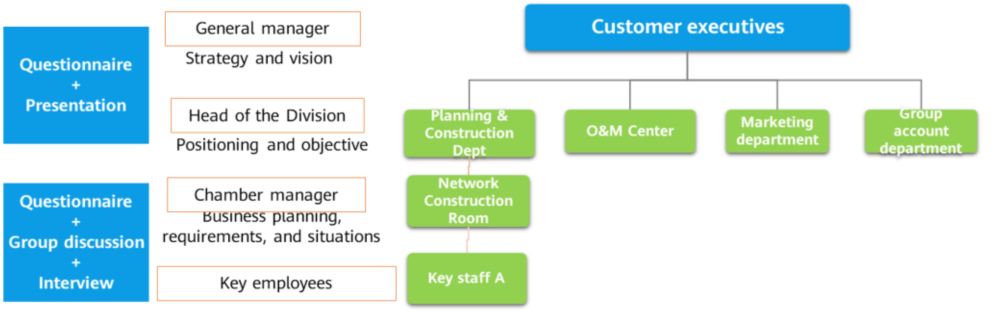
Requirement Research

Why

What

How

- Based on different interviewees, formulate appropriate questionnaires to quickly and effectively learn customer status and requirements.
- The customer interview is a cyclic iteration process and the PDCA method is adopted.



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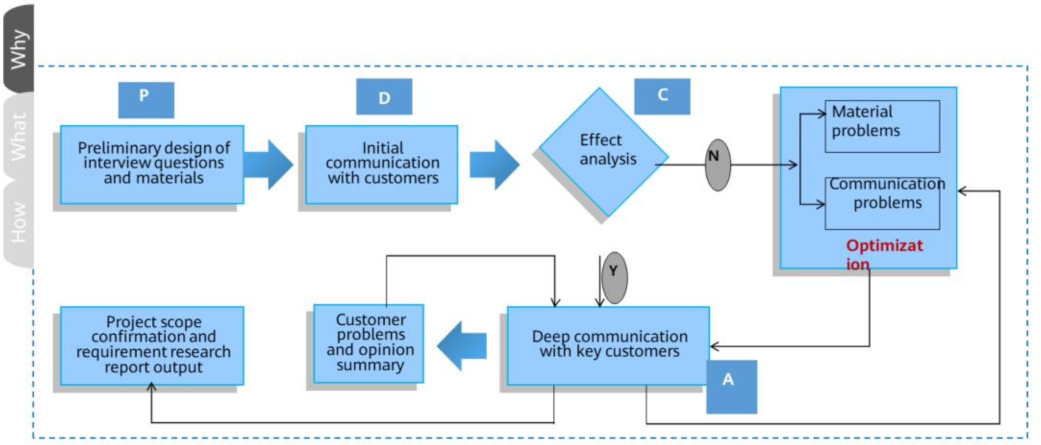
Customer Interview Methods



Feasibility Research Service Contents

Application scenarios

- Building DC

- Prefabricated DC

- Warehouse DC

- Container DC

Construction scheme

- Environment and building structure planning
- Construction standard planning
- Electrical system planning
- HVAC system planning

Investment estimation

- CAPEX estimation
- OPEX estimation
- TCO estimation

Economic assessment

- Financial assessment
- Social benefit assessment

Milestones

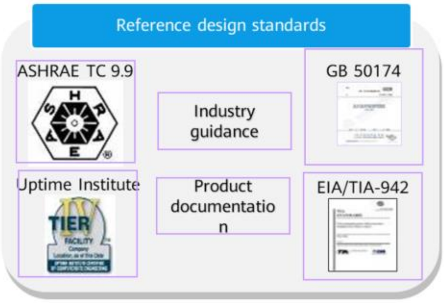
- Three phases: preparation phase, research phase, and analysis and validation phase

Risk analysis

- Risk analysis: Market analysis, technical risks, and project construction risks
- Countermeasures

Feasibility Research Construction Scheme – Construction Standard Determination (1)

Why
What
How



International standards
ISO/IEC IS 11801

North American standards
EIA/TIA-568A/B/C

International standards
CENELEC EN 50173

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Feasibility Research Construction Scheme – Construction Standard Determination (2)

Why
What
How

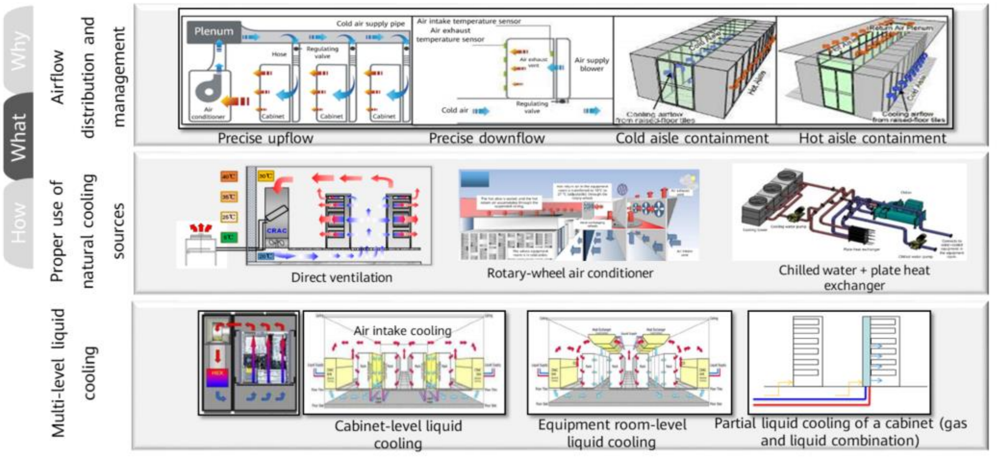
Power Supply System	Construction Standards
External mains supply	Two independent power supplies
Transformer	1+1
HV power distribution system	1+1
LV power distribution system	1+1
HV generator set	N+X
UPS system	2N dual-bus system
Battery backup time	Backup duration of each UPS ≥ 30 min

Feasibility Research Construction Scheme – Construction Standard Determination (3)

Why
What
How

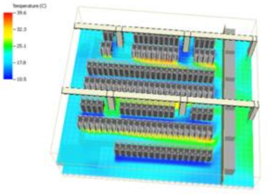
Refrigeration System	Construction Standards
Natural cooling source	Adopted
Continuous cooling	Based on IT equipment requirements, consider whether to use continuous cooling for all IT equipment or some IT equipment.
Cooling equipment configuration	N+X redundancy (X = 1 to N)
Cooling pipes	Consider system reliability and redundancy.
Cabinet layout	Layout of cold and hot aisles
Air conditioner in the equipment room	N+X redundancy (X = 1 to N). *X* air conditioners work in redundancy mode in each air conditioning area in the computer room.
Water storage	Water assurance based on independent dual-municipal water or stored water

Feasibility Research Construction Scheme – HVAC System Architecture Determination

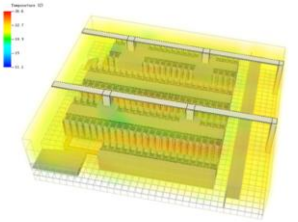


Feasibility Research Construction Scheme – CFD Simulation for Solution Selection

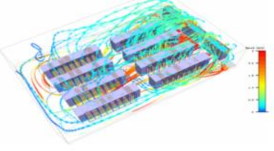
Method 1:
Without aisle containment

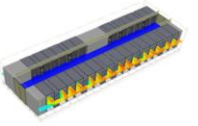


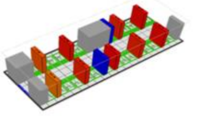
Method 2:
With aisle containment



- Without aisle containment: The temperature at certain areas is close to 40°C, causing a high temperature only in some areas and unbalanced temperature fields in areas outside the positions for installing cabinets in an equipment room.
- Aisle containment: The temperature in the entire equipment room is not higher than 26.6° C. The temperature field is relatively balanced for areas outside the positions for installing cabinets in the equipment room.







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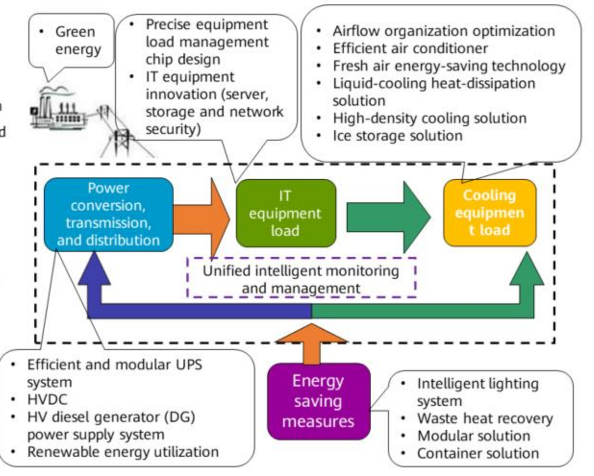
Feasibility Research Construction Scheme – Energy Saving Scheme

Why
What
How

- E2E energy-saving design for DCs:
  - IT system energy saving: Energy is saved from the beginning, involving use of low-power consumption chips, virtualization/distributed technology, and load balancing management
  - Power distribution system energy saving: With reliability ensured, improve the power distribution efficiency to reduce the power consumption
  - Refrigerating system energy saving: Involve airflow distribution design and use of the efficient refrigerating system and free cooling.
  - Cabinet system energy saving: Ensure reasonable distribution of high- and low-density cabinets, cold/hot-aisle containment system, and precise air supply.



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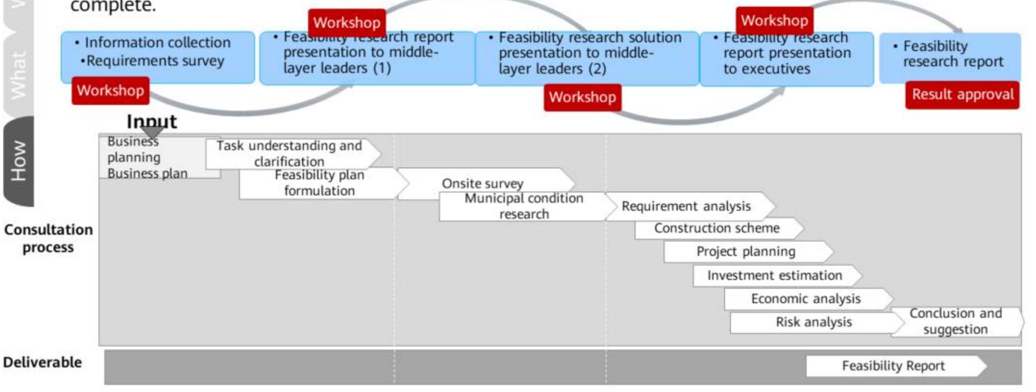
Feasibility Research Consultation Service – Delivery Process

- Theme technologies and solutions are discussed by a hierarchical organization from the lower level to the top level on a **workshop**. In addition, **an agreement is reached**, indicating that deliverable delivery is complete.



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Feasibility Research Construction Scheme – Electrical System Planning

Why

What

How

Electrical load calculation → **Key technology analysis and system selection**

Based on business requirements and IT planning, determine the power load of each system:

- Calculate the IT equipment loads.
- Calculate engine equipment loads, such as loads and loss of the air conditioner and electrical equipment.
- Determine the capacity of the mains supply.

No.	Equipment	Rated Load (kW)	Demand Coefficient	PF	Load Requirement P (kW)	Q (kVar)	S (kVA)
1	IT load	4800	1.00	0.95	4800.0	1577.7	5052.6
2	Chiller	1965	0.67	0.80	1316.6	987.4	1645.7
3	Water pump and cooling tower	930	0.67	0.95	623.1	204.8	655.9
4	Air conditioner in the electricity room	40	0.70	0.95	28.0	9.2	29.5
5	Battery charging	533.2	0.90	0.95	479.9	157.7	505.1
6	UPS loss	418.4	0.90	0.95	376.6	123.8	396.4

Based on service requirements, determine the power supply system architecture and key equipment models:

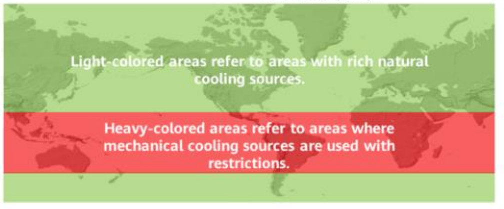
- Architecture of the power distribution system – Tier III/Tier IV system architecture design
- Model selection and analysis on advantages and disadvantages of technical solutions for the key equipment, such as the DG, transformer, UPS, and power distribution cabinet

Feasibility Research Construction Scheme – HVAC System Planning

Why
What
How

Calculation of air conditioner loads → Key technology analysis and system selection

- Based on business requirements and IT planning, determine the power load of each system:
  - Calculate the IT equipment loads.
  - Calculate the loads of electrical equipment, such as the UPS.
  - Calculate the water amount.
- Based on service requirements, determine the air conditioning system architecture and key equipment models:
  - Architecture of the air conditioning system – Tier III/Tier IV system architecture design/cooling source selection analysis
  - Model selection and analysis on advantages and disadvantages of the technical solutions for key equipment, such as the chiller, air conditioner, and water pump.



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Feasibility Research – Risk Analysis

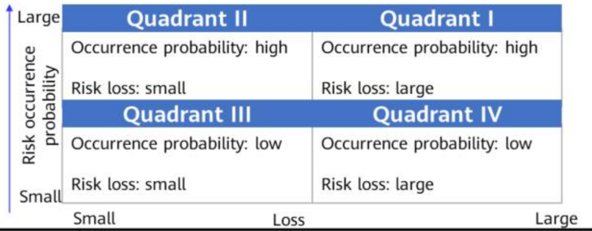
Why
What
How

- The risk identify and quantum (RIQ) model helps identify potential market risks, technical risks, and project construction risks to minimize the impact of the negative factors.
- The RIQ, a risk identification and quantification model, is used to identify project risks and calculate project loss caused by risks.

Market risk analysis

Technical risk analysis

Project construction risk analysis



Quadrant	Importance	Measure
I	High	Disassemble high risks by key step.
II	Relatively low	Develop measures for reducing the risk occurrence probability.
III	Low	Extract the risk contingency.
IV	Relatively high	Develop the alternative emergency measures and solution.

Feasibility Research Consultation Service – Deliverable

Why
What
How

Feasibility Consultation Service Deliverable

Summary

- DC Planning Process
- DC Assessment Models
  - Reliability Model
  - Energy Efficiency Model
  - Economic Model
- Site Selection Report
- Feasibility Research

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Quiz

1. (Multiple choice)In the consulting and planning stage of a new data center, some of the following items are indispensable?
   A. Site Selection Report
   B. Feasibility Research
   C. Operating environment analysis
   D. Business model analysis

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- A B

Thank you.

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Overview of Data Center Power Distribution System Planning and Design

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Foreword

- The slides describe the planning and design of the power distribution system in a data center. Some executable standard steps and key decisions made in these steps can simplify and shorten the planning process and improve the planning quality.

Objectives

On completion of this course, you will be able to:

- Describe the planning and design process of the data center power distribution system.
- Master the procedure for planning the data center power distribution system.
- Describe the composition of the data center power distribution system.

Contents

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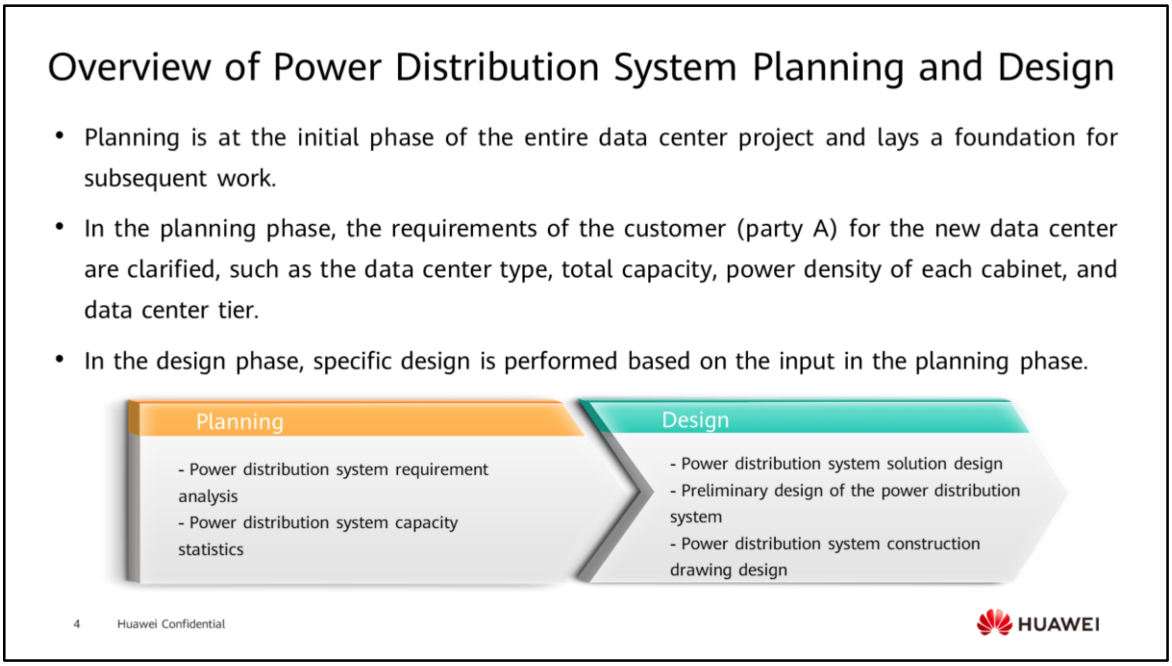


- In the planning phase, the customer's requirements are logically presented in documents using scientific methods and steps. The documents are transferred to the design company. Then the design company performs specific design according to the requirements.

Planning Procedure

- Power distribution system requirement analysis
  - Data center tier (requirements for the power distribution system)
  - Power density
  - Overall capacity planning
  - Data center power usage effectiveness (PUE)
- Power distribution system capacity statistics
  - Based on the previous requirement analysis input, calculate current and future load requirements as the input of the design phase.

- Power distribution system requirement analysis:
  - Data center tier: specified by the customer and determines the reliability level of a data center.
  - Power density: specified by the customer and determines the power distribution system capacity.
  - Capacity planning: The capacity planning of the power distribution system is output based on the customer's IT load capacity. You need to consider how to meet the customer's current and future requirements by reasonable planning.
  - PUE: specified by the customer and determines the selection of core devices (mainly the UPS) in the power distribution system. The PUE mainly determines the cooling system.
- Power distribution system capacity statistics:
  - Collect statistics on the current and future load requirements based on the power density input and power load (mainly the load of the cooling system) of the customer, and use the statistics as the input for the design phase.

Design Procedure

- Power distribution system solution design
  - Based on the previous power distribution capacity statistics and requirement analysis, design the power distribution system architecture and the plane of the main equipment, and output the main equipment list and solution description of the power distribution system.
- Preliminary design of the power distribution system
  - Use the previous power distribution system solution design as the input to design the overall layout of the power distribution system, and output the material list and technical proposal of the power distribution system.
- Power distribution system construction drawing design
  - Use the preliminary design of the power distribution system as the input to output the bill of quantities (BOQ) and the detailed installation diagram of the power distribution system.

- This course describes the power distribution system solution design, focusing on the power distribution system architecture design, main equipment list, and power distribution solution description.

Precautions for Planning and Design

- Pay attention to the following in the planning and design process:
  - Separating solution design and detailed design
    - In the early phase of the design process, pay special attention to the following: Ensure that there is consensus on the most important functions of a data center and their costs and do not invest time and efforts in handling detailed design and specifications. In the early phase, properly plan the performance, cost, scale, location, and timing of a data center involved in the project.
  - Separating key project specifications and user preferences and restrictions
    - During early planning, focus on reaching consensus on specifications such as data center tier and power density, and delay processing user preferences and most of the restrictions to efficiently decide system concepts.

- Separating system concepts and detailed design: Determine system concepts before generating detailed technical specifications, performing detailed design, or discussing various user preferences or requirements. This can bring high efficiency. If performance or cost issues occur after the start of the detailed design, the basic system concept may change, resulting in a large amount of rework and project delay. In the early phase of the design process, pay special attention to the following: Ensure that there is consensus on the most important functions of a data center and their costs and do not invest time and efforts in handling detailed design and specifications. When the system concept is to be determined, high-level decision makers need to determine the macro objectives and properly plan the performance, cost, scale, location, and timing of a data center involved in the project. If stakeholders do not understand the features or costs of the basic design before the detailed design starts, problems may occur in the later phase of the process. This method aims to avoid such problems that are frequently encountered.
- Separating key project specifications and user preferences and restrictions: We found that some macro key project specifications are necessary and can support the selection of system concepts. We found that some key specifications, such as power density and expansion plan, were not clearly defined and the quantification method was unclear. During early planning, focus on reaching consensus on specifications and delay processing user preferences and most of the restrictions to efficiently decide system concepts. This ensures that high-level decision makers focus on making the most important decisions, rather than getting stuck in discussions about details.

Contents

Overall Function Requirements for the Power Distribution System

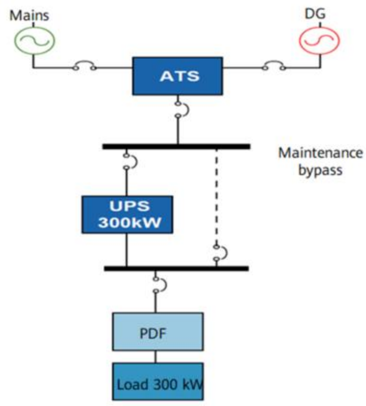
- Uptime Tier Ⅳ data center (corresponding to TIA Tier 4 data center): must meet the requirements for fault tolerance (one fault) and online maintenance. The power supply and distribution system must meet the requirements for active-active power supply and distribution routes. The two power supply and distribution routes must meet the fault isolation requirements.
- Uptime Tier Ⅲ data center (corresponding to TIA Tier 3 data center): must meet the requirements for planned online maintenance. The requirements for active-standby power supply and distribution routes must be met.
- Uptime Tier Ⅱ data center: must meet the requirements for redundancy backup.
- Uptime Tier Ⅰ data center: only needs to meet the requirements for device running.

- Uptime Tier Ⅳ data center: In terms of fault tolerance, only one fault can be tolerated. In terms of fault isolation, physical fault isolation is required. For example, two routes cannot be routed together, but must be physically isolated. In addition, the distance between the two routes must meet certain requirements, and threats such as fire must be considered.
- Uptime Tier Ⅲ data center: Requirement for planned online maintenance must be met. At least active-standby power supply and distribution routes are required. In most cases, both routes are active.
- Uptime Tier Ⅱ data center: Requirements for redundancy backup must be met. For example, for the UPS, diesel generators (DG) are redundant, but one single point of failure still occurs on the power supply route.
- Uptime Tier Ⅰ data center: There is no redundancy.
- The redundancy mentioned here is device redundancy, rather than module redundancy in a modular UPS.

Specific Requirements for Uptime (1)

- Tier Ⅰ: basic data center infrastructure
- Basic requirements:
  - An Uptime Tier Ⅰ basic data center has non-redundant capacity components and a single non-redundant power distribution route to serve the critical environment. The infrastructure of an Uptime Tier Ⅰ data center includes dedicated space for IT systems, UPSs, cooling equipment, and engine generators.
  - Onsite fuel reserve should support 12-hour operation of engine generators.

Example of the power distribution solution for an Uptime Tier I data center



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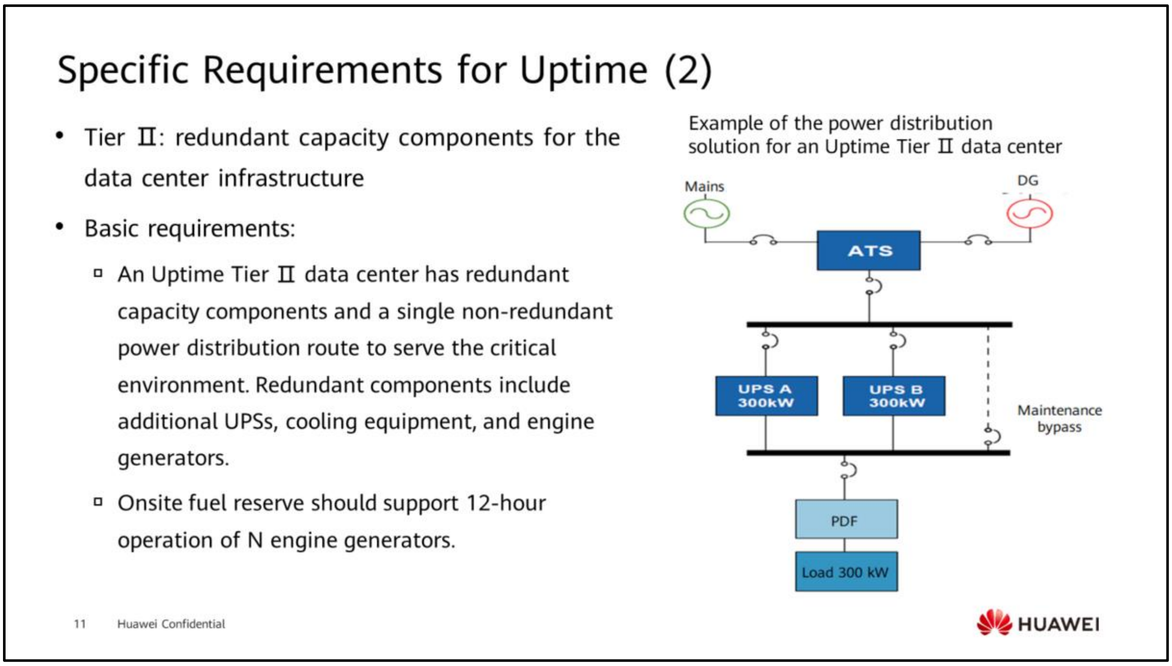
- Operation effects:
  - A data center is prone to interruption during planned and unplanned activities. Misoperations (man-made) on the infrastructure may cause interruption of a data center.
  - Unexpected interruptions or failures of any capacity systems, capacity components, or distribution components will affect the critical environment.
  - The data center infrastructure must be completely shut down every year to ensure that necessary preventive maintenance and repair work can be performed safely. If an emergency occurs, the infrastructure may need to be shut down more frequently. If maintenance is not performed on a regular basis, the risk of unexpected interruption is greatly increased.

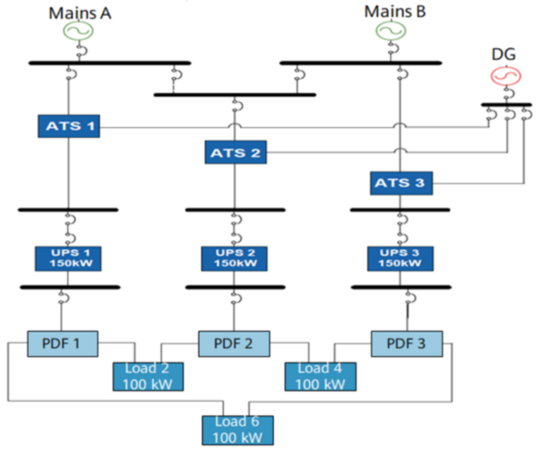


- Operation effects:
  - A data center is prone to interruption during planned and unplanned activities. Misoperations (man-made) on the infrastructure may cause interruption of a data center.
  - Unexpected capacity component failures may affect the critical environment. Unexpected interruptions or failures of any capacity systems or distribution components will affect the critical environment.
  - The data center infrastructure must be completely shut down every year to ensure that necessary preventive maintenance and repair work can be performed safely. If an emergency occurs, the infrastructure may need to be shut down more frequently. If maintenance is not performed on a regular basis, the risk of unexpected interruption is greatly increased.

Specific Requirements for Uptime (3)

- Tier Ⅲ: concurrently maintainable data center infrastructure
- Basic requirements:
  - Data centers that can be concurrently maintained have redundant capacity components and multiple independent power distribution routes to serve critical systems. At any time, only one power distribution route is required to serve the critical environment.
  - All IT devices use dual power supplies and are properly installed to be compatible with the data center architecture topology. If the critical environment does not meet this specification, a transmission device such as a switch must be used.
  - Onsite fuel reserve should support 12-hour operation of N engine generators.

Example of the power distribution solution for an Uptime Tier Ⅲ data center



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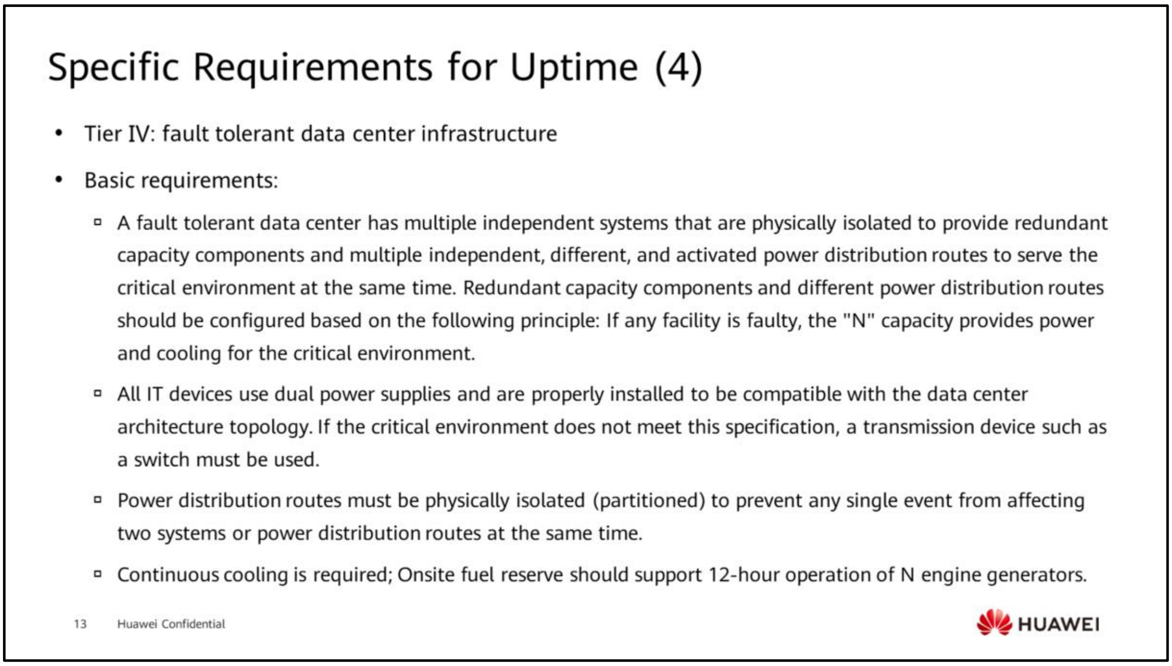
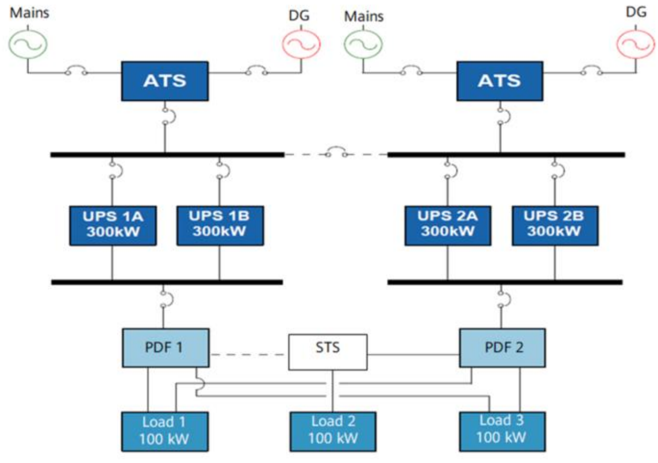
- Operation effects:
  - A data center is prone to interruption during planned and unplanned activities. Misoperations (man-made) on the infrastructure components may cause interruption of a data center.
  - Unexpected interruptions or failures of any capacity systems will affect the critical environment.
  - Unexpected interruptions or failures of any capacity components or power distribution route components may affect the critical environment.
  - Planned infrastructure maintenance can be accomplished by using redundant capacity components and power distribution routes to continue safe operation on other devices.
  - During maintenance activities, the risk of interruption may increase.



- Operation effects:
  - The data center is not easily interrupted during unplanned activities beyond a single plan.
  - The data center is not easily interrupted during planned activities.
  - The data center infrastructure can be maintained by using redundant capacity components and power distribution routes to continue safe operation on other devices.
  - During maintenance activities where redundant capacity components or power distribution routes are disabled, if the remaining routes are faulty, the risk of interruption in the critical environment increases.
  - Using the fire alarm, fire extinguishing, or emergency power-off (EPO) function may interrupt a data center.

Specific Requirements for Uptime (5)

Example of the power distribution solution for an Uptime Tier IV data center



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Comparison of Uptime

Data Center Tier	Tier Ⅳ	Tier Ⅲ	Tier Ⅱ	Tier Ⅰ
Overall function requirement	Fault tolerance (one fault), active-active power supply and distribution routes	Planned online maintenance, active-standby power supply and distribution routes	One power supply and distribution route	One power supply and distribution route
Physical isolation requirement	√	/	/	/
Mains input requirement	/	/	/	/
DG requirement	2N is recommended, but N+1 can also be used.	N+1	N+1	N
Transformer requirement	/	/	/	/
UPS requirement	2N	N+1	N+1	N
Backup time requirement	Meeting DG startup requirements	Meeting DG startup requirements	Meeting DG startup requirements	Meeting DG startup requirements
DG fuel storage requirement	12 hours	12 hours	12 hours	No specific requirements

Comparison of TIA-942

Data Center Tier	Tier 4	Tier 3	Tier 2	Tier 1
Overall function requirement	Fault tolerance (one fault), active-active power supply and distribution routes	Planned online maintenance, active-standby power supply and distribution routes	One power supply and distribution route	One power supply and distribution route
Physical isolation requirement	√	/	/	/
Mains input requirement	At least two active-active routes between different substations	One active mains input and one standby mains input (can be from the same substation)	One mains input	One mains input
DG requirement	2N	N+1	N	/
Transformer requirement	2N	N+1	N	N
UPS requirement	2N	N+1	N+1	N
Backup time requirement	10 minutes	10 minutes	10 minutes	10 minutes
DG fuel storage requirement	96 hours	72 hours	24 hours	/

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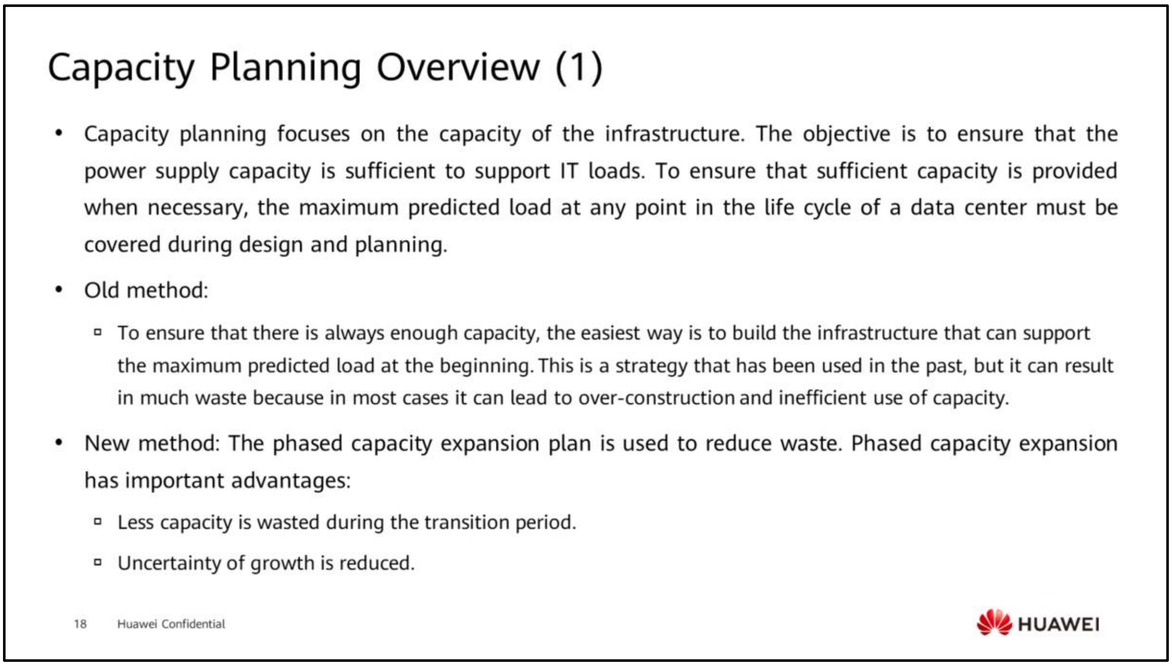

- Old method: Over-construction leads to waste.
- Such waste includes capital costs for idle equipment and operating costs for idle capacity. During the life cycle of a data center, the cost of supplying power to unnecessary capacity components and the cost of maintaining and repairing them may be huge.
- The idle capacity can be generated in either of the following ways:
    - If the IT load is small at the beginning and increases with time, the system will be over-constructed during the transition period.
    - If the IT load never reaches the predicted level, the system is over-constructed in the entire life cycle. Most data centers will never reach their predicted full capacity. In practice, data centers typically operate with less than half of the capacity.

Capacity Planning Overview (2)

- IT load capacity curve: It is provided by the customer's IT department and shows the IT capacity planning of the entire data center lifecycle.
- Power distribution system capacity curve: The IT load capacity curve is used as the input and capacity is expanded by phase to ensure that the power supply capacity is sufficient to support IT loads.

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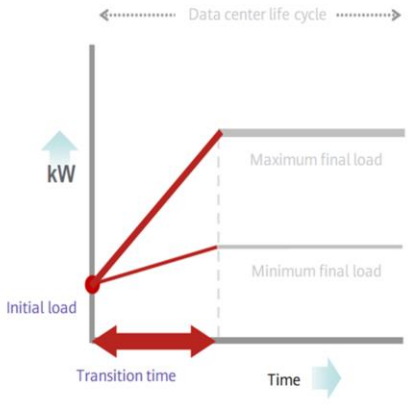
IT Load Curve (1)

- Most data center plans are vague because they do not incorporate the evolving technology feature of IT devices. One way to solve the uncertainty problem is to set reasonable maximum and minimum values that can be expected in the life cycle of a data center to provide support for the prediction. Once the maximum and minimum estimated values of the final load are determined, you only need to add the initial load and transition time to predict the IT load growth.
  - Maximum final load: predicted maximum IT load.
  - Minimum final load: predicted minimum IT load.
  - Initial load: IT load that is initially installed.
  - Transition time: time required from the initial load to the final load. Generally, the life cycle of a data center is 10 years.



IT load curve example

- Most data center plans are vague because they do not incorporate the evolving technology feature of IT devices. In addition, the business requirements that drive data center design and/or service requirements are difficult to be understood in advance. The reliability of the prediction decreases as the IT load in a farther future is predicted. Any model with forward-looking capacity requirements needs to take into account information about the quality (certainty) of the predictive activity itself. One way to solve the uncertainty problem is to set reasonable maximum and minimum values that can be expected in the life cycle of a data center to provide support for the prediction. The preceding figure shows the concepts of the minimum and maximum values of the final load. Generally, the life cycle of a data center is 10 years. Once the maximum and minimum estimated values of the final load are determined, you only need to add the initial load and transition time to predict the IT load growth.
- The model shows the predicted maximum and minimum values of the final load, but does not explicitly predict the actual value of the final load. Any description of the actual value of the final load is just a guess in most cases. The actual value of the final load of a particular device generally depends on multiple variables, some of which may not be predicted by the planner or even may be unknown.

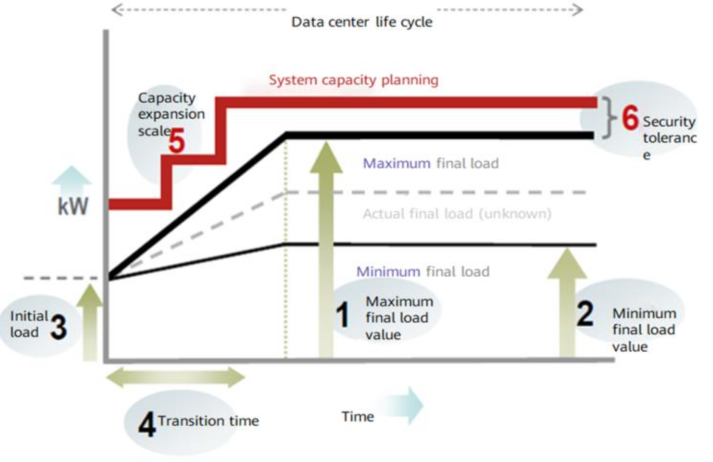
IT Load Curve (2)

- A more effective planning method of this growth model is to identify the upper and lower limits of the final load, which can be more reliable and consistent than a single predicted load level.
- When the predicted maximum and minimum values of the load are identified, the intelligence of the model is increased and the system capacity planning can cover the uncertainty of growth, which provides a simple strategy to minimize the risk of over-construction and reduce the total cost of ownership.

- During planning, users tend to adopt the predicted maximum load, because the possible maximum load was always the "safe" value used during the initial deployment of the design system, and planners have got used to that way of thinking. The predicted minimum load may seem superfluous, but it is the key to achieving the considerable cost-effectiveness of the growth model.

Power Distribution System Capacity Curve (1)

- Capacity expansion scale: incremental scale of the physical infrastructure system (capacity expansion delay).
- Security tolerance: extra capacity to cope with unexpected situations (such as unexpected increase of IT loads or unexpected consumption of system capacity).



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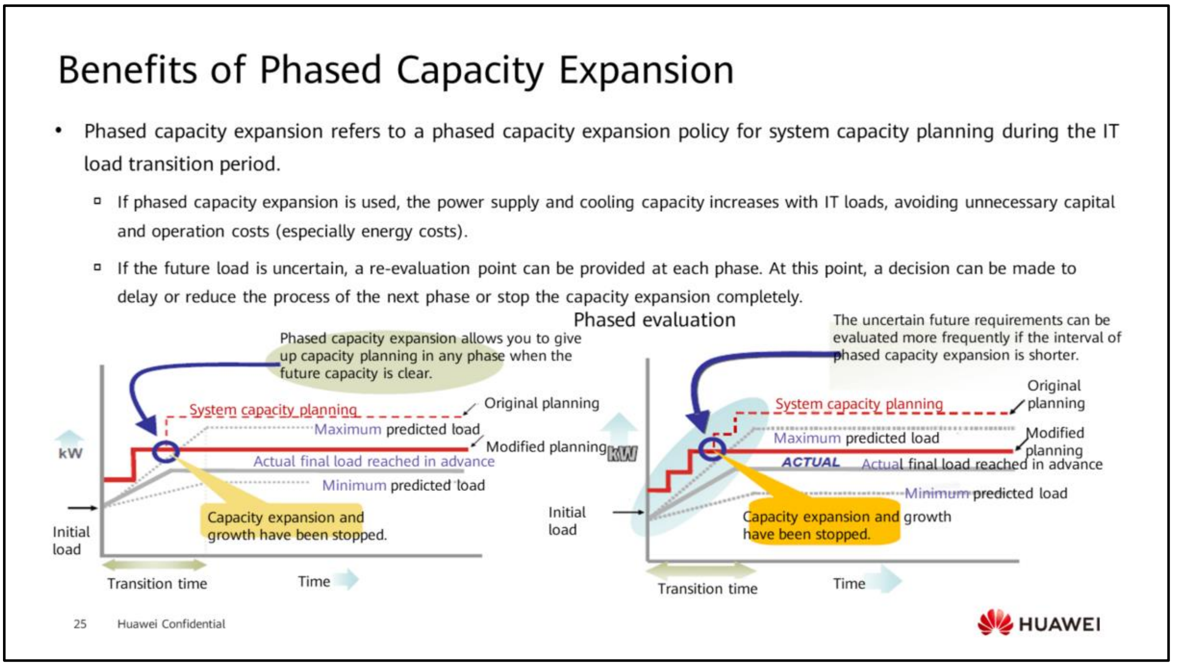
- Capacity expansion scale is an attribute of system capacity planning, not an attribute of the IT load curve. It is decided at the later stage of the planning process, taking into account the scalability of the selected system architecture.
- Security tolerance refers to the "extra" infrastructure capacity required to cope with unexpected changes, which may be an increase in the power demand for IT loads (for example, adding servers without authorization) or a decrease in the capacity provided by the power supply and cooling infrastructure (for example, cooling capacity decrease caused by cooling pipe blockage).

Power Distribution System Capacity Curve (2)

- Differences between the IT load curve and system capacity planning
  - The model provides a common language and framework to help users understand IT load requirements and help physical infrastructure designers plan a system with sufficient power and cooling capacity to meet the load requirements. They are interdependent.
  - First part of the model: The IT load curve is provided by the user as an input to the planning process.
  - Second part of the model: The system capacity planning is provided by the planning process as the output to the user to define the deployment of the power supply infrastructure (including the step-by-step capacity expansion phase) to support the IT load curve of the user.

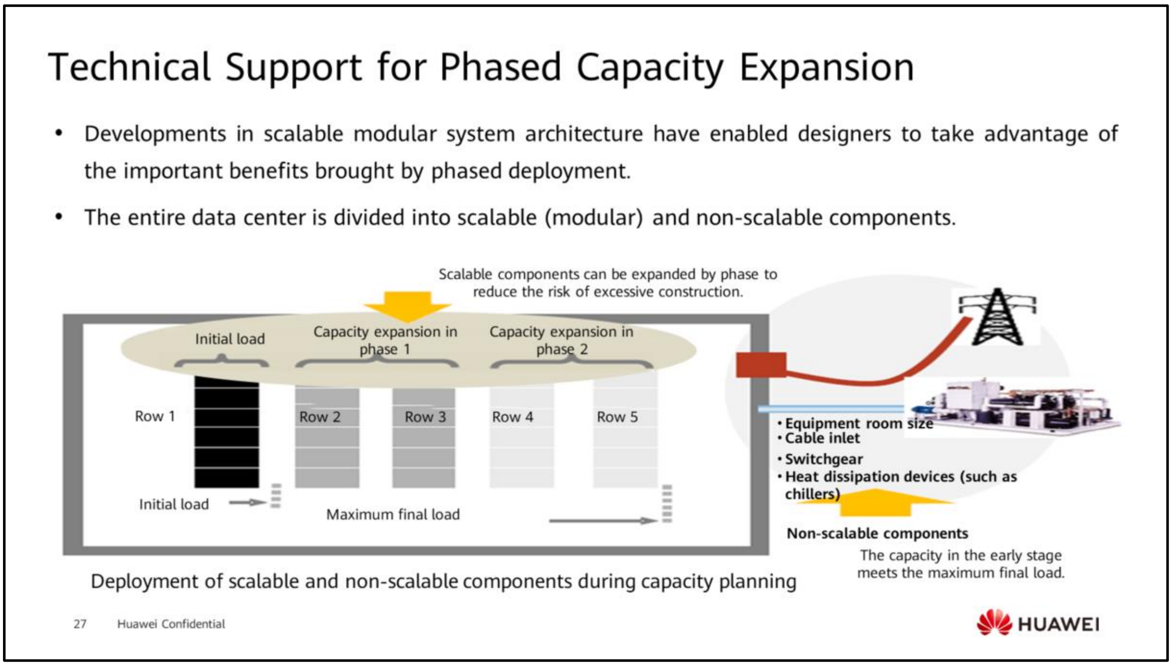
Power Distribution System Capacity Curve (3)

- Therefore, for a specific project, the model development is divided into two parts:
  - First, establish an IT load curve. The IT load curve consists of parameters 1 to 4 of the model. It is created based on the understanding of enterprise service requirements at the early stage of the planning process. The key to this step is to get the participants in the planning process to agree on the predicted IT load.
  - Second, the system capacity planning is established to support the IT load curve. The system capacity planning is represented by (capacity expansion scale and security tolerance) of the model. The system capacity planning is performed at the early stage of the planning process to roughly estimate the capacity expansion scale.

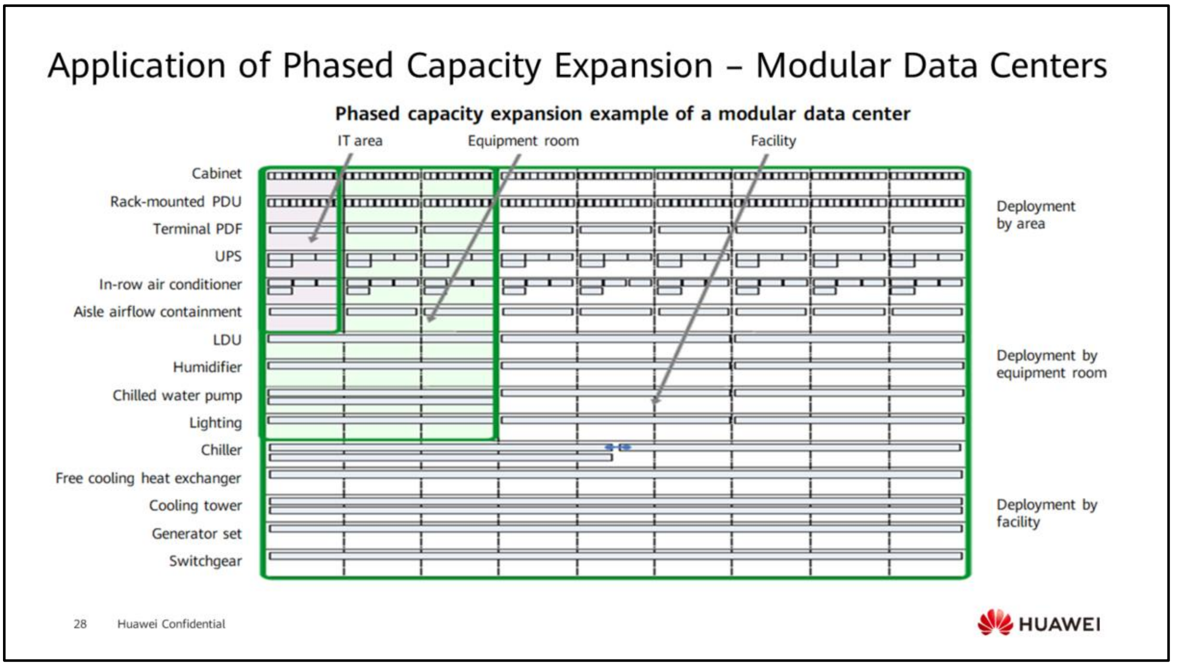


- Although these concepts are not new to many applications in daily life, the legacy power supply and cooling architecture that cannot be expanded in a data center has dominated the initial capacity expansion of the entire facility for decades. However, recent developments in scalable modular system architecture have enabled designers to take advantage of the important benefits brought by phased deployment.
- There are three factors that make phased capacity expansion particularly attractive:
  - Energy has become a major expense. Electricity bills provide a powerful incentive to avoid overcapacity. Incentives for "green buildings" and "demand-side management" programs that reward efficient operations provide more incentives for running streamlined data centers. A data center with "reasonable planning" (power supply and cooling capacity keeping pace with the IT load growth) is more efficient than a data center with too much idle capacity.

- Most data centers never expand to their predicted largest scales. Research shows that the final load of most data centers is far lower than the maximum load predicted during planning. Phased capacity expansion reduces the risks caused by waste of installation resources. This is the biggest advantage of phased capacity expansion for most data centers.
- Idle capacity causes unnecessary maintenance costs. Even if the capacity is idle, the installed equipment must be maintained and repaired. By installing only the capacity equipment required to support the current load, you can save a large number of maintenance costs, because no maintenance costs will be incurred for unavailable equipment.



- Non-scalable components are installed at the beginning to accommodate the predicted maximum load (the maximum final load value) in the data center life cycle. Non-scalable components include the physical equipment room size, electrical cable inlet capacity, and pre-existing in-room air conditioners. These "rigid" capacity limits can seriously impact time, availability, and cost.
- Scalable components are installed at the beginning to support loads lower than the maximum value (enough to support the initial load for a period of time), and then are gradually increased as time goes by according to the phased capacity expansion planning. Scalable components include racks, rack-level power protection and distribution equipment, and rack-level cooling equipment.



- The left part of the figure lists the subsystems of the data center. Gray blocks indicate devices. If all device blocks exist, the data center uses the maximum configuration. However, the device blocks are deployed from left to right to gradually expand the data center to meet the increasing IT load requirements. The capacity of all subsystems listed on the left must match the given IT capacity (kW). The gray modules of the subsystem must be added in a way that meets the capacity expansion requirements of the data center. The figure also provides the association between different subsystem modules. As shown in the figure, in-row air conditioners are deployed by area. Every three in-row air conditioners have one backup device to form N+1 redundancy. One humidifier is deployed for every twelve in-row air conditioners, and one humidifier is associated with one equipment room.
- As shown in the preceding figure, the preceding subsystems are associated with each other in the unit of 60 kW. These associated subsystems form an area with a certain IT capacity as the core deployment module of the architecture. In this architecture, the area includes the cabinet, rack-mounted PDU, terminal PDF, UPS, in-row air conditioner, and hot aisle airflow containment system.
- As discussed earlier, IT area-based deployment is not effective for some subsystems. In the architecture shown in the figure, the humidifier, liquid distribution unit (LDU), chilled water pump, and lighting are associated and matched to support three IT areas at the same time. In this architecture, these subsystems and three IT areas form an equipment room module. The boundary of an equipment room can be a physical wall or a virtual wall, which usually refers to a partition in a large equipment room.

- In a data center, there are also some centralized subsystems that are optimally deployed in units of facilities. As shown in the figure, these subsystems include the chillers, free cooling heat exchangers, cooling towers, generators, and switches. Some subsystems, such as generators, are not modular, while others, such as chillers, are modular.
- In this example, the chillers work in N+1 redundancy mode, and each module supports 4.5 areas. In this example, modular chillers deployed in a centralized manner do not need to correspond to areas or equipment rooms. In this architecture, the two chillers on the left must be installed at the initial stage to provide N+1 redundancy. Install the third chiller after the fifth area is added. The blue line between two chillers in the upper row indicates that the two chillers are connected to the same main pipe. Therefore, the N+1 chillers in the lower row are redundant devices for the two chillers. At the beginning, it seems that small chillers can provide high scalability, which is consistent with area deployment. However, if the chillers are divided into small modules, the cost is high and the complexity increases. In this architecture, a chiller can supply cooling to a large area. To save energy, you need to select a model with an inverter compressor.

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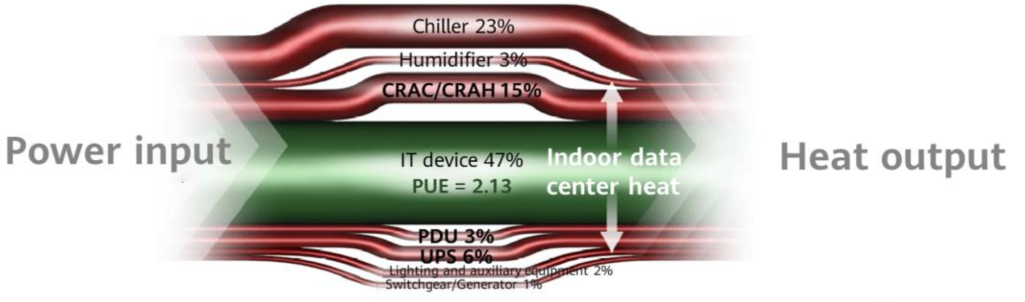
PUE

- PUE is proposed by The Green Grid and has become a core indicator for evaluating the efficiency of the physical infrastructure layer (equipment room) of a data center.

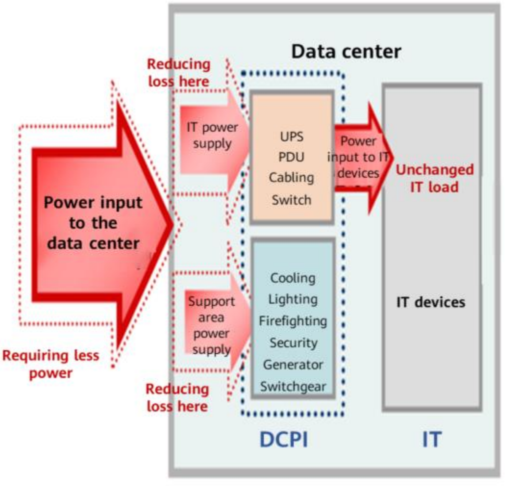
$$PUE = \frac{\text{Total energy input to a data center}}{\text{Energy consumed by IT loads}}$$



- The PUE value is greater than 1. Currently, the PUE value of a modular data center ranges from 1.1 to 1.8 (using cold and hot aisle containment, in-row air conditioners, and modular UPSs). The PUE value of a traditional data center ranges from 1.8 to 3.5 (using in-room air conditioners, without cold and hot aisle containment).
- PUE determination is important for device selection and data center architecture. It is mainly reflected in the cooling solution, for example, whether to use air-cooled direct expansion air conditioners, chilled water air conditioners, or cooling devices with the indirect evaporation function. For example, the PUE of a data center using common air-cooled in-row air conditioners ranges from 1.5 to 1.7; the PUE of a data center using chilled water in-row air conditioners can be about 1.3; the PUE of a data center using indirect evaporative cooling devices can be less than 1.2.
- Modular UPSs and PDUs are used to reduce power distribution loss.

Methods of Reducing the PUE of a Data Center (1)

- There are three methods to improve the data center efficiency:
  - Improve the internal design of the data center facility (DCF) equipment to reduce the energy consumption during operation.
  - The planning of DCF components better matches the actual IT load (moderate planning) to improve the operating efficiency of components.
  - Develop new technologies to reduce the power required to provide the data center physical infrastructure (DCPI) support functions, such as free cooling.



Methods of Reducing the PUE of a Data Center (2)

- The planning of DCF components better matches the actual IT load (moderate planning) to improve the operating efficiency of components. This provides the maximum and most direct opportunity for improving the efficiency of a data center, because the operating efficiency of a device is the highest when the load rate is reasonable.
- Therefore, you need to:
  - Properly plan the system capacity.
  - Select modular UPSs and rack-mounted PDUs.

Section Summary

- Specify the requirements for the power distribution system based on the data center tier.
- The capacity needs to be expanded by phase. Different components need to be expanded in different modes. For example, a data center is constructed in three phases, and eight sets of high-voltage (HV) DG systems are required to work in 7+1 mode. In the initial construction, 2+1 DGs can be installed to meet the requirements of phase 1. However, all high-voltage (HV) cabinets corresponding to the DGs need to be installed, and ports need to be reserved for installing DGs in batches in the future. Other devices, such as modular UPSs and in-row air conditioners, should be expanded gradually based on load requirements.
- Proper planning of infrastructure capacity improves the operating efficiency of components and provides the maximum and most direct opportunity for reducing the PUE of a data center.

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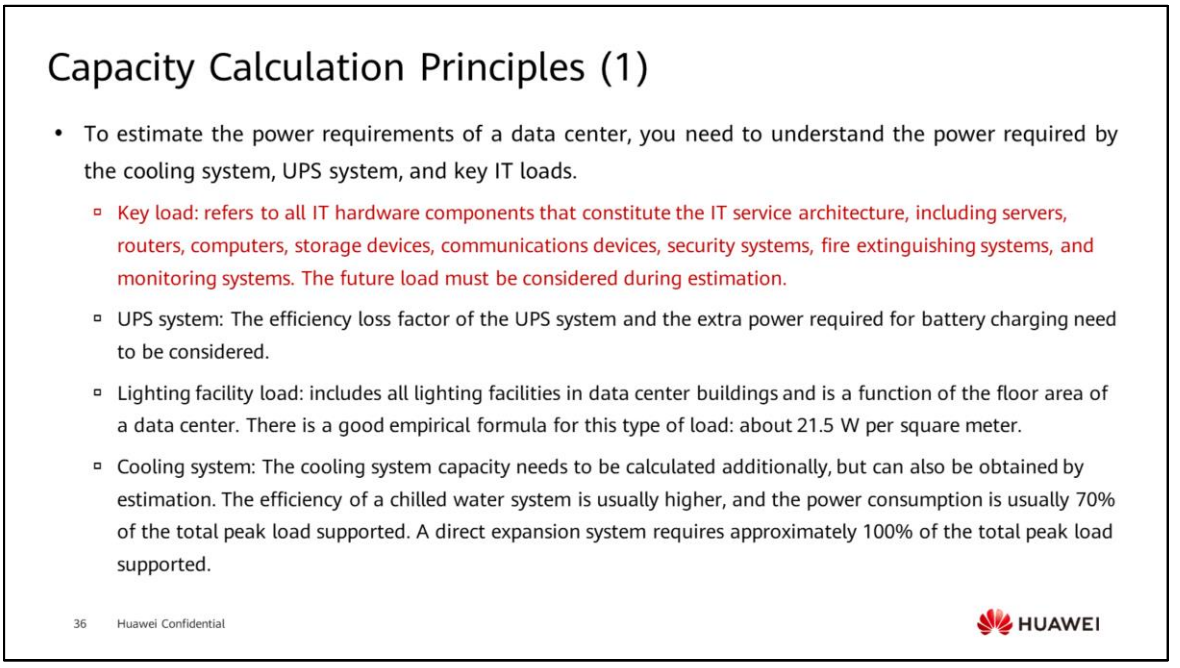


- Although the power requirements of these elements may differ greatly from each other, if the power requirements of the planned IT loads are determined, the power requirements of these elements may be accurately estimated using a simple method. In addition to estimating the capacity of the power lines, these elements can also be used to estimate the power output capacity of the standby generator system if the load of a data center requires a standby generator system.
- Why does the future load need to be considered? Because IT devices in data centers are constantly updated, we must fully estimate the capacity of power lines that supply power to DCPI components so that the known initial load and future load can be supported. After the future load is estimated, add it to the calculated basic load to obtain the key load of the power supply in the unit of kW.
- The UPS efficiency varies with the load rate. Generally, the UPS efficiency of 0.9 is considered. Battery charging does not continuously consume power. When a battery is fully charged, its charge load can be ignored. However, after the battery is partially or completely discharged, the charge power can reach 15% to 20% of the rated power of the UPS. Although such loads are rare, they must be included in the estimation of generator and line inlet capacity.

Capacity Calculation Principles (2)

- After the total power capacity in the unit of kW is estimated, two key calculations can be performed: First, estimate the capacity of the power lines required for supplying power to a data center. Second, estimate the capacity of all standby generators required for achieving the expected availability.
  - Determine the capacity of the power lines.
    - Current (A) = (Power (kW) x 1000)/(Voltage (V) x 1.73). The voltage is the line voltage. The power needs to be multiplied by a coefficient ranging from 1.2 to 1.25 according to the corresponding specifications.
  - Determine the generator capacity.
    - The generator capacity is in the unit of kVA, but the preceding capacity is in the unit of kW. Therefore, the power factor needs to be considered. Generally, the power factor of 0.8 is used. In addition, the load characteristics and startup voltage of the chiller or UPS need to be considered.

Key Load Capacity Statistics (1)

- Principle
  - Statistics are collected based on the data center layout, that is, based on different functional areas, such as the IT room, access equipment room, operation room, and fire control room.
- Input
  - Cabinet power density
  - Number of cabinets
  - Power requirements of fire extinguishing, access control, and monitoring devices

Example of Key Load Capacity Statistics

Key load statistics of a data center

Functional Room	Device Name	Rated Power (kW)	Quantity	Power Factor	Required Power		
					Active Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)
IT room 1	Server cabinet	7	200	0.9			
	Network cabinet	3	20	0.9			
	Test cabinet	4	5	0.9			
IT room 2	Server cabinet	10	150	0.9			
	Network cabinet	3	15	0.9			
	Test cabinet	4	5	0.9			
Operation room	PC in the operation room	0.3	16	0.8			
	61-inch screen	1.2	1	0.8			
	Monitoring device	7	1	0.9			
Fire control room	Fire extinguishing device	5	1	0.9			

- In the industry, the IT power factor of 0.9 is usually used for estimation.

Questions

- Based on the following table, customers may ask the following questions:
  - Is the server cabinet power 7 kW the maximum power, minimum power, or average power?
  - If the peak power of a cabinet exceeds 7 kW, can the cabinet work properly?
  - If the power consumption of a cabinet is lower than 7 kW, can adjacent cabinets use the remaining power of the cabinet?
  - How to meet the requirement of adding extra services in the future?

Functional Room	Device Name	Rated Power (kW)	Quantity	Power Factor	Required Power		
					Active Power (kW)	Reactive Power (kVAR)	Apparent Power (kVA)
IT room 1	Server cabinet	7	200	0.9			
	Network cabinet	3	20	0.9			
	Test cabinet	4	5	0.9			

- This table cannot answer the preceding questions. A more detailed table is required to convince customers that the current plan can meet the actual requirements.

IT Load Capacity Statistics (1)

- Layers of the entire data center:
  - Data center facilities, consisting of one or more IT rooms
  - IT room, consisting of one or more IT areas
  - IT area, consisting of one or more IT cabinets
  - IT cabinet
- Since some attributes of a data center are affected by the power density specifications of each layer, the power density specifications of the four layers must be specified to control the entire design and predict the performance of the data center.
- Although the power density specifications of each part can be "accumulated" into a single facility-level power density value, the single power density value obtained in this manner is not enough to control the entire design and obtain a predictable result.

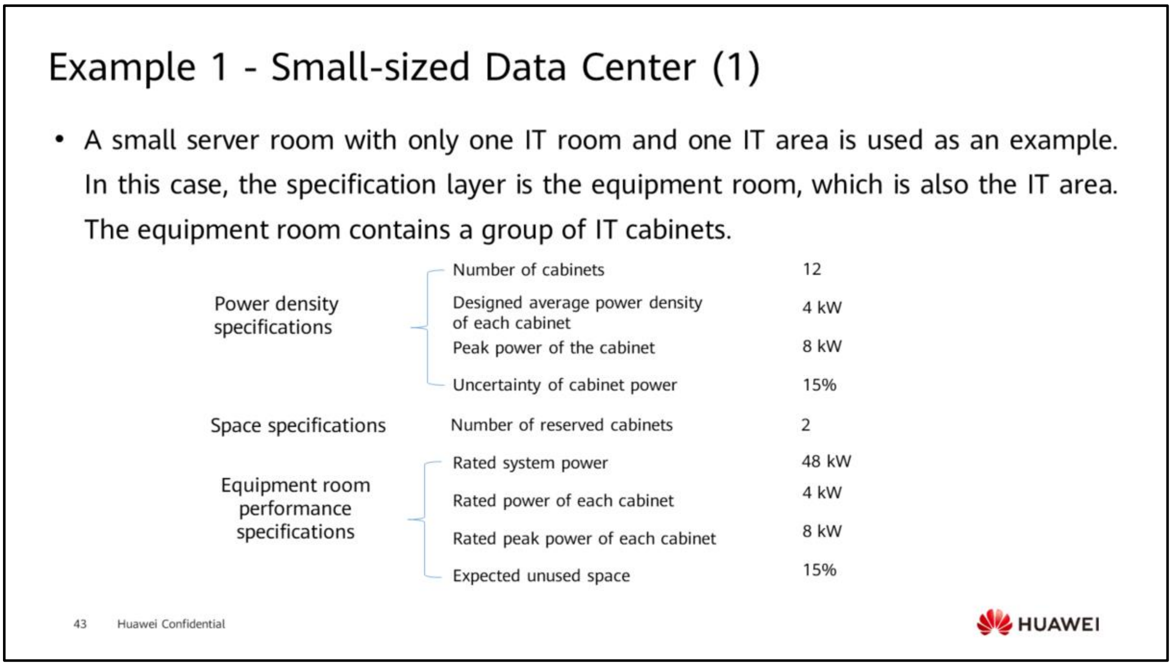
- The power density varies with IT cabinets, IT areas, and equipment rooms. This difference exists between cabinets or between equipment rooms, and the power density also varies with time. Because some IT devices are added or removed from time to time and the workloads of these IT devices are different, the power consumed by these IT devices is also different. The operating power of each cabinet is different, and the power of the same cabinet varies in different periods. From this point of view, trying to define power density also seems to be futile. However, considering that the objective of defining the power density is to determine a data center design that can support an IT device cluster, we can determine many important statistical parameters of the device cluster, and these statistical parameters are sufficient to form power density specifications that do not vary with the power density difference.

IT Load Capacity Statistics (2)

- Determining specifications

Specifications	Definition	Usage Method
Number of units	Number of cabinets in an IT area, number of IT areas in an equipment room, or number of equipment rooms	Convert the values of each unit requiring power supply to a total value (each cabinet, each IT area, and each equipment room).
Designed target average power of each unit (kW)	Average expected load power (average power or rated power) of each unit	Determine the capacity of the power distribution system at each layer (IT area, equipment room, and facility).
Peak power of each unit (kW)	Maximum expected power of a unit	Determine the requirements for the power distribution system.
Uncertainty of unit power (%)	The expected uncertainty of the actual power is quantified compared to the designed target average power.	Determine the required reserved space to ensure that the low-density power deployment does not cause the power supply capacity to be wasted, which increases the cost.

- The number of units and the designed target average power of each unit are necessary information for determining the power density specifications. The peak power and the uncertainty of unit power are new concepts introduced here. These are necessary because the designed target average power does not provide the necessary information to determine the power distribution system, and does not provide sufficient information to determine the energy efficiency calculation point.
- The relationship between the designed target average power of each unit and the peak power of each unit is as follows: As long as the average power of a unit does not exceed the target average power, the peak power of the unit can be reached. For example, in an IT area where the average power is 5 kW/rack and the peak power is 10 kW/rack, if the average power of the area is 5 kW/rack or lower, the power of one or more cabinets can reach 10 kW. In this case, the actual power of other cabinets must be lower than 5 kW, for example, 3 kW or 3.5 kW.
- Uncertainty of unit power: If the actual power of installed equipment is lower than the target power but the actual installation space is all occupied, the power distribution and cooling capacity will be wasted. In this case, if certain space is reserved during planning, more IT loads can be installed. This ensures that the utilization of the infrastructure capacity is maximized during low-density installation.



- The power density in the specifications can be determined by the following procedure:
  - Determine the number of cabinets based on IT requirements.
  - The target average power of each cabinet is determined by the specifications of the IT cabinet supplier or by the typical designed average value of the application. In this example, the typical value of an enterprise server room (4 kW/cabinet) is selected.
  - Select the peak power by setting the maximum expected or allowed cabinet power. In this example, the maximum capacity is 8 kW. This value is mainly determined by the rPDU provided by the cabinet supplier to support the cooling capacity and power supply capacity.
  - Estimate the uncertainty of the cabinet power by considering different IT deployment solutions or selecting the typical designed value of the application. In this example, the expected deployment power density is set to 15% of the designed target average power (4 kW).

Example 1 - Small-sized Data Center (2)

- The key point here is not that the plan can accurately reflect the detailed IT plan of each cabinet (because the IT plan of each device cannot be obtained in advance), but that the plan can ensure that the performance of a data center is known and predictable.
- In this example,
  - The specifications clearly define design that supports a cabinet group containing up to 12 cabinets.
  - In the cabinet group, the designed average power is 4 kW, and the peak power of each cabinet is less than or equal to 8 kW.
  - To ensure that the peak power is not exceeded, a pre-deployment IT policy can be formulated for the data center. According to the policy, the maximum power of each cabinet is 8 kW. When the load increases, the power must be allocated to each cabinet.
  - If the actual IT power density is less than 15% of the designed average value (4 kW), the extra reserved space can ensure that all available power supply and cooling capacity can be used.

- If the traditional method is used to describe the IT load of the equipment room, these issues cannot be explained.

Example 2 - Large-sized Data Center (1)

- In this data center example, the data center adopts the following layered structure:
  - The data center facilities consist of
  - Four IT rooms, each of which consists of
  - Six IT areas, each of which consists of
  - 16 IT cabinets
- The procedure is as follows:
  - Determine the number of cabinets in each IT area and set the cabinet power.
  - Determine the number of IT areas in each equipment room and set the IT area power.
  - Determine the number of equipment rooms and set the equipment room power.
  - Set specifications for facilities, IT areas, and equipment room space.
  - Integrate the overall specifications and verify the specifications based on the design constraints. Continuously adjust the design and repeat the procedure until the design meets the requirements.

Example 2 - Large-sized Data Center (2)

		Facility Equipment room	Equipment room IT area	IT area cabinet
Power density specifications	Number of units	4	6	16
	Designed average power density of each unit	480 kW	80 kW	5 kW
	Peak power of each unit	480 kW	80 kW	10 kW
	Power uncertainty of each unit	/	/	15%
Space specifications	Reserved space of each unit	/	/	3 cabinets
Equipment room performance specifications	Rated system power	1920 kW/facility	480 kW/equipment room	80 kW/IT area
	Rated power of each unit	480 kW/equipment room	80 kW	5 kW/cabinet
	Rated peak power of each unit	480 kW/equipment room	80 kW	10 kW/cabinet
	Expected unused space	/	/	15%

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- Note: In this case, only the IT cabinet unit involves uncertainty. Three cabinet positions are reserved. In actual applications, one or two IT area positions can be reserved (if necessary) to plan the new IT area without interrupting the existing IT areas and to fully utilize the power supply and cooling of the equipment room when the average power of deployed cabinets is lower than 5 kW.
- This table is more complex than the previous example of a single equipment room because it clearly records the space reserved for dealing with the uncertainty of power density. Users do not need to enter the IT area or equipment room because the uncertainty at the IT layer of a single cabinet has been predicted and considered. These layers are formed by accumulating lower layers. However, during design, users may reserve space to deal with uncertainty at different layers. Users can reserve extra cabinet positions in the IT area, reserve more IT area positions in the equipment room, reserve extra equipment room space in the facilities, or combine the three methods to reserve space for dealing with the uncertainty of power density. Which method of reserving space is most preferred depends on the geometric shape of the equipment room or other factors. This table records the overall space requirements so that users can reserve space using any combination of additional cabinets, IT areas, or equipment rooms.

Example 2 - Large-sized Data Center (3)

- For simplicity, this example assumes that the specifications of the IT area in all equipment rooms are the same, and the changes only exist at the cabinet layer.
- The table is concise, but contains a large amount of design information. The table consists of three columns. The left column indicates the equipment room composition of the facility, the middle column indicates the IT area composition of the equipment room, and the right column indicates the cabinet composition of the IT area. The table defines the attributes of the 2 MW (IT load) data center example as follows:
    - An IT area consists of 16 IT cabinets and three reserved cabinet positions.
    - The designed average power of each cabinet is 5 kW.
    - If the IT area power of all 16 cabinets does not exceed 80 kW, the allowable peak power of any cabinet is 10 kW.
    - Three cabinet positions are reserved in each IT area. If the deployed average power is less than 5 kW per cabinet, the power supply and cooling in the IT areas can be fully utilized.

Capacity Statistics Example (1)

Data center power requirement estimation and calculation table

Item	Required Data	Calculation	Total (kW)
Power Requirement – Electricity			
Key load capacity	Rated power of each IT device (initial)		#1________kW
	Other load capacity (including fire extinguishing, security, and monitoring devices)		#2________kW
	Rated power of each future IT load		#3________kW
Attenuation coefficient	Total power decrease of the key load in the stable state	(#1 + #2 + #3) x 1.05	#4________kW
UPS power loss and battery charge	Actual load + Future load (kW)	(#1 + #2 + #3) x 0.3	#5________kW
Lighting facilities	Total floor area related to the data center	0.0215 x Floor area (m^2)	#6________kW
Total power required for power supply	Sum of #4, #5, and #6	**#4 + #5 + #6**	#7________kW

- 0.3 = 0.2 + 0.1, including battery charge loss and UPS efficiency

Capacity Statistics Example (2)

Data center power requirement estimation and calculation table

Item	Required Data	Calculation	Total (kW)
Power Requirement – Cooling			
Total power required for cooling	Sum of the values in #7	Chiller system: #7 x 0.7 DX system: #7 x 1.0	#8________kW
Total Power Consumption			
Total power required for power supply and cooling	Sum of #7 and #8	#7 + #8	#9________kW
Estimating the Capacity of Power Lines			
Capacity meeting the requirements of various standards	Sum of the values in #9	#9 x 1.25	#10________kW
Three-phase AC voltage provided at the entry of the lines	AC voltage		#11________kW
Power capacity to be obtained from the power supply company (in amperes)	Sum in #10 and AC voltage in #11	(#10 x 1000)/(#11 x 1.73)	________A

Capacity Statistics Example (3)

Data center power requirement estimation and calculation table

Item	Required Data	Calculation	Total (kW)
Estimating the Capacity of the Standby Generator			
Key load that requires a standby generator	Sum of the values in #7	#7 x 1.3	#12________kW
Cooling load that requires a standby generator	Sum of the values in #8	#8 x 1.5	#13________kW
Required generator capacity	Sum of #12 and #13	#12 + #13	________kW

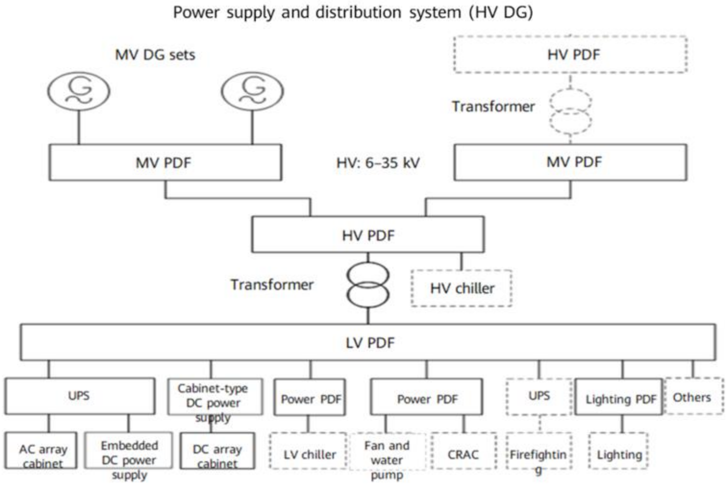
Section Summary

- Capacity statistics are collected by area (room), such as IT load, cooling load, lighting load, and fire extinguishing load.
- When collecting statistics on key loads (IT loads), you need to collect statistics on the loads at four layers: cabinet, area, equipment room, and data center facility. The number of units, average power, maximum power, and space reserved for uncertainty must be specified.
- Finally, the active power, reactive power, and apparent power required by a data center are obtained by accumulating all loads and are used as the input for the selection of the DG and mains.

Contents

Design Overview

- Design the power distribution system based on the plan input in the early stage.
- The design covers the 35 kV and lower power supply and distribution systems, including the 35 kV/10 kV/400 V transformer, 35 kV/10 kV/400 V DG, HV or low-voltage (LV) PDF, bus, UPS, and ATS.



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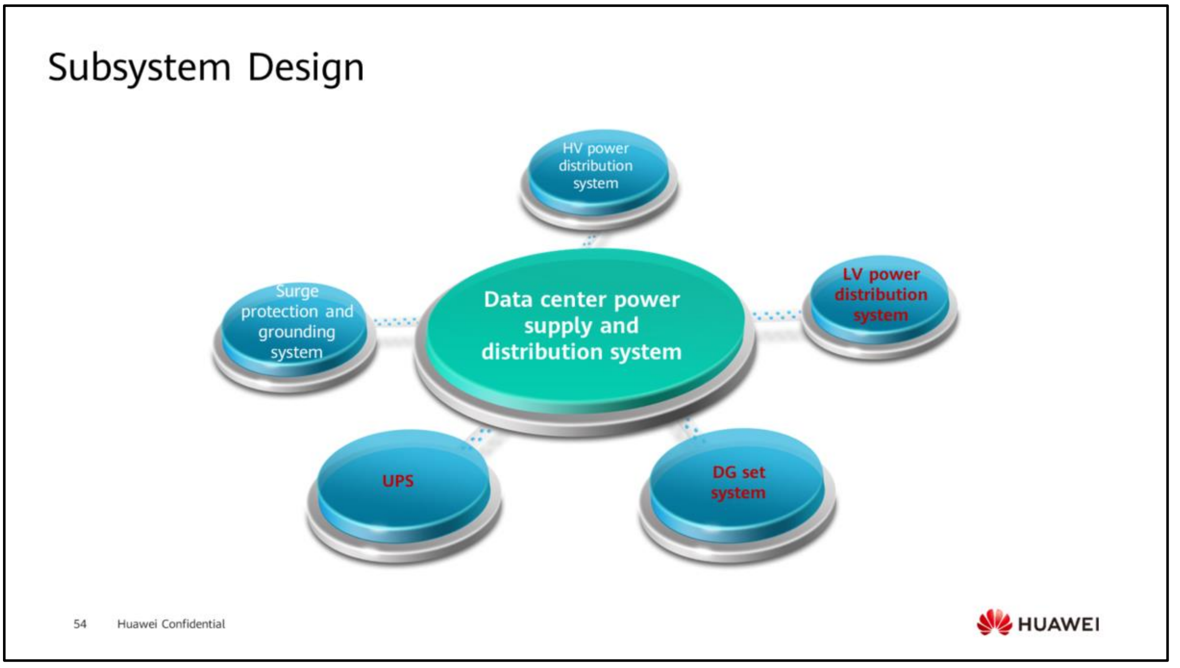
- The power supply and distribution system of a data center provides stable and reliable power for all devices in the equipment room, including subsystems of HV power distribution, LV power distribution, DG set, UPS, HVDC, battery, grounding, and server power supply.
  - HV power distribution system: introduces the HV mains power supply (such as 6 kV/10 kV/35 kV) into the transformer, which is then converted into LV mains to supply power to the LV power distribution equipment.
  - DG set system: quickly starts to provide backup power for the downstream LV equipment in case of mains failures.
  - LV power distribution system: introduces the LV mains power from the transformer and distributes the mains power to the UPS PDF, DC, and power PDFs. Then, the power is distributed to IT loads, cooling loads, and other auxiliary devices based on load requirements and standards.
  - UPS and HVDC: purify and back up electric energy, and provide pure and reliable power protection for IT loads.
  - Battery: stores energy based on chemical principles and ensures that the UPS and HVDC supply power to IT loads without interruption.
  - Grounding system: provides reliable grounding for the system to ensure the safe operation of the equipment and personal safety.
  - Server power supply: converts AC or DC power into 12 V power to provide stable power for internal components (such as CPUs, hard disks, and memory) of the server.



- HV power distribution system: In China, the voltage of HV power distribution systems is generally 35 kV or lower. If the voltage is higher than 35 kV, the power grid is greatly affected. Generally, a professional power supply company provides systems of more than 35 kV. The system includes: HV switches, HV power distribution facilities (if any), HV DG sets (if any), and transformers. The design includes load analysis, determination of the number of inlet circuits and voltage level, power supply topology design, and HV switchgear and transformer configuration.
- LV power distribution system: LV power supply topology design (single-route or dual-route power supply solution), and selection and design of various LV switches, conductors, and PDFs
- DG set: type (HV or LV), operating mode (single or parallel), operating condition (emergency or continuous), fuel tank capacity, controller, parallel cabinet, and ATS cabinet
- UPS: type (modular or tower-mounted), operating mode (parallel, single, or dual-bus), battery backup time, and battery switch selection
- Surge protection and grounding system: includes the surge protection system and grounding system, involving the power surge protection design, signal system surge protection design, grounding mode, equipotential bonding mode, and grounding device design.
- This course describes the design of the UPS, LV power distribution system, and DG system.

Summary

- Planning and Design Introduction
- Planning Composition
  - Requirement Analysis
    - Data Center Power Distribution System Requirements
    - Power Distribution System Capacity Planning
    - Data Center PUE
  - Capacity Statistics
- Design Composition

Quiz

1. (short-answer question) What is the purpose of reserving 15% cabinet space for power uncertainty during planning?

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- Answer:
  - 1. If the actual power density of the installed equipment does not reach the designed value, the standby cabinet can be used to install IT devices to fully use the facility capacity.

Thank you.

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Data Center UPS System Planning

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Foreword

- The slides describe the data center UPS system planning, including requirement analysis, typical configuration solutions, capacity calculation, device selection, and battery configuration.

Objectives

On completion of this course, you will be able to:

- Master UPS system requirement analysis.
- Be familiar with common UPS configuration solutions.
- Master the way to calculate the UPS system capacity.
- Understand the UPS system battery configuration.

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System Composition (1)

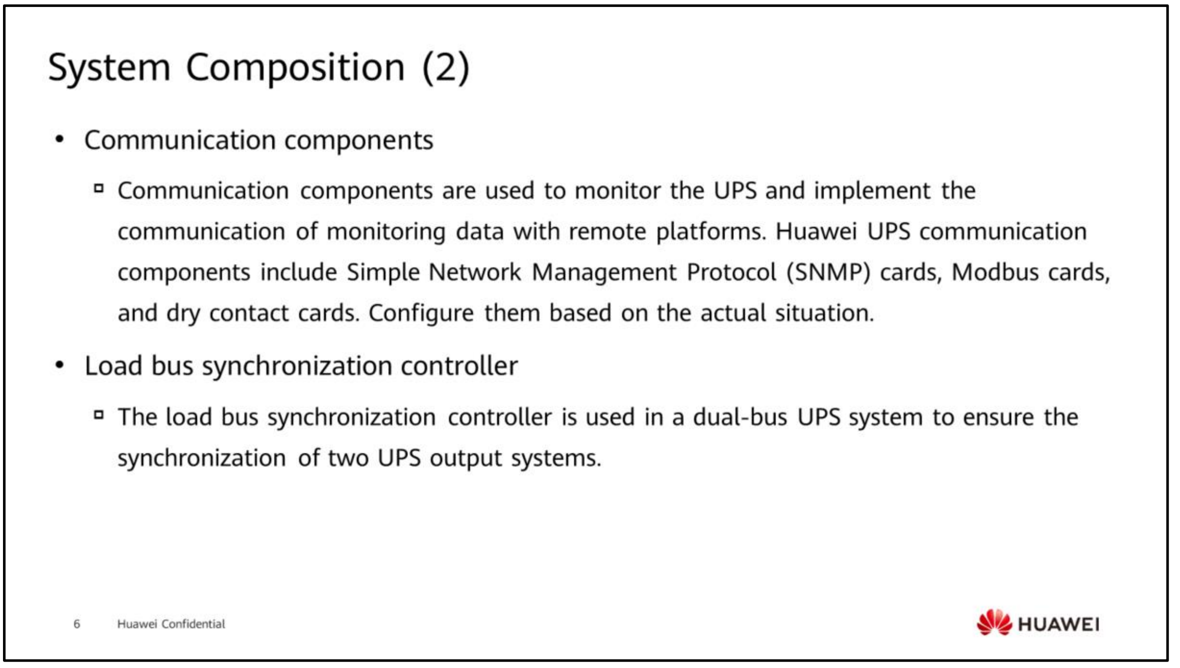
- The static uninterruptible power system (UPS) consists of UPS, battery strings, battery racks, battery switches, battery switch boxes, parallel components, communication components, and connecting cables.
- UPS
  - By the technology, UPS are classified into transformer-based UPSs and transformerless UPS (modular UPS are transformerless UPS).
  - By the architecture, UPS are classified into offline UPS, online interactive UPS, and double-conversion UPS. Only double-conversion UPS can meet all the core requirements of data center customers. Double-conversion UPS are most widely used in data centers.
  - By the capacity, UPS are classified into small-capacity UPS (< 20 kVA), medium-capacity UPS (20 kVA–200 kVA), and large-capacity UPS (> 200 kVA). The UPS used in data centers are mainly medium-capacity and large-capacity UPS.

- When selecting UPS for data centers, customers first consider the UPS technology classification (transformer-based UPS and transformerless UPS). Currently, mainstream vendors in the industry are shifting to production of transformerless UPS.
- Note:
  - The UPS and the inverter cannot be configured concurrently in the same data center. If a data center requires multiple AC power sources (UPS and inverter), it is advised to configure either the UPS or inverter based on the total power. Do not select the UPS power supply for some devices and the inverter power supply for other devices.
  - Use UPS from the same vendor for one data center in one solution. All product lines must reach consensus with each other during the preparation and final review of the same bidding document. Do not use UPS from various vendors for all devices.

System Composition (2)

- Battery string
  - The battery string serves as the backup power supply. When the mains supply is faulty, the battery string supplies power to the load.
- Parallel components
  - Parallel components include parallel cards and parallel cables. When multiple UPS are connected in parallel, a parallel card is required for each UPS to implement parallel control. Parallel UPS communicate with each other over the parallel cards.

- Parallel components: UPS exchange information through parallel cables that are connected in a closed loop. The closed-loop connection provides redundancy for cable connections (there are communication cables between independent UPS). This connection method allows the online access and exit of one UPS. Each UPS provides a controller to communicate with other UPS, which ensures proper running of the entire parallel system.



- The load bus synchronization controller is used in a dual-bus UPS system to ensure the synchronization of two UPS output systems. It works as follows: Any parallel UPS system is set as the master UPS. The system monitors the UPS output frequency and phase on the two buses at the same time. Once they exceed the synchronization tracking range, the synchronization controller is activated. The internal control system continues to track the mains for the master UPS. The UPS on the other bus tracks and controls the slave UPS through the synchronization controller. In this way, the two systems are synchronized.

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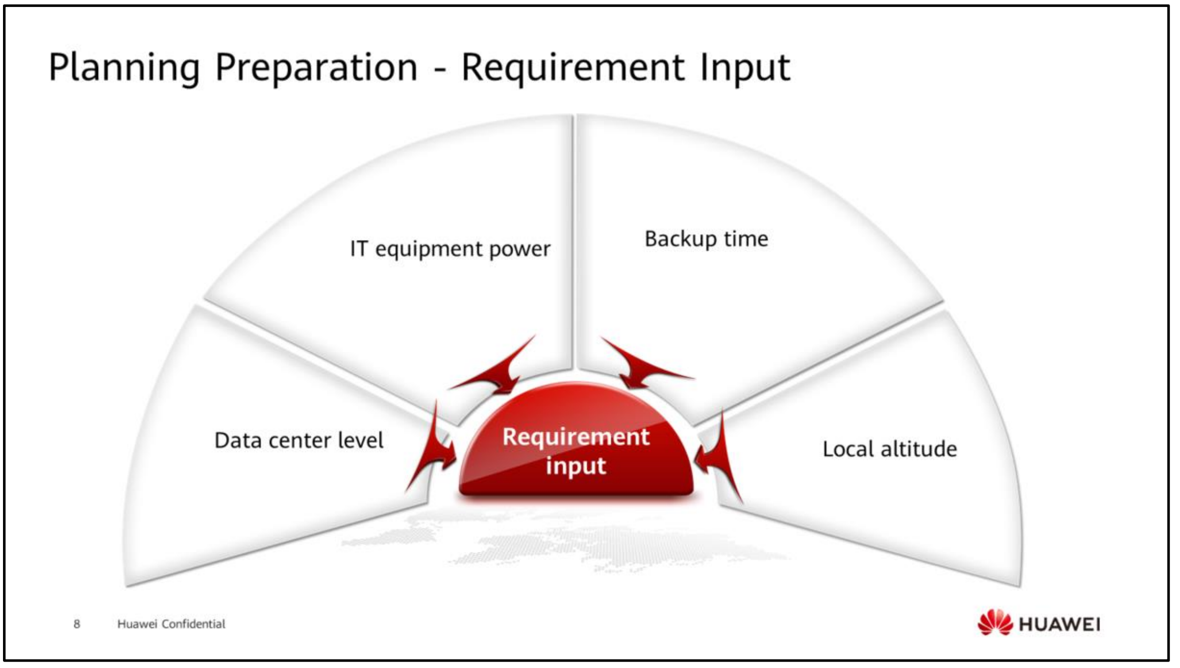
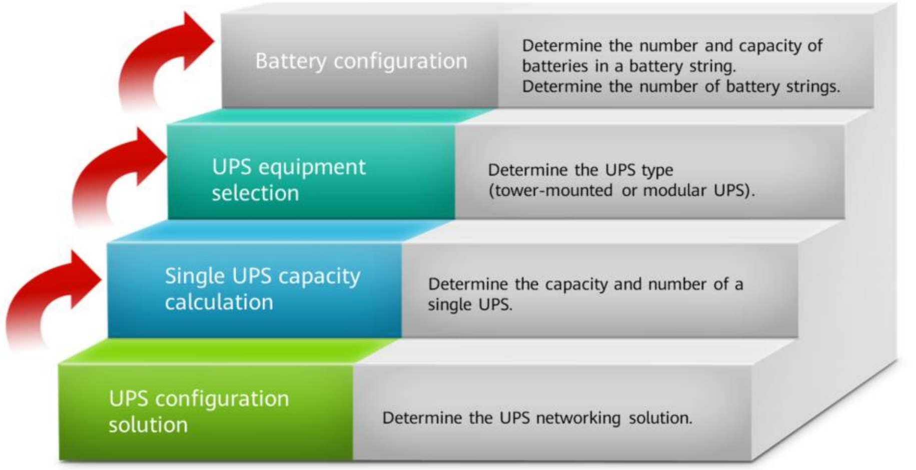


- The requirement input includes the following four points:
    - The data center level determines the UPS configuration solution.
    - The IT equipment power determines the capacity of a single UPS and UPS quantity.
    - The backup time determines the capacity of a single battery string and the number of battery strings.
    - The local altitude affects the UPS output and determines whether it should be derated. If the altitude increases, the pressure decreases due to thin air, which affects the heat dissipation of the UPS. The performance of electronic components inside the UPS will also be affected, which causes the sealed capacitor to bulge and further deteriorates the performance.

Contents

Planning Method Overview

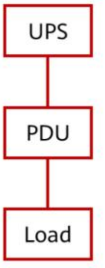


Contents

Typical UPS Configuration Solution (1)

- Single UPS solution:
  - The single UPS power supply solution is the simplest solution. In the solution, the output of a single UPS is directly connected to the load. This solution has no redundancy configurations and features low reliability. Single point of failure (SPOF) exists. Power supply should be disconnected when any component is faulty or needs overhauling.
  - This solution is applicable to small power supply devices that require low reliability. The load power is about thousands of watts and this solution can be used only in Uptime Tier I data centers.

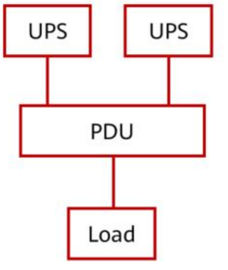
Single UPS solution

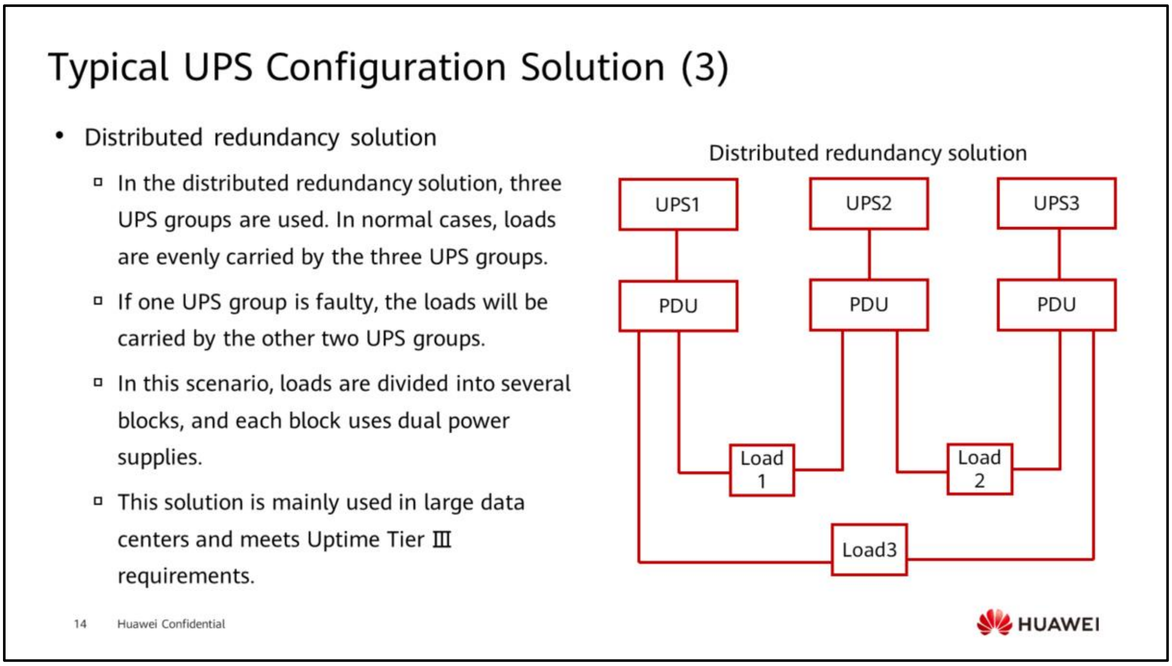


Typical UPS Configuration Solution (2)

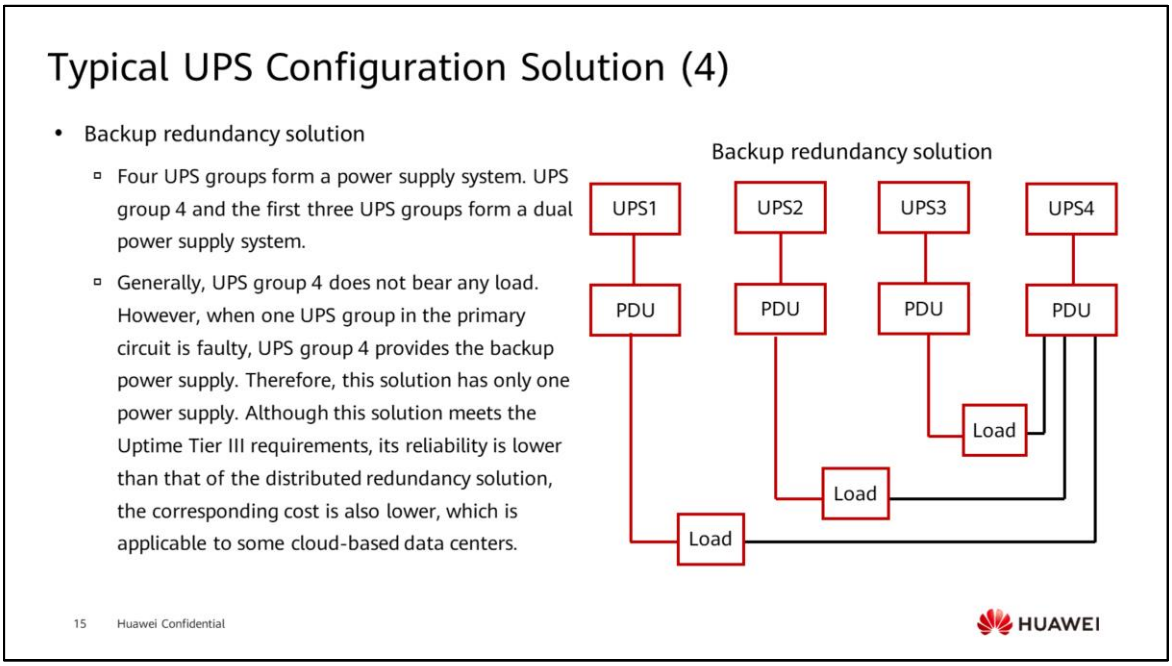
- Parallel UPS solution:
  - This solution is more reliable than the single UPS power supply solution, but SPOF still exists.
  - In this solution, there are two redundancy options for the UPS system: N+1 (N working UPS and one redundant UPS) and N+M (N working UPS and M redundant UPS). To reduce the cost, the N+1 parallel solution is recommended. To improve reliability, the N+M parallel solution is recommended.
  - This solution is applicable to small and medium data centers. If the reliability level of the data center is Uptime Tier II, the UPS power distribution solution should at least use this redundancy solution.

Parallel UPS (N+X) solution

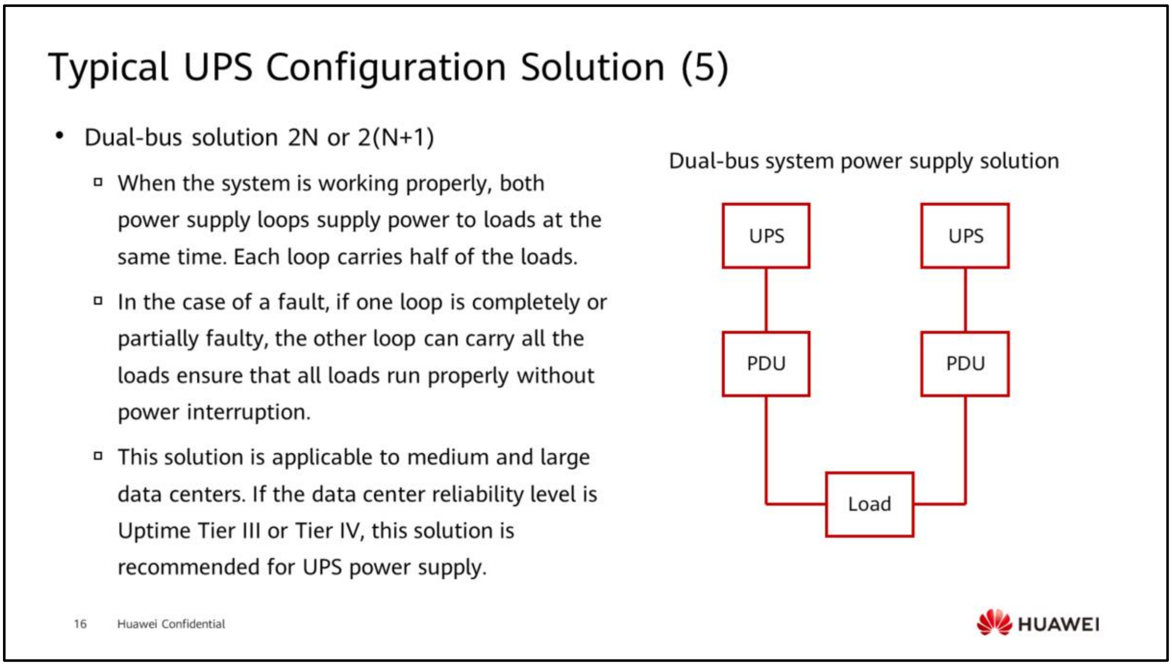




- Advantages
  - The solution facilitates online maintenance of all components (if all loads are dual-power loads).
  - Compared with the 2N design, the solution has fewer UPS modules. Thus, its cost is lower. For any specific dual-power load, two independent power supplies are redundant .
  - You do not need to transfer the loads to bypass mode for maintaining UPS modules, switch devices, and other power distribution devices. Maintenance bypass circuits usually do not need to be added in most distributed redundancy solution.
- Disadvantages
  - The cost is high as a large number of switch devices are used.
  - The configuration solution is complex. In a large data center with multiple UPS, static transfer switches (STS), and power distribution units (PDU), it is a great task to keep each UPS system evenly loaded and to learn well about which system supplies power to which load.
  - Unpredictable UPS running mode: Because UPS systems have various running modes and the systems can switch between multiple modes. It is impractical to test all these modes in a test environment with preset conditions and simulated faults to check whether the control policy and restored devices are functioning properly.
  - The UPS efficiency is low because it does not work with full load.



- The capacity of group 4 is variable. It can provide backup power for one load, multiple loads, or even all loads. However, power backup for all the loads cannot save device investment and goes against an original intention of this solution: saving costs.



- The advantages of this power supply solution are simple system, easy maintenance, high reliability, and no SPOF.
- In actual design, the two UPS are physically isolated. They are placed in different power rooms. If a fire occurs in one room, the power supply of the UPS in the other room is not affected, ensuring uninterruptible power supply to loads.

Solution Comparison (1)

- Discussion: Assume that the load is 300 kW and the capacity of a single UPS is 75 kW. Compare the UPS capacity configurations and load rates of the five solutions. (The UPS can be fully loaded.)

Solution comparison

	Single UPS	**N+1 Parallel UPS**	**DR Redundancy (three)**	**Backup Redundancy (four)**	**Dual-Bus**
Load capacity	300 kW	300 kW	300 kW	300 kW	300 kW
Single UPS	75 kW	75 kW	75 kW	75 kW	75 kW
Number of UPSs					
Total UPS capacity					
UPS load rate					

- Note:
  - Three: The load is divided into three parts.
  - Four: The load is divided into four parts.

Solution Comparison (2)

- According to the preceding analysis, the costs and reliability of these solutions are in direct proportion:
  - Single UPS < N+1 parallel UPS < Backup redundancy < Distributed redundancy < Dual-bus

Networking solution comparison

	Single UPS	N+1 Parallel UPS	Distributed redundancy (three)	Backup Redundancy (four)	Dual-Bus
Load capacity	300 kW	300 kW	300 kW	300 kW	300 kW
Single UPS	75 kW	75 kW	75 kW	75 kW	75 kW
Number of UPSs	4	5	3 x (1 + 1)	4 + 1	4 + 4
Total UPS capacity	300 kW	375 kW	450 kW	375 kW	600 kW
UPS load rate	100%	80%	66.7%	80%	50%

- Note: This table briefly displays the total capacity and actual UPS efficiency of each solution. Only qualitative analysis is performed. The actual cost and efficiency involve specific loads and UPS capacity.
- The backup redundancy solution is the same as the N+1 parallel UPS solution in terms of the UPS. However, the backup redundancy solution requires a large number of switch cabinets and cables, which is more expensive and more reliable than the N+1 parallel UPS solution.

Solution Comparison (3)

Application scenarios of different solutions

Configuration	Used in the Past	Reason for Use
No redundancy	Small companies Companies with multiple local offices Companies with geographically redundant data centers	Reduced investment and energy costs Support for less critical applications Simple configuration and installation Power-off maintenance is allowed
Parallel redundancy	Small and medium companies with data centers whose IT capacity is usually less than 500 kW	Better fault tolerance than "N" Loads can be added in the future
Distributed redundancy	Large companies with data centers whose IT capacity is usually greater than 1 MW	Online maintenance is supported More economical than "2N"
Dual-bus	Large MW-level data center	Full redundancy between path A and path B Easier to balance loads of the UPS system

- How to select the most suitable configuration solution? Let's review the precautions to be considered when selecting a proper configuration:
  - Breakdown cost/impact: How much cash flow does the company have per minute? If a fault occurs, how long does it take for the system to recover? The answers to the above questions can be used as the beginning of the budget solution discussion. The discussion direction varies with the answer.
  - Budget: In any aspect, the cost of implementing the 2(N+1) design is much higher than that of the N (capacity) design, parallel redundancy design, or even distributed redundancy design. Let's take a large data center as an example to see the cost gap. If the data center uses the 2(N+1) design, thirty 800 kW modules may be required (each parallel bus has five modules, and there are six parallel buses in total). For the same load, if the distributed redundancy design is used, only eighteen 800 kW modules are required, and the cost is much lower.
  - IT architecture type: Virtualization and rapid improvement of network bandwidth and speed enable the entire data center to be switched to another site without delay. This also raises questions about the perception that data centers with the highest availability are facilities with highly redundant power and cooling architectures. As the virtualization technology matures, two distant "N" system data centers may have higher availability than a highly redundant data center.

- Availability: How long can the company tolerate downtime in a year? If the answer is never to shut down, then the high availability design should be chosen in the budget. However, if the company allows shutdown after 10 p.m. every night and at most weekends, then the parallel redundancy design is recommended for the UPS configuration. Some parts of each UPS need maintaining. And some unexpected faults will occur in the UPS from time to time. The less the time used in maintenance is, the more redundant components are required.
- Reliability: The higher the reliability of a UPS, the higher the probability of continuous operation of the system.
- Maintainability: Long-time system breakdown caused by faults cannot be prevented by high reliability.

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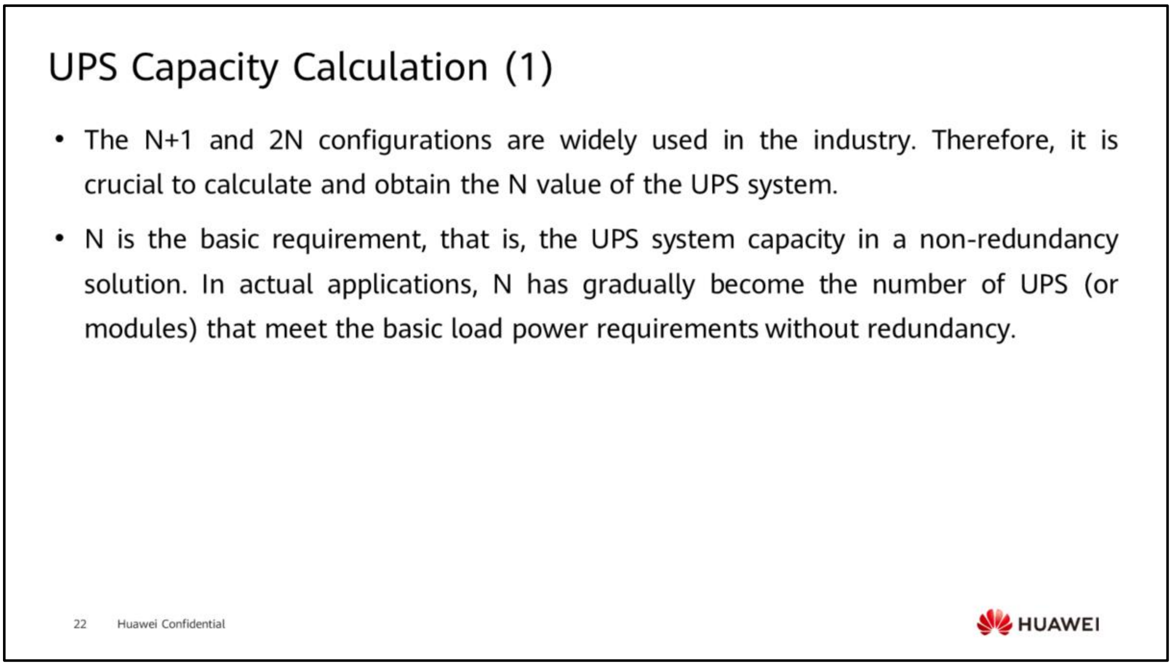
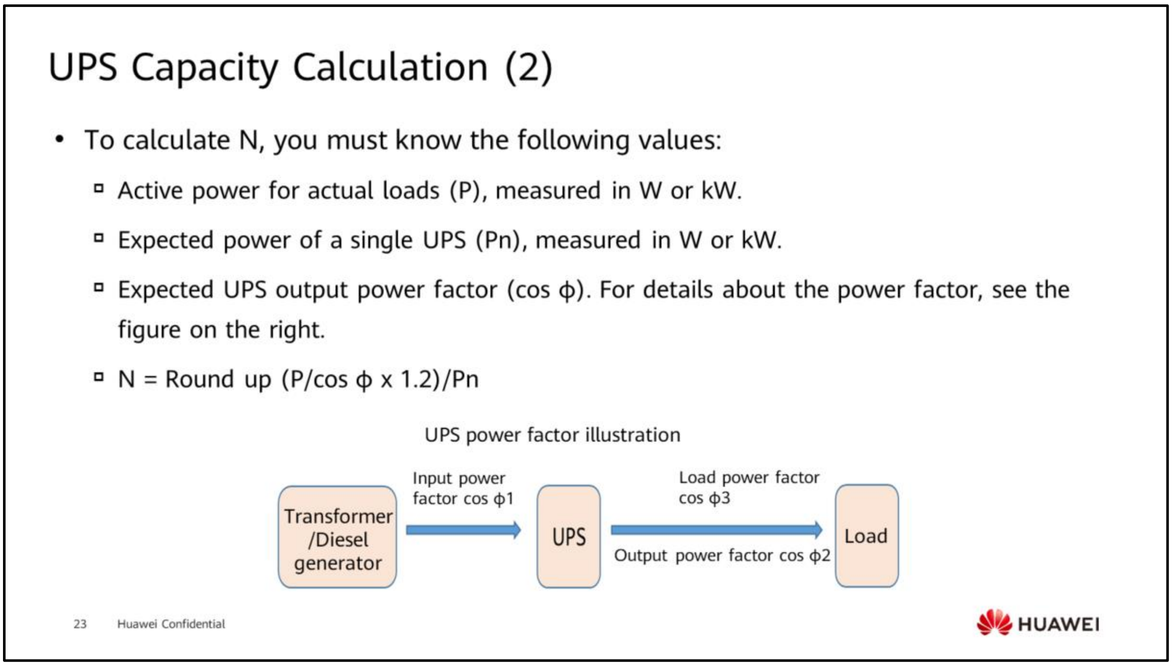


- 1.2 is a coefficient, and E ≥ 1.2 P. E is the basic capacity of the UPS, and P is the calculated load of the electronic information equipment.
- Power factor description:
  - Input power factor (cos ϕ1): indicates a UPS's rectification and correction capability of the UPS and loads.
  - Output power factor (cos ϕ2): indicates the active power output capability of a UPS.
  - Load power factor (cos ϕ3): varies with products. The power factor of IT equipment ranges from 0.98 to 1, that of Huawei air-cooled DX air conditioners is 0.9, that of Huawei water-cooled indoor units is 0.94, and that of pumps ranges from 0.8 to 0.9.



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UPS Capacity Calculation (3)

- Example: The actual active power of loads is 1000 kW. Huawei UPS5000-E series are used to meet the N+1 backup requirement. The UPS system configuration is provided as follows.
- The calculation process is as follows:
  - For the UPS500-E series, the output power factor is 1, the load power factor is 0.9, and the capacity of a single UPS is 125 kVA, 200 kVA, 300 kVA, 400 kVA, 500 kVA, 600 kVA, or 800 kVA. The N value of different capacities are calculated as follows:
  - When the capacity of a single UPS is 300 kVA: N = (1000/0.9 x 1.2)/300 ≈ 5.
  - When the capacity of a single UPS is 500 kVA: N = (1000/0.9 x 1.2)/500 ≈ 3.

UPS Capacity Calculation (4)

- The calculation process is as follows:
  - Considering that four UPS can be configured at most in an N+1 parallel system, you can select four 500 kVA UPS to form an N+1 system.
  - If the system is expanded to the 2N architecture, you can configure two groups with three 500 kVA UPS in each group. Thus, a total of six UPS are configured.
  - In the 2(N+1) architecture, you can configure two groups with four 500 kVA UPSs in each group. Thus, a total of eight UPS are configured.

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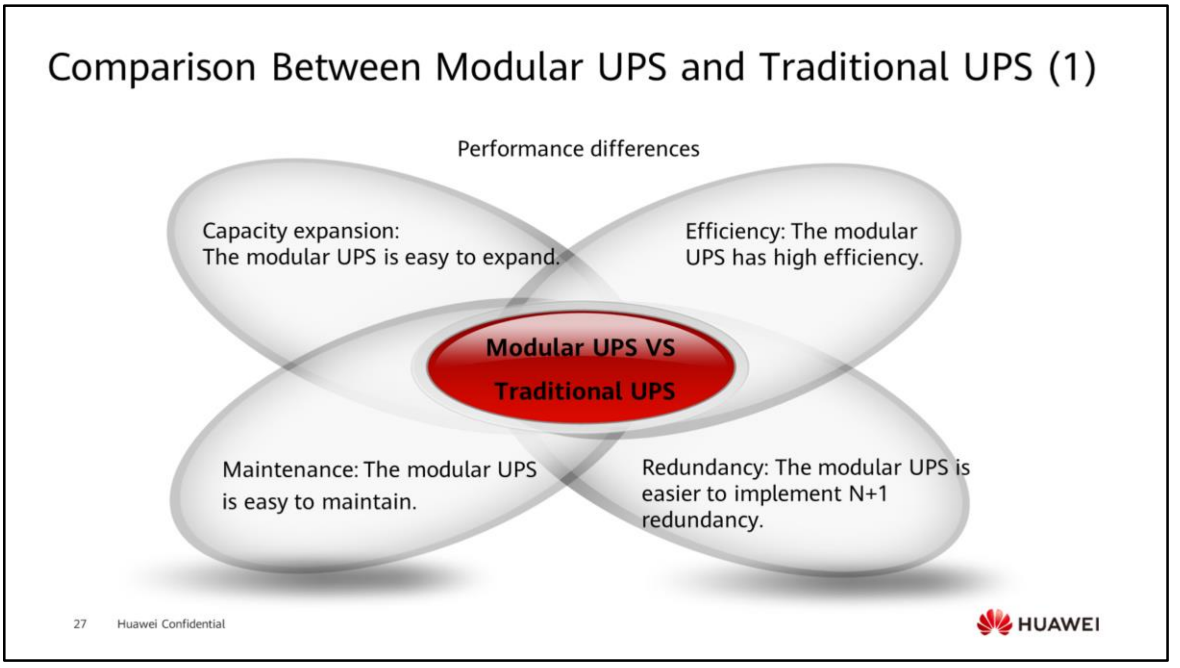
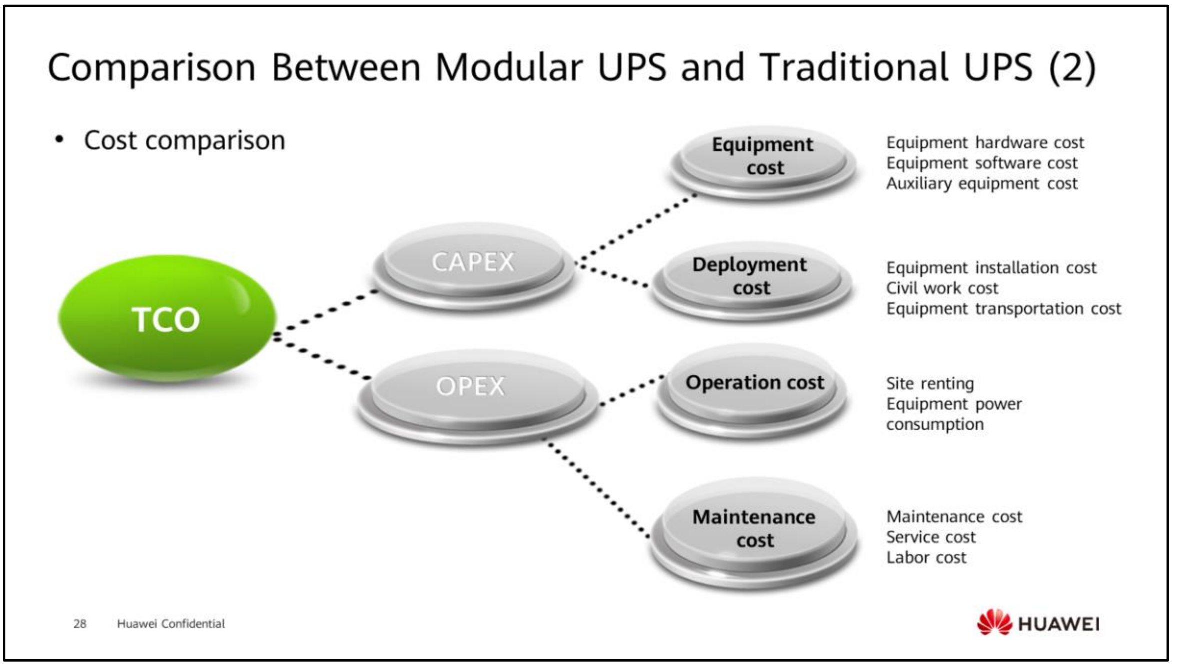


- The modular UPS is easy to expand. You only need to purchase the required power module (about 50 kVA) for future capacity expansion, which does not require cable reconstruction. Tower-mounted UPSs can be expanded by adding power units. However, the power unit is large (usually 100 kW or 200 kW), which cannot meet the requirement of flexible configuration due to the increase of the load. Thus, before expanding capacities for a tower-mounted UPS, you need to shut down the UPS.
- The modular UPS has high efficiency and saves energy. The high efficiency of a modular UPS depends on the flexibility of power configuration. When the load is light, the power module hibernation technology ensures that the UPS works at the maximum efficiency. However, the efficiency of a tower-mounted UPS is greatly reduced due to the large power unit.
- The modular UPS itself is a redundancy solution. When one module in the modular UPS is faulty, the module can be hot-swapped quickly and maintained with the power on. To maintain some of the parts in the tower-mounted UPS, the UPS has to transfer to bypass mode, which decreases the reliability of the UPS.
- It is easier to implement N+1 redundancy in modular UPSs. For example, in a 400 kVA system, the original 1+1 configuration requires 800 kVA, and one module can be used for redundancy. The 450 kVA configuration with 50 kVA modules implements (8+1) redundancy.



- TCO: Total cost of ownership
- CAPEX: Capital expenditure
- OPEX: Operating expense

Comparison Between Modular UPS and Traditional UPS (3)

- Equipment cost: The cost of a modular UPS is about 30% higher than that of a traditional tower-mounted UPS.
- Deployment cost: Traditional tower-mounted UPS are integral, and modular UPS are small. Therefore, the deployment cost of modular UPS is small.
- Operation cost: The modular UPS is easy to expand. As modules are gradually deployed along with the project progress, the efficiency is high. Therefore, a large amount of electricity fees can be saved.
- Maintenance cost:
  - Tower-mounted UPS are difficult to maintain. Once a fault occurs, only professional personnel from the manufacturer can maintain the UPS. Thus, the maintenance cost is high.
  - The modular UPS adopts the modular design. If a module is faulty, it can be directly replaced. The faulty module can be sent to the manufacturer for repair, which greatly reduces the labor cost and the round-trip cost of professional personnel from the manufacturer.

Comparison Between Modular UPS and Traditional UPS (4)

- Summary
  - The traditional UPS features low CAPEX, while the modular UPS features low OPEX. These advantages can be converted based on different scenarios. If the customer requires N+1 redundancy, the modular UPS can greatly reduce the CAPEX.
  - In the first three years, the TCO of tower-mounted UPS is low. In the fourth year, modular UPS have obvious cost advantage. Take the mainstream data center UPS with the lifetime of 8 to 10 years as an example. The advantages of modular UPSs are obvious.

Contents

Single UPS Configuration (1)

- There are two methods for configuring the battery capacity: constant current method and constant power method. The constant power method is widely used in the industry because it is more accurate. Here, the constant power method is introduced.
- Parameters required for configuring the battery capacity of a single UPS
  - Active power for loads (P), measured in W or kW
  - Battery inversion efficiency (η)
  - Number of 12 V batteries (n)
  - Expected battery constant power discharge table

- Single UPS configuration refers to the configuration of a single UPS instead of an N system, because an N system can also be a parallel system.

Single UPS Configuration (2)

- The calculation is performed using the following method:
  - Calculate the required discharge power of each battery cell: W = P/η/(n x 6).
  - Compare the battery constant power discharge table to obtain the configuration of four or fewer battery strings with the power deviation ranging from –5% to +10%.
  - Use the UPS charging current to check whether the UPS meets the charging requirements.
  - Select the most economical solution.

Single UPS System Configuration Example (1)

- Example: A single UPS5000-E-80K is configured, η is 0.97, the actual load is 32 kW, a single battery string contains 32 batteries (12 V), and the backup time is 15 minutes.
- Calculation process:
  - W = 32000/0.97/32/6 = 172W/cell
  - Look up the table for 1.67 V–15 min.
  - Select two 26 Ah battery strings.

26 Ah constant power discharge table of a brand

F.V/Time / FVPC	5min	10min	15min	30min	1hr	1.5hr	2hr
1.60V	208.0	135.2	104.0	59.8	33.8	23.5	18.3
1.67V	197.7	131.1	100.9	58.9	33.3	23.2	18.1
1.70V	192.7	129.4	99.7	58.4	33.1	23.0	18.0
1.75V	181.3	125.0	96.7	57.1	32.5	22.7	17.8
1.80V	156.7	115.3	92.4	55.0	31.5	22.1	17.3
1.85V	143.5	107.7	87.3	51.8	30.2	21.2	16.7

Single UPS System Configuration Example (2)

- Calculation process
  - Check whether the UPS charging power meets requirements:
    - Calculate the UPS battery charging power as follows: when the charging power is: N_group x N_bat x 2.35 x 0.1 x C_ah (W), the charge power is: 2 x 32 x 6 x 2.35 x 0.1 x 26 = 2346.24 W.
      - N_group: number of battery strings for a single UPS
      - N_bat: number of cells in a battery string. A 12 V battery contains six cells.
      - C_ah: capacity of a single battery, measured in Ah
      - 2.35 V: equalized charging voltage of a single battery
      - 2.35 x 0.1 x C_ah: charge power of each cell

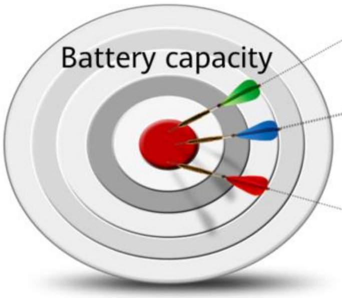
- Pay special attention to check whether the UPS charge power meets the requirements for long backup time of a small-capacity UPS as excessive batteries will affect the battery lifespan.
- If the battery charge current does not meet the requirement, the charge time is prolonged. If the power is unstable, the batteries cannot be fully charged for a long time, which causes great damage to the batteries.

Single UPS System Configuration Example (3)

- Calculation process
  - Check whether the UPS charging power meets requirements:
    - The charge power of a single UPS5000-E module is 10% of the module capacity. The charge power of the UPS5000-E-80K is 8 kW (the capacity of each power module is 40 kVA). Therefore, the charge power meets the requirements.

- Pay special attention to check whether the UPS charge power meets the requirements for long backup time of a small-capacity UPS as excessive batteries will affect the battery lifespan.
- If the battery charge current does not meet the requirement, the charge time is prolonged. If the power is unstable, the batteries cannot be fully charged for a long time, which causes great damage to the batteries.

Single UPS System Configuration Analysis (1)



Load power, power factor, and inverter efficiency

End-of-discharge (EOD) voltage and discharge time

Number of batteries

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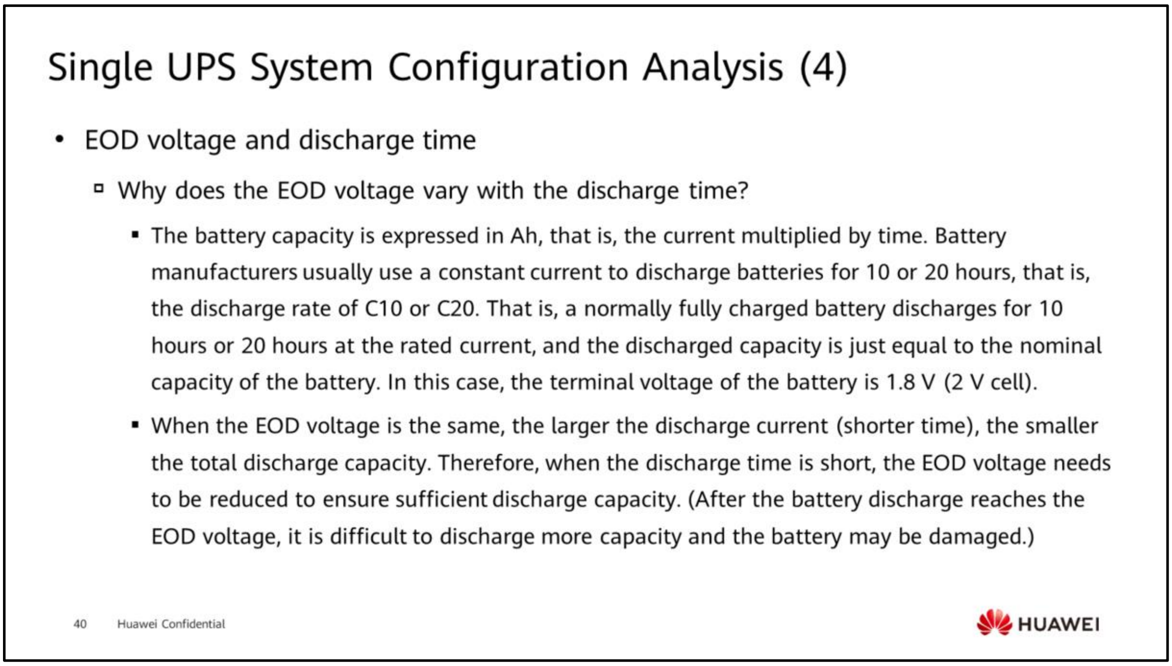
Single UPS System Configuration Analysis (2)

- Load power, power factor, and inverter efficiency
  - The rated output power of the UPS is expressed in the form of apparent power kVA. The actual maximum output power of the UPS is the kVA multiplied by the UPS output power factor. From the perspective of load usage, the output power factor of the UPS is the input power factor of the load, which varies with the load power. For example, if the nominal power of a load is 1000 VA and the input power factor is 0.7, the actual maximum power is 700 W. Currently, some AC devices use the power factor correction (PFC) circuit to ensure that the power factor is greater than 0.9. The power factor for common loads is 0.9.
  - The UPS efficiency refers to the system efficiency, that is, the overall conversion efficiency of the current after rectification and inversion when the UPS works properly. The battery inversion efficiency refers to the conversion efficiency of the current passing through the battery, inverter circuit, and load when the battery is discharging. Generally, the efficiency is higher than the UPS system efficiency. The battery inversion efficiency of Huawei UPS5000 series is usually calculated based on 95%.

Single UPS System Configuration Analysis (3)

- EOD voltage and discharge time
  - Why is the battery EOD voltage 1.67 V/cell in the example?
    - Generally, if the battery backup time is less than 1 hour, the EOD voltage is 1.67 V/cell. If the battery backup time is 1 to 3 hours, the EOD voltage is 1.75 V/cell. If the battery backup time is greater than 3 hours, the EOD voltage is 1.80 V/cell.

- Take a 150 Ah battery as an example. The discharge current is fixed at 15 A. After the battery is discharged for 10 hours, the discharge capacity is 150 Ah. In this case, the battery voltage should be about 1.8 V. If the battery continues discharging, the battery may be damaged.
- Theoretically, if the discharge current is different and the total discharge capacity equals the rated battery capacity, the EOD voltage should be about 1.8 V. Actually, the larger the battery discharge current (the shorter the discharge time), the lower the discharge capacity. Take SD150 as an example. When the discharge time is 4 hours, the discharge voltage is 1.8 V, and the EOD voltage is 1.8 V, the power of a single cell is 63.3 W, and the total energy discharged within 4 hours is 253.2 Wh (4 x 63.3 = 253.2 Wh). When the discharge time is 1 hour, and the EOD voltage is 1.8 V, the power of a single battery is 173 W, and the total energy discharged within 1 hour is 173 Wh (1 x 173 = 173 Wh).



- Take a 150 Ah battery as an example. The discharge current is fixed at 15 A. After the battery is discharged for 10 hours, the discharge capacity is 150 Ah. In this case, the battery voltage should be about 1.8 V. If the battery continues discharging, the battery may be damaged.
- Theoretically, if the discharge current is different and the total discharge capacity equals the rated battery capacity, the EOD voltage should be about 1.8 V. Actually, the larger the battery discharge current (the shorter the discharge time), the lower the discharge capacity. Take SD150 as an example. When the discharge time is 4 hours, the discharge voltage is 1.8 V, and the EOD voltage is 1.8 V, the power of a single cell is 63.3 W, and the total energy discharged within 4 hours is 253.2 Wh (4 x 63.3 = 253.2 Wh). When the discharge time is 1 hour, and the EOD voltage is 1.8 V, the power of a single battery is 173 W, and the total energy discharged within 1 hour is 173 Wh (1 x 173 = 173 Wh).

Single UPS System Configuration Analysis (5)

- Number of batteries
  - According to the calculation formula, the battery configuration varies with the number of batteries. In some special cases, batteries are over-configured to ensure that the battery capacity meets the customer's requirements (if the number of batteries supported by the UPS is variable). In this case, if you configure an appropriate number of batteries, the overall cost can be reduced on the premise that the customer's requirements are met.

Parallel System Configuration (1)

- The battery calculation in a parallel UPS system is the same as that in a single UPS system. However, considering factors such as costs and space, the battery calculation in a parallel UPS system can be optimized. The solutions in descending order of cost are as follows: single UPS power backup (highest reliability) > system power backup > battery string sharing (lowest reliability).
- Single UPS power backup solution
  - Each UPS is equipped with one or more battery strings. When a UPS is faulty, the UPS and the battery strings connected to it exit the parallel system, and the remaining battery strings can supply sufficient power to the UPS.
  - Example: The load is 300 kVA, three 200 kVA UPSs are used to form a 2+1 system, and the backup time is 10 minutes.

- The parallel system refers to the N+X solution. The N+1 solution is used as an example. The dual-bus system will be described later.

Parallel System Configuration (2)

- Single UPS power backup solution
  - When single UPS power backup is used, batteries can be configured based on the single UPS load power of 150 kVA (300/2=150 kVA) for 10 minutes. Each UPS is configured with the same battery string.
  - Note: In this solution, the backup time is longer than the time required by the customer when the UPS system works properly. When the redundant UPS is faulty and exits the system, the backup time of the entire UPS system can still meet the requirements.

- The parallel system refers to the N+X solution. The N+1 solution is used as an example. The dual-bus system will be described later.

Parallel System Configuration (3)

- System power backup solution
  - If the customer does not specify the backup time of a single UPS, batteries can be configured in load balancing mode. In this case, when all UPSs are working, the system backup time can be ensured. However, if one UPS is faulty (the battery string is unavailable), the remaining battery strings cannot reach the required backup time.
  - Example: If the load is 300 kVA, 200 kVA UPSs are connected to form a 2+1 system, and the backup time is 10 minutes, batteries can be configured based on the single UPS load power of 100 kVA (300/3 = 100 kVA) for power backup of 10 minutes.

Parallel System Configuration (4)

- System power backup solution
  - If the load power is 500 kVA, 200 kVA UPSs are connected to form a 3+1 system, and the backup time is 10 minutes, batteries can be configured based on the single UPS load power of 125 kVA (500/4 = 125 kVA) for power backup of 10 minutes.
  - Note: The backup time of the entire system meets the requirements only when the UPSs work properly. If the redundant UPS is faulty and exits the system, the backup time cannot meet the requirements.

Parallel System Configuration (5)

- Battery string sharing solution
  - To reduce the overall cost, the battery string sharing solution can be used. When battery strings are shared, all battery strings and UPSs are connected to the same busbar.
  - Advantages: Because battery strings are directly connected in parallel, they can be configured for one UPS. Battery strings do not need to be evenly distributed to each UPS. In some scenarios, costs can be reduced. (If the total capacity is the same, the cost of a small number of battery strings is low. For example, three 400 Ah battery strings are cheaper than four 300 Ah battery strings. In addition, related accessories such as battery racks and switch boxes are fewer.)
  - Disadvantage: SPOF may occur. If one battery string is faulty, all batteries may be unavailable. In actual applications, each battery string should be configured with an independent switch.

Parallel System Configuration (6)

- Comprehensive comparison of configuration solutions:
  - A 2+1 parallel system consisting of 200 kVA UPSs for 300 kVA loads is used as an example. The backup time is 15 minutes.

Solution cost comparison

Battery backup solution	Battery	Price (¥)	Reliability
Single UPS power backup	3 x (100 Ah, three strings, 32 batteries)	475,137	High
System power backup	3 x (100 Ah, two strings, 32 batteries)	308,628	Relatively high
Battery string sharing	150 Ah, four strings, 32 batteries	293,329	Medium
Battery string sharing + Battery quantity adjustment and optimization	100 Ah, four strings, 40 batteries	244,985	Medium

  - Note: The price in the table includes the prices of the battery rack and battery switch and is the price of the entire battery system.

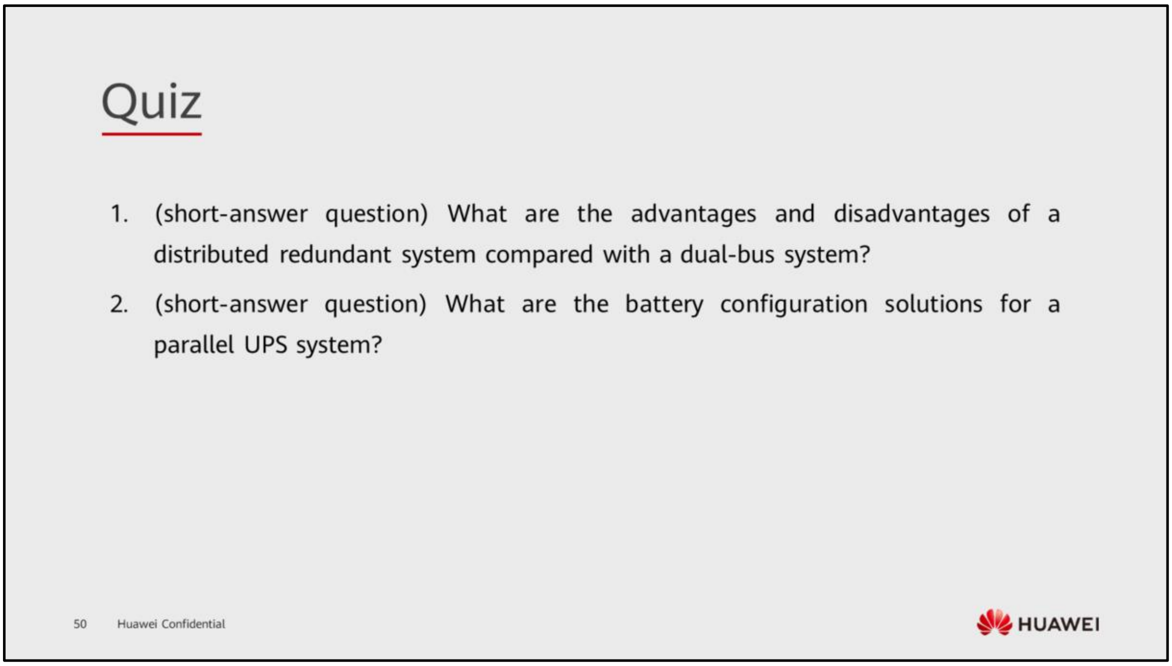
- Conclusion:
  - Battery configurations cannot be accurately matched. To meet customer requirements, over-configuration often occurs.
  - Compared with single UPS power backup, system power backup reduces the cost by about 35%.
  - Compared with single UPS power backup, battery string sharing reduces the cost by about 40%.
  - By adjusting the number of batteries, the cost can be reduced by about 12% compared with the solution with a fixed number of batteries.
- The total cost is the lowest when battery strings are shared and the number of batteries is adjusted. Compared with the maximum configuration solution, the cost is reduced by about 50%. In a common UPS configuration solution, the battery string cost accounts for 20% to 40% of the total cost. If the backup time is long, the battery string cost may even exceed the UPS price. Therefore, it can be concluded that the UPS solution quotation can be reduced by 10% to 30% by optimizing the battery string configuration.

Parallel System Configuration (7)

- Dual-bus system
  - System power backup solution
    - The loads of the dual-bus system are balanced. Path A carries half of loads while path B carries the other half. The battery configuration can be reduced, and the entire system can still meet the customer's requirements. However, this solution reduces the system availability.
  - Single UPS power backup solution
    - Both path A and path B can meet the basic capacity and designed backup time. Path A can fully back up path B. For the UPS system, this solution is a dual-bus system in the strict sense.

Summary

- System Composition
- Planning Preparation
- Planning Method
    - Planning Method Overview
    - UPS Configuration Solution
    - UPS Capacity Calculation
    - UPS Equipment Selection
    - Battery Configuration



- 1. Answer
    - Advantage: The UPS load rate of the system is higher than that of 2N when two power supplies are available, which reduces costs.
    - Disadvantage: The system operation and maintenance (O&M) are complex because loads need to be partitioned. When a load is added, the group to which the load is added must be specified. The loads of all UPS groups must be basically the same.
- 2. Answer
    - Single UPS power backup solution: The number (N) of requisite UPSs is used for calculation. The actual backup time exceeds the required time. If the redundant UPS is faulty, the backup time of the system can still meet the requirements.
    - System power backup solution: The number of all UPSs is used for calculation. The backup time meets requirements only when all UPSs in the system are running properly. If one UPS is faulty, the remaining UPSs cannot meet the backup time requirements.
    - Battery string sharing solution: All battery strings are connected to the UPS through a bus. The cost is low, but the reliability is reduced accordingly.

Thank you.

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Data Center Low-Voltage Power Distribution System Planning

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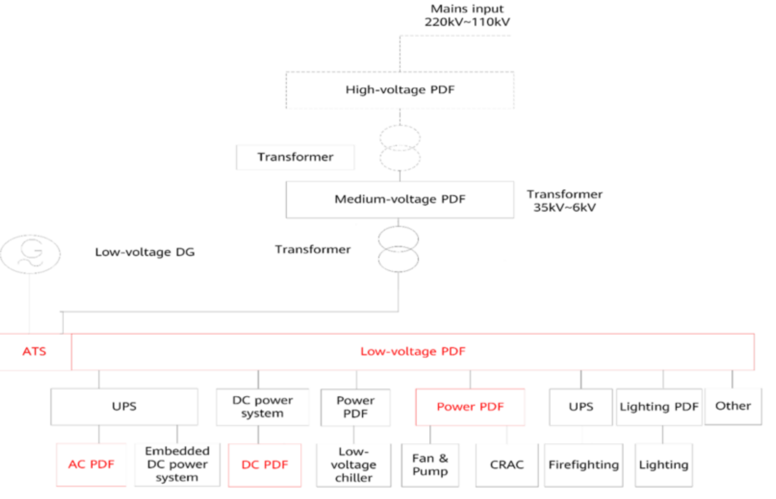
Contents

System Scope

- The following figure shows the position of a low-voltage power distribution subsystem in a power supply and distribution system.



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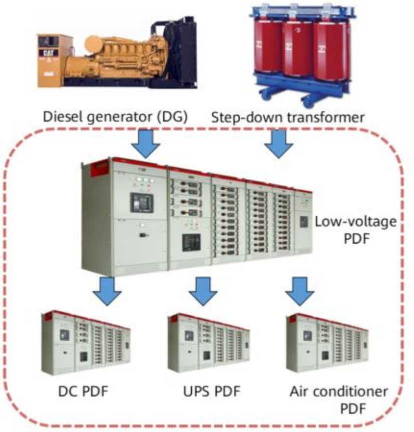
System Overview

- Main components
  - A low-voltage power distribution system consists of a low-voltage power distribution frame (PDF) and power cables.
  - The low-voltage PDF leads in the low-voltage mains output from the transformer, distributes the mains to the uninterruptible power system (UPS) PDF, DC PDF, and power PDF, which distribute the mains power to loads.
  - Power cables are used to connect systems at all levels and lead power from the mains to loads. Conductors include cables and busways, and they have different application scenarios.

Components of a low-voltage power distribution system



- The low-voltage power distribution system of a data center refers to the power distribution system with an AC voltage of 1200 V or lower.
- The low-voltage PDF consists of the circuit breaker, fuse, load switch, automatic transfer switch (ATS), and electric energy metering device.

Contents

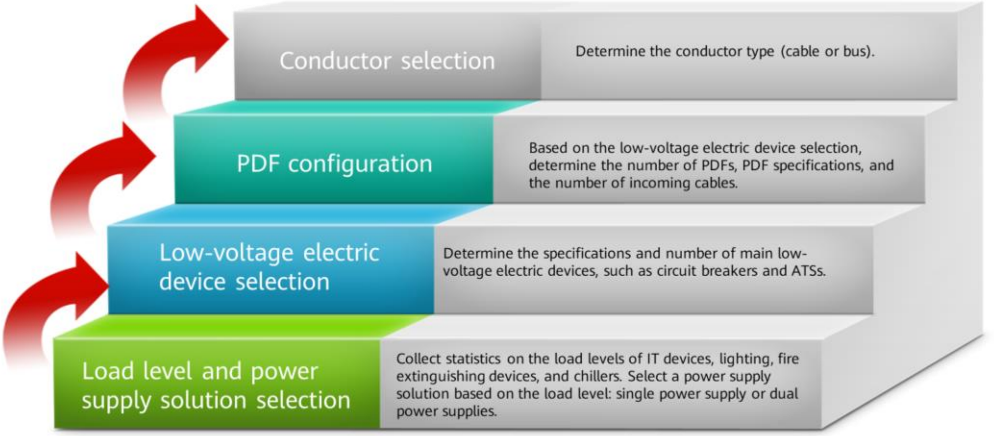
Planning Preparation - Requirement Input

- Data center levels determine the power supply solution for loads, for example, single or dual power supplies.
- Load power and voltage modes determine the capacity and type of low-voltage electric devices, for example, single-phase circuit breakers or three-phase circuit breakers.

- The data center reliability level should be determined. Generally, for Tier III or higher, the dual power supply solution is used to provide two independent power supplies for dual-power loads such as ICT equipment, air conditioners, fire extinguishing devices, and lighting devices. For Tier IV, each subsystem adopts the 2N redundancy mode. If Tier II or lower is required, the single power supply solution is generally used for loads. The implementation of these two solutions must comply with relevant standards such as Uptime or TIA-942.
- In the dual power supply solution, to ensure that the entire IT loads run normally when one power supply fails, the low-voltage electric device and conductor specifications of each power supply should be determined to support the load rate of 100%.
- If the dual power supply solution is used for single-power loads in the data center, such as air conditioners, lighting devices, and even ICT equipment, the ATS, manual transfer switch (MTS), or static transfer switch (STS) (for single-power service loads) is required. When one power supply is faulty, the ATS/MTS/STS switches to the other power supply to ensure power supply. For dual-power loads, use dual power supplies.

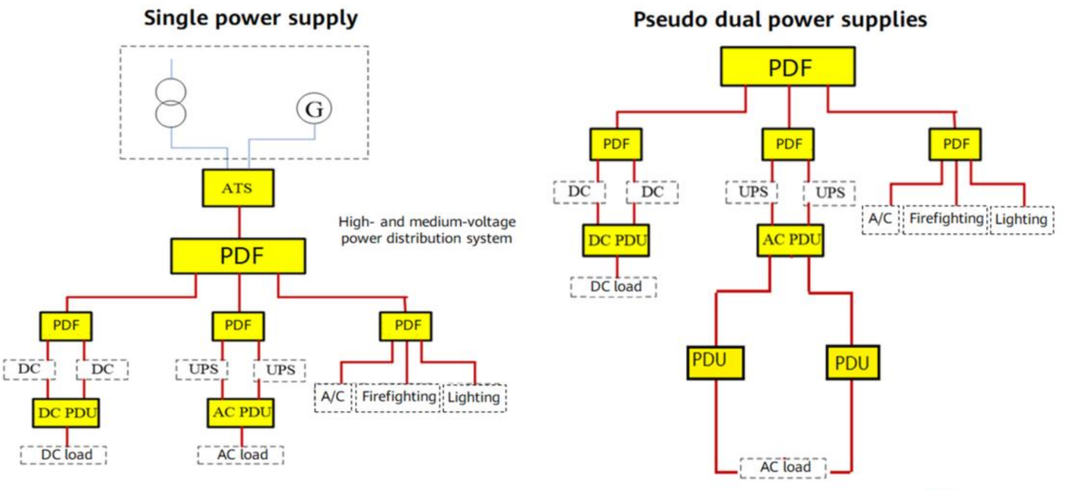
Contents

Planning Procedure

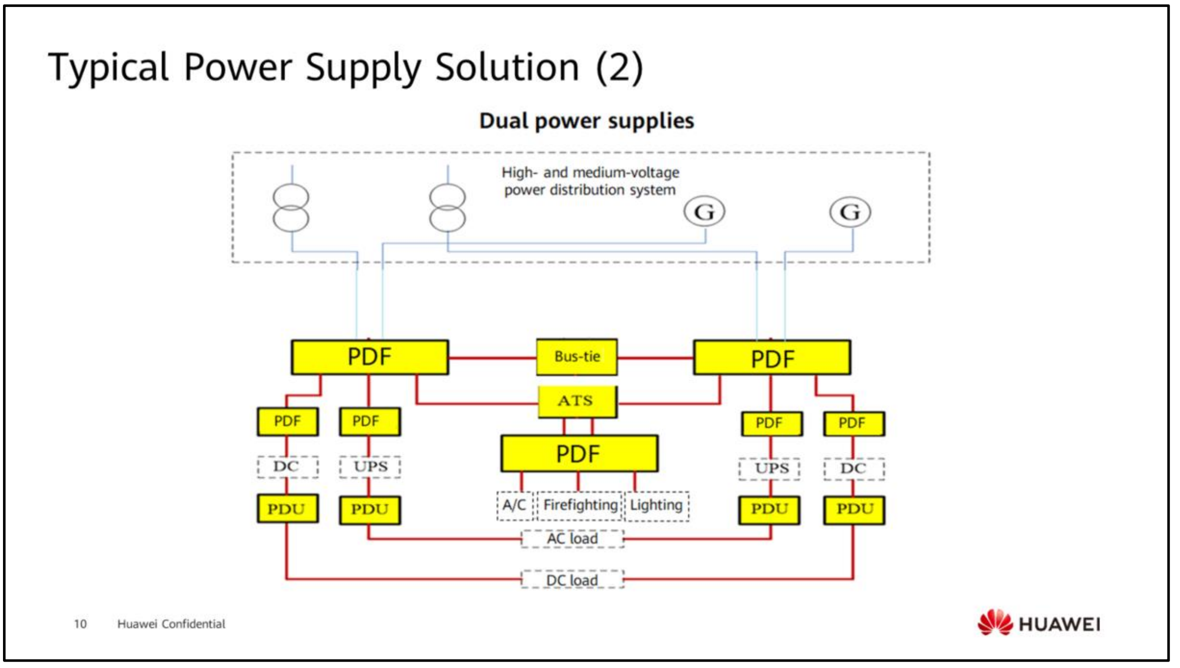


Contents

Typical Power Supply Solution (1)



- The single power supply solution on the left is often used in the Tier I or Tier II data centers. If you want to improve reliability or dual power supply IT loads are used, you can use the pseudo dual power supply solution on the right.

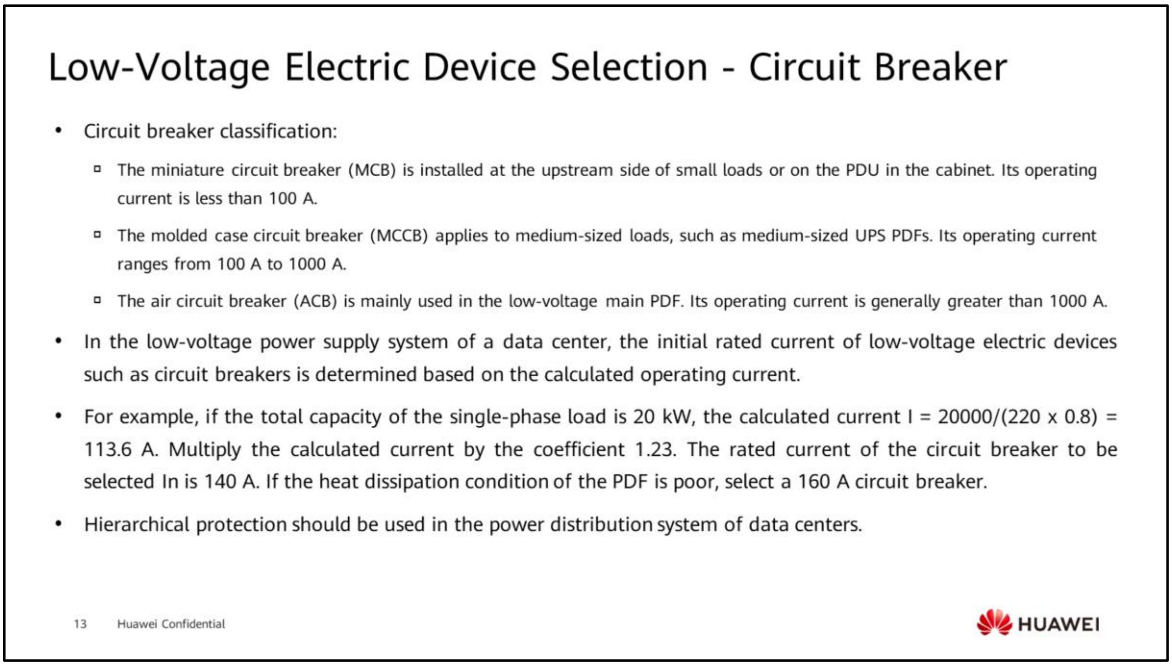


- Note that the preceding figure is a rough topology. The final design prevails.
- The dual power supply solution is generally used in Tier III or higher data centers. For key loads such as air conditioners, lighting, and fire extinguishing devices, an ATS needs to be configured to facilitate online maintenance.
- In the dual power supply solution, a bus tie switch can be configured to improve reliability.

Contents

Calculating the Capacity of Low-Voltage Electric Devices

- Current calculation method
  - Measure the active power of each load, and calculate the current using the following formulas. The rated current of a low-voltage electric device is equal to the calculated current multiplied by a coefficient ranging from 1.2 to 2.0.
  - Single-phase load: $P = UI \cos\theta$, $I = P/U\cos\theta$
    - where: U : single-phase voltage; $\cos\theta$: power factor; P : active power; I : calculated current;
  - Three-phase load: $P = \sqrt{3}UI\cos\theta$
    - where: U : line voltage; $\cos\theta$: power factor; P : active power; I : calculated current.



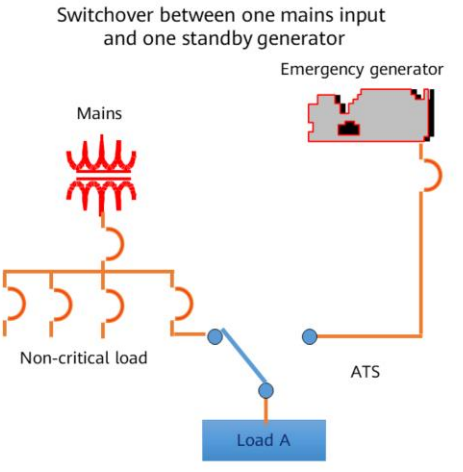
- In the low-voltage power supply system of a data center, the initial rated current of low-voltage electric devices such as circuit breakers is determined based on the calculated current.
- According to the related standard, the rated current of a circuit breaker is tested on a separate circuit breaker without shells. Therefore, if the device is installed in a power distribution box (PDB) or PDF with poor heat dissipation, the circuit breaker capacity should be derated to 0.7–0.8. For other low-voltage electric devices such as fuses, the rated current calculation is similar to that of circuit breakers, that is, by multiplying the calculated current by the corresponding coefficient.
- In the power distribution system of a data center, hierarchical protection should be used. That is, if a system has multiple levels of circuit breakers, the rule of selecting circuit breakers is to ensure that when a circuit breaker at a certain level is faulty, only the circuit breaker at the corresponding level trips and the power of other levels is not affected. Therefore, a circuit breaker should have a lower capacity than the upstream one and larger capacity than the downstream one.

Low-Voltage Electric Device Selection - ATS

- The ATS is used to automatically switch between the mains supply and the DG supply, or to provide dual power supplies for devices such as air conditioners. The STS is used to provide dual power supplies for single-power critical loads. The selection rules are as follows:
    - The ATS and STS should be selected based on the rated operating voltage and calculated current. The rated current of the selected device should be greater than or equal to the calculated current.

ATS Typical Application Solution (1)

- Working logic:
  - When a mains outage occurs, the ATS sends a startup signal to start the standby generator.
  - The ATS automatically detects the voltage and frequency of the standby generator. When the voltage and frequency reach the rated values, the ATS automatically switches to the generator supply.
  - After the mains is restored and stable, the ATS automatically switches back to the mains supply.
  - The ATS sends a stop signal to shut down the standby generator after DG cold start.
- This solution applies to scenarios that require low costs and low reliability.



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- Note: The figure only displaies the switching between the DG and mains. The power supply topology of loads is not displayed.

ATS Typical Application Solution (2)

- If the customer wants to improve the power supply reliability, how to configure a standby DG or mains?
  - 1 mains supply + 2 DGs (one active and one standby)
  - 2 mains supplies (one active and one standby) + 1 DG

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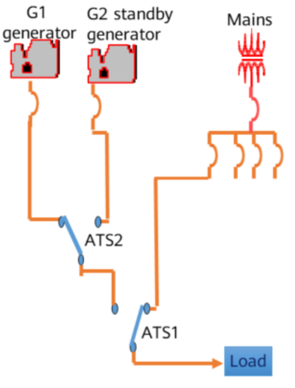
ATS Typical Application Solution (3)

- Switchover between one mains input and two standby generators
  - If the mains supply fails, the generator G1 starts and ATS 1 switches to the generator.
  - If both the mains supply and G1 generator supply fail, the G2 generator starts and ATS 2 switches to the G2 generator.
  - In this solution, when the mains supply fails, the generator directly carries the load. There is a redundant generator, so the reliability is relatively high.
  - This solution applies to scenarios where the mains supply is normal and high reliability is required.

Switchover between one mains input and two standby generators



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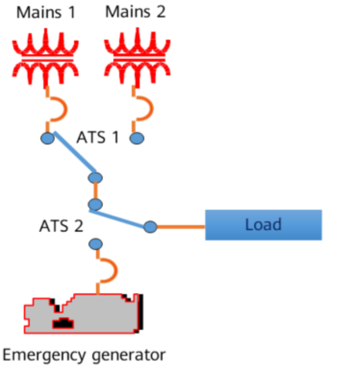
ATS Typical Application Solution (4)

- Switchover between two mains inputs and one standby generator
  - If mains 1 or 2 fails, the generator is not started, and ATS1 switches to mains 1 or 2.
  - When both mains 1 and mains 2 fail, the generator starts, and ATS2 switches to the generator.
  - This solution has high reliability when the mains supply is normal. If the mains supply is unavailable, the DG directly carries the load, and the reliability is relatively low.
  - This solution applies to scenarios where the mains supply is good and high reliability is required.

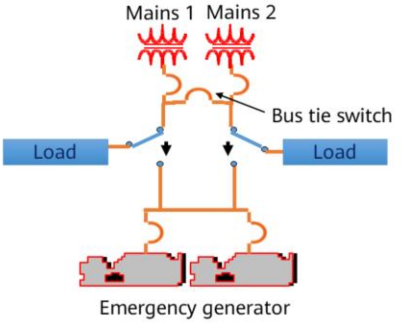
Switchover between two mains inputs and one standby generator



ATS Typical Application Solution (5)

- If the customer requires higher power supply reliability and wants to deploy two mains inputs and multiple standby generators, how to achieve this?

Switchover between two mains inputs and multiple standby generators



Reactive Power Compensation

- In a data center, reactive power compensation is required for low-voltage power supply to achieve the required power factor and improve the power grid quality. The formula for calculating reactive power compensation is as follows:

$$\Delta Q = P \times (\tan\ \theta_1 - \tan\ \theta_2)$$

  - θ_1 is the angle of the power factor before the compensation.
  - θ_2 is the angle of the power factor after the compensation.
  - P is the active power.
- Then select the corresponding capacitor based on the calculated reactive power.

- Obtain the active power, reactive power, and apparent power of all devices. Calculate the power factor of the current data center based on the active power, reactive power, and apparent power, and calculate the reactive power to be compensated based on the formula.
- The power factor after compensation should be 0.9 or above.

Example of Reactive Power Compensation

- Load statistics of a data center:
  - Active power: 2739.47 kW; reactive power: 1701.81 kVar; total apparent power: 3225 kVA; current power factor: 0.85; power factor after compensation: 0.9.
- The calculation is as follows: $\Delta Q = P \times (\tan\theta_1 - \tan\theta_2)$

  = 2739 x (0.619 – 0.4843) = 369 kVar
  - After compensation: active power: 2739.47 kW, reactive power: 1332.81 kVar, total apparent power: 3043 kVA, power factor: 0.9.

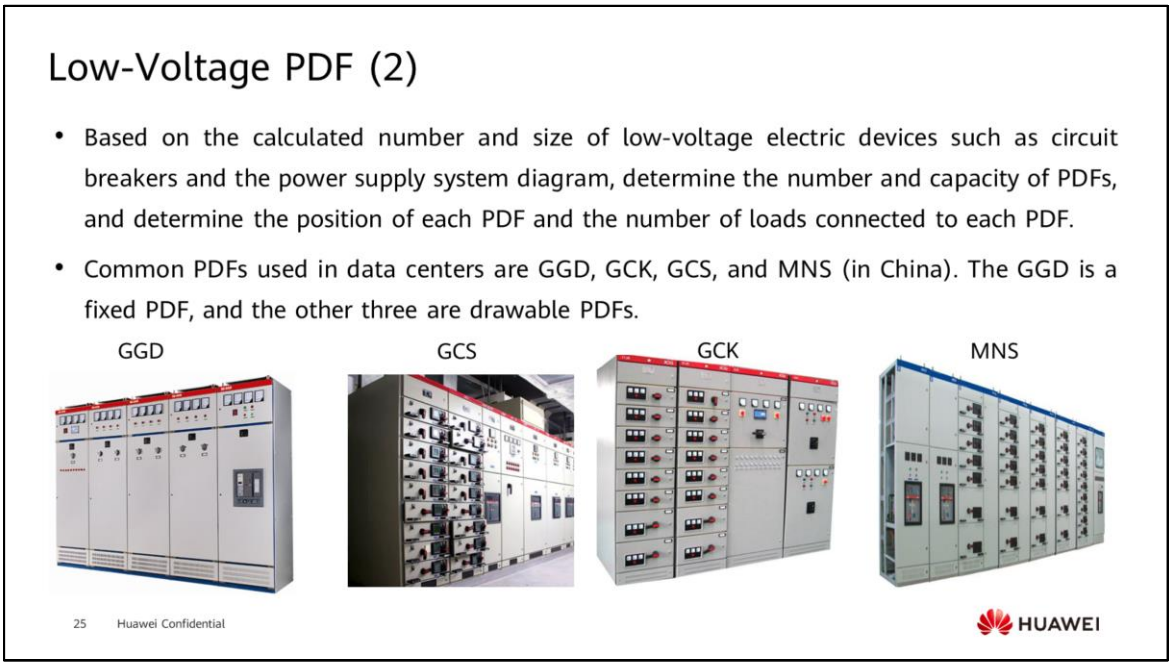
Section Summary

- Determine which loads are powered by the UPS and which loads are powered by the mains.
- Complete the preliminary power supply solution. For loads with dual power supplies, use dual power supplies. For important loads with a single power supply, use dual power supplies and ATS/STS switching.
- Understand the switchover solution between the mains supply and DG.
- Estimate the reactive power compensation scale.
- Calculate the capacity of low-voltage electric devices for different loads and the number of low-voltage electric devices, for example, the low-voltage electric devices numbers for UPSs, chillers, and other power equipment such as the cooling water pump. This helps determine the number and capacity of low-voltage PDF.

Contents

Low-Voltage PDF (1)

- The main low-voltage PDF is the load control center in a data center. It is a set of combined cabinets including the cable entry cabinet, reactive power compensation cabinet, bus-tie cabinet, and feeder cabinet.
- Passing through a transformer, the high-voltage mains supply is stepped down and connected to the general switch of the cable entry cabinet. The output end of the general switch is connected to the bus of the PDF. The current passes the feeder cabinet, reactive power compensation cabinet, and bus-tie cabinet through the bus. The bus-tie cabinet is used to switch between multiple power supplies.
  - Note: If two power inputs are required for important loads, use a bus-tie cabinet to connect the two main low-voltage PDFs to improve system reliability. In normal cases, the two low-voltage PDFs run separately, and the bus interconnection switch is turned off. When one mains supply is faulty, the bus interconnection switch is turned on, and the normal mains supplies power to loads.



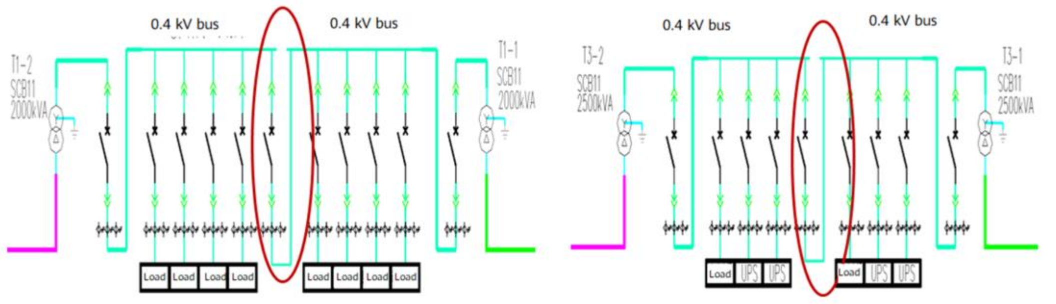
- The GGD AC low-voltage PDF applies to the power distribution system with the AC frequency of 50 Hz, rated operating voltage of 380 V, and rated operating current of less than 3150 A. It is used to convert, distribute, and control power for power, lighting, and power distribution devices. The disadvantages of the GGD are that the loop is few, the units cannot be combined arbitrarily, the footprint is large, and it cannot communicate with the computer.
- The GCK low-voltage drawable switch cabinet consists of a power distribution center (PC) and a motor control center (MCC). It is applicable to the power distribution system with an AC frequency of 50 Hz, a rated operating voltage of less than or equal to 660 V, and a rated current of 6300 A or lower. It can distribute power for power devices and lighting and control motors. The cabinet is made of type-C materials, and the height of a standard unit (E) is 25 mm.
- The GCS low-voltage drawable switch cabinet is used in a power supply/generation system with a three-phase AC frequency of 50 Hz, rated working voltage of 400 V (690 V) and rated current of 4000 A or lower. It controls the power devices and motors, distributes power, and compensates capacitance. The cabinet can be operated only from one side. The cabinet is made of type-KS materials, and the height of a standard unit (E) is 20 mm.
- The MNS cabinet can be operated from two sides. The depth of the cabinet is 600 mm, 800 mm, or 1000 mm, and the supported current of the cabinet reaches 6300 A. The cabinet is made of type-C materials, and the height of a standard unit (E) is 25 mm.

- Drawable cabinet:
  - The height of the cabinet is 2200 mm, and the effective height of drawers (that is, the height of drawers) is 1800 mm. Therefore, the two types of cabinets can be installed with nine layers of drawers. 8E (E = 20/25) = 160/200: The drawer heights are less than 1800.
  - In the following example, E=25.
  - 8E/4 = 200/4 (indicating that four drawers are placed in the space of 200 mm high and the width is 150 mm)
  - 8E/2 = 200/2 (indicating that two drawers are placed in the space of 200 mm high and the width is 300 mm)
  - 8E: The drawer height is 200 mm and the width is 600 mm. 12E: The drawer height is 300 mm and the width is 600 mm.
  - 16E: The drawer height is 400 mm and the width is 600 mm. 20E: The drawer height is 500 mm and the width is 600 mm.
  - 24E: The drawer height is 600 mm and the width is 600 mm.
- The heights of common circuit breakers with different capacities are as follows:
  - Molded case circuit breaker (MCCB) less than 250 A: 200 mm, occupying 8E (one drawer)
  - 400 A or 630 A MCCB: 400 mm, occupying 16E (two drawers)
  - 800 A MCCB: 600 mm, occupying 24E (three drawers)

- Quantity of MCCBs installed in a low-voltage switch cabinet (for reference):
  - Three 800 A MCCBs can be installed in a cabinet.
  - Four 400 A or 630 A MCCBs can be installed in a cabinet.
  - A maximum of nine 250 A or lower MCCBs can be installed in a cabinet.

Example of Low-Voltage PDF Configuration (1)

- The low-voltage side works in single bus mode and bus tie switches are configured. At any time, there are only two main inlet switches and bus tie switches are turned on.
- Critical loads are powered by two supplies, two different transformers, and different buses.



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- Note that in a large-sized data center, different transformers are used for UPS loads and power loads to avoid mutual impact.

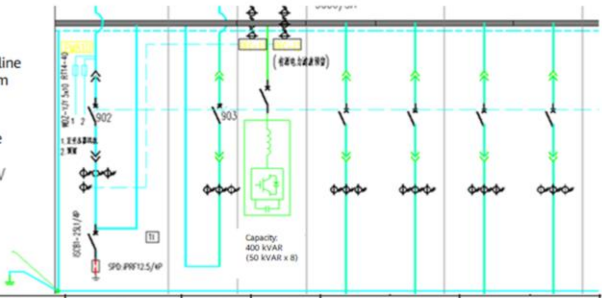
Example of Low-Voltage PDF Configuration (2)

- Cable entry cabinet: main cable entry ACB, 5000 A.
- Cable outlet cabinet: 1250 A ACB, responsible for supplying power to chillers. One cable outlet cabinet can be installed with only two ACB.

Single-line diagram

Rated voltage

~0.4kV

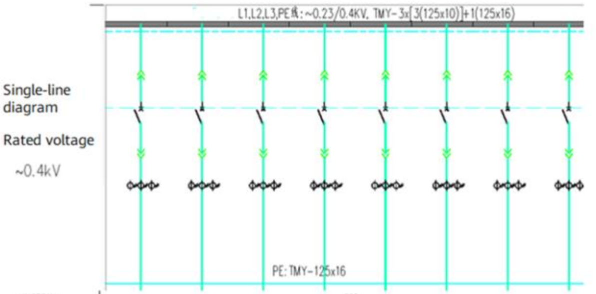


LV PDF No.	7P1	7P2	7P3	7P4		7P5	
LV PDF	Cable entry cabinet	Connecting cabinet	Compensation cabinet	Cable outlet cabinet		Cable outlet cabinet	
Loop	Transformer cable inlet	Connecting	Reactive power compensation	Chiller 1	chiller 2	Chiller 3	standby
Long-delay trip current	5000	5000	800	1250	1250	1250	1250
Short-delay trip current multiple/Action time	5 (0.4s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)
Instantaneous trip current multiple	10	10	10	10	10	10	10
Device capacity (kW)			400	500	500	500	
Power factor				0.8	0.8	0.8	
Calculated current				950	950	950	

- Circuit breakers for chillers: 500000/0.8/380/1.732 = 950; Round up and select 1250 A circuit breakers.

Example of Low-Voltage PDF Configuration (3)

- Cable outlet cabinet: eight loops in total.
- Calculate the capacity of low-voltage electric devices corresponding to different loads and the number of cables required, and then determine the PDF model based on the PDF space and current capacity.



LV PDF No.	7P6							
LV PDF	Cable outlet cabinet							
Loop	Chilled water pump	Floor 1 precision A/C	Floor 1 precision A/C	Cooling water pump 3	Cooling water pump 1	Standby	Pump room equipment	Elevator 2
Long-delay trip current	250	63	50	300	300	100	100	125
Short-delay trip current multiple/Action time	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)	5 (0.2s)
Instantaneous trip current multiple	10	10	10	10	10	10	10	10
Device capacity (kW)	85	23	10	95	95		25	30
Power factor	0.8	0.8	0.8	0.8	0.8		0.8	0.8
Calculated current	162	39	17	180	180		43	61

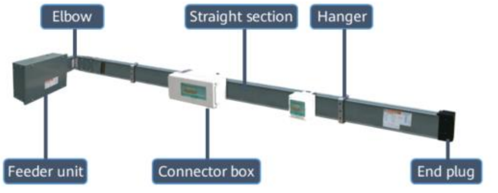
Contents

Power Cable Selection

- Common power cables in a data center include cables and busways.
- A cable consists of copper cores, an insulation layer, and a jacket. Cables are classified into single-core cables, three-core cables, three-phase four-wire cables, and three-phase five-wire cables.
- A busway consists of the conductive strip, protective shell, and connector box. It is used in scenarios with large calculated current and load density.

cables

Busway



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- In the power distribution system of a data center, the conductor type is selected based on the load type, calculated current, and onsite conditions. For example, if the calculated current of a loop exceeds 400 A, the cross-sectional area of a common cable is too large and hard to install. In this case, the busway power supply solution should be chosen. In addition, if there are many terminal devices in the power distribution system, for example, dense loads in cabinets, the busway power supply solution is also suitable when factors such as economy and cabling space are considered. The busway solution is also a trend.

Cable Selection Rules

- The cable type (rigid or flexible and insulation layer type) is determined based on factors such as construction site characteristics, nature of power loads, and capacity. The cable specifications are determined based on the calculated current and the cable specifications provided by the manufacturer.
  - Select the cable type based on the power supply mode. For single-phase power supply, use single-core or three-core cables. For three-phase power supply, use three-phase four-wire or three-phase five-wire cables.
  - Select the corresponding cable cross-sectional area based on the calculated current according to the table of the current-carrying capacity of cables.
  - Select the appropriate fireproof material of cables according to the requirement on data center reliability level. The fireproof material must comply with the American standard (NEC), European standard (IEC), or Chinese Ministry of Public Security standard (GA 306). In China, ZA-YJV, BVV, and RVV cables are generally used.

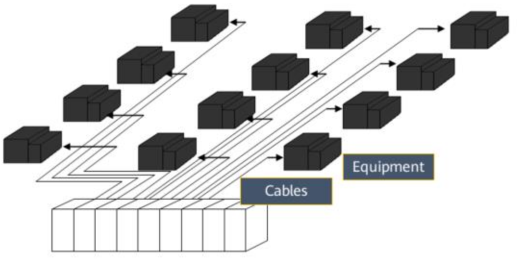
- In a three-phase four-wire power distribution system, the current-carrying capacity of the N wire should be no less than the sum of the maximum unbalanced load current and harmonic current in the line. When the phase wire is not greater than 16 mm2 (copper) or 25 mm2 (aluminum), the neutral wire should have the same cross-sectional area as the phase wire. When the phase wire is larger than 16 mm2 (copper) or 25 mm2 (aluminum), if the neutral wire current is small, the N wire can have a smaller cross-sectional area than the phase wire but cannot be smaller than 50%. The current-carrying capacity table provided by the manufacturer generally takes phase wire selection into consideration. Therefore, select the cable type based on the current.
- ZA-YJV: copper-core XLPE insulated PVC sheathed class A flame-retardant power cable

Busway Selection Rules

- The busway is applicable to the power supply and distribution system with a rated current of 250 A to 6300 A. The selection requirements are as follows:
  - High protection level.
  - When the calculated current of the loop is greater than 400 A, the busway power supply system is recommended.
  - When terminal devices are densely deployed, busway power supply lines are recommended to improve reliability and reduce installation difficulties.

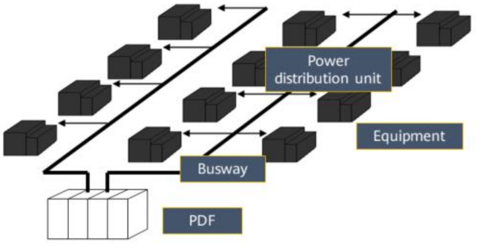
- For example, if the operating current of a large-sized UPS exceeds 1000 A, a busway can be used to supply power from the main low-voltage PDF to the UPS PDF.

Comparison Between the Cable and Busway Solutions (1)



Cable power distribution solution

Cables are routed separately and there are many loops. Each time a new device is added, cables need to be re-led from the PDF, causing many fault points.



Busway power distribution solution

Fewer loops and fault points, easy capacity expansion, and reduced total length of power supply paths.

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Comparison Between the Cable and Busway Solutions (2)

Item	Cable Solution	Busway Solution
Material cost	Relatively low	Relatively high
Installation mode	During cable installation, cable trays must be configured if cables are exposed. Trenches need to be dug for underground routing, which requires high construction costs.	Easy to install. Dedicated installation supports are provided.
Footprint	Cables with large diameters require a larger turning radius.	Elbows can be used at the turning of a busway, which occupies a small space.
Current-carrying capacity	Maximum current of a single cable: 400 A (VV type)	Maximum: 6300 A (intensive)
Circuit voltage drop	Large	Small
Service life	10–15 years	≥ 20 years
Solution design	Designed based on the power supply and distribution layout and does not need to be customized.	The design must be based on the floor plan. In addition, the site survey must be performed, and the straight section and elbow must be customized based on the site requirements.
Capacity expansion mode	Cannot be expanded. Cables need to be connected to the PDF again.	A branching loop can be added at the branch port.
Power transmission loss	High	Low

Summary

- System Composition
- Planning Preparation
- Planning Method
  - Planning Procedure
  - Power Supply Solution Selection
  - Low-Voltage Electric Device Selection
  - Low-Voltage PDF Configuration
  - Conductor Selection

Quiz

1. (short-answer question) Why is reactive power compensation required for a data center?

- 1. This is a requirement of the power company. The initial power factor of data center loads is generally less than 0.9. When the power is small, the quality of the power grid is affected because power consumption is large in data centers. When the power factor is small, the same power requires a larger current, and the line loss also increases. Therefore, reactive power compensation is required.

Thank you.

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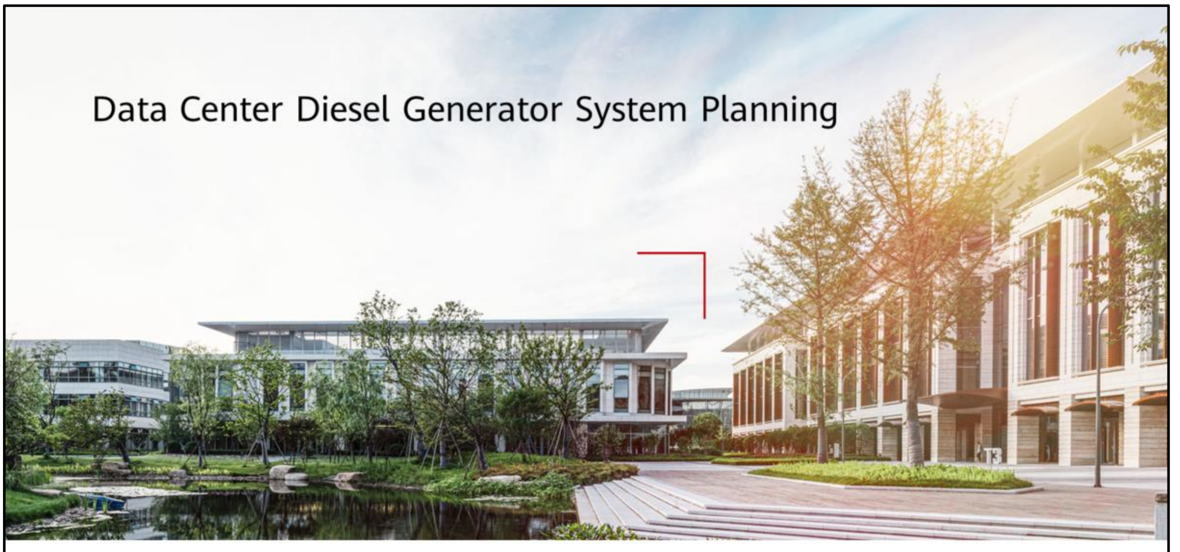
Data Center Diesel Generator System Planning



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Foreword

- The slides describe the diesel generator (DG) system planning for data centers, including the DG system requirement analysis, DG networking mode, DG model selection, DG capacity calculation, and fuel tank capacity calculation.

Objectives

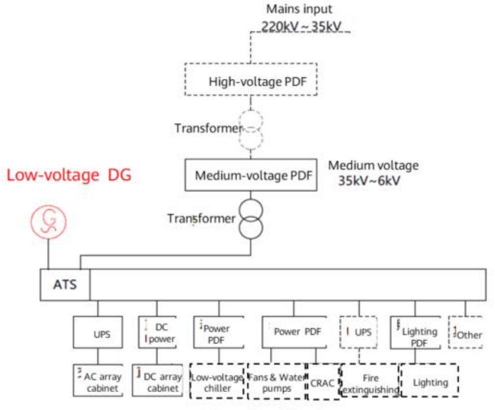
On completion of this course, you will be able to:

- Get familiar with the DG system requirement analysis.
- Get familiar with the DG system networking modes.
- Master DG model selection.
- Master DG capacity calculation.

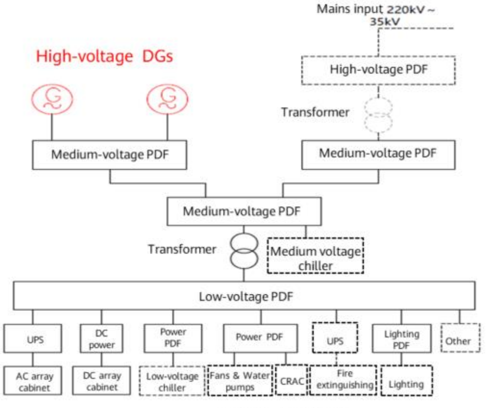
Contents

System Scope

- The following figures show the position of a DG subsystem in a power supply and distribution system.



Low-voltage DG system



High-voltage DG system

System Overview

- A DG system is composed of a diesel engine, generator, control panel, fuel tank and so on.

DG exterior

- Engine: a machine that converts a type of energy into another type of energy, usually chemical energy into mechanical energy. Sometimes it refers to a mechanical energy generation device. It can also refer to the entire machine including the mechanical energy generation device, such as a gasoline engine and an aeroengine. The engine was invented in England. The engine concept was also originated from English. Its original meaning is "an apparatus that produces mechanical energy."
- Generator: It has many forms, but all operate according to the law of electromagnetic induction and electromagnetic force. Therefore, the general structure of the generator is as follows: Circuits and magnetic circuits that are inductive to each other are made of appropriate magnetic and conductive materials to generate the electromagnetic power and achieve the purpose of energy conversion.
- Control panel: serves as an auxiliary device of the DG for users to operate and control the DG as well as set and view the operating parameters (voltage and frequency) and status of the DG. It consists of power distribution, mechanical energy, and signal ports.

Contents

Planning Preparation - Requirement Analysis

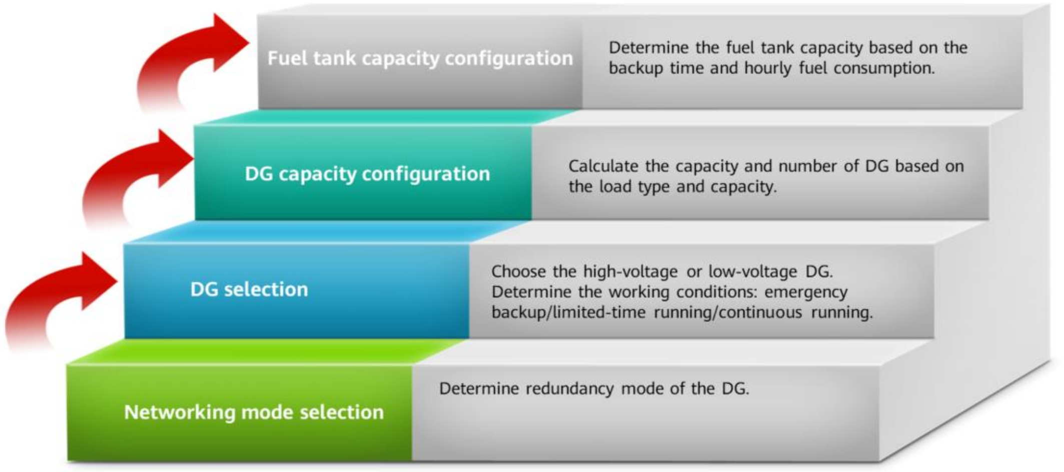
- Requirement analysis
  - Data center tier: The data center tier determines the DG redundancy mode and DG operating mode (backup, limited-time running, or continuous running).
  - Operating environment: altitude, ambient temperature and humidity, and indoor or outdoor environment
  - Total load: The total load determines the DG type, capacity of a DG, and the number of DG.

- The data center DG is generally a three-phase one. According to the reliability requirements, the running mode is backup/limited-time running/continuous running, and the redundancy mode is N, N+1, or 2N.
- If the system reliability level is Uptime Tier I, select the N redundancy mode. If the system reliability level is Uptime Tier II or III, select the N+1 redundancy mode. If the system reliability level is Uptime Tier IV, usually select the 2N redundancy mode.
- Select an appropriate voltage level and frequency based on the local voltage system. There are two voltage levels: high voltage (about 10 kV) and low voltage (about 0.4 kV).
- Total load: Calculation based on the preceding information.

- Operating environment
  - Indoor or outdoor: IP rating. If the DG is deployed outdoors, a high IP rating is required.
  - Ambient temperature and humidity: The normal operating temperature of the DG ranges from –15° C to +40° C. If the temperature is beyond this range, protection measures must be taken for the DG. For example, if the temperature is low, auxiliary startup measures should be taken. The air humidity also affects the DG. If the DG is used in an environment with high air humidity for a long time, the DG will be greatly damaged or even cannot be used.
  - Altitude: DG are used in places with an altitude lower than or equal to 1000 m. When the altitude exceeds 1000 m, the output power is derated. Higher altitude leads to lower local atmospheric pressure, thinner air, and lower oxygen content. As a result, the combustion condition of the DG deteriorates due to insufficient air intake.

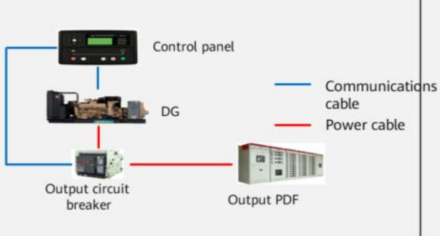
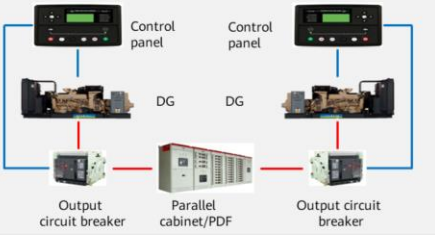
Contents

Planning Procedure



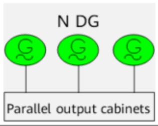
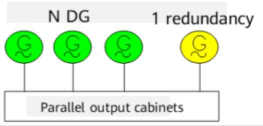
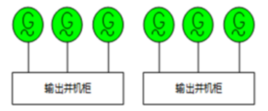
Contents

Running Mode

	Single Operating	Parallel Operating
Topology		
Power range	Maximum power of a single DG: 3600 kVA	The power of parallel DG can reach 12 MVA or higher. (Theoretically, it can be infinite.)
Maintenance mode	DG can be maintained only when they are powered off.	DG can be maintained in turn, and power-off is not required.
Technical complexity	Easy to deploy due to simple control logics.	Difficult to deploy due to complex control logics. The voltage, frequency, and phase must be synchronous among parallel DG.
Applicable scenario	Medium- and small-sized data centers and large-size modular data center.	Large-sized data centers

- Parallel operation requires auxiliary parallel cabinets, synchronization modules, load distribution modules, and air circuit breakers allowing fast switch-on.
- Application scenario of the single operating solution
  - A single DG supports a maximum capacity of 3600 kVA. If the low-voltage power distribution capacity is less than 3600 kVA, the single operating solution can be used. Then connect the DG output cabinet and transformer output cabinet to the low-voltage power distribution system through an ATS. The capacity of the single operating solution can meet the requirements of small- and medium-sized data centers. If the single operating solution can meet the power requirements of a large-sized modular data center, the single operating solution can be used. For systems with the same power, the cost of a single operating solution is lower than that of a parallel solution.
- Application scenario of the parallel solution
  - The maximum capacity of a parallel system is not limited. Non-modular large-sized data centers have high power supply requirements, and the single operating solution cannot meet the system capacity requirements. In this case, the parallel solution is required. For example, in the DG parallel solution of a data center, five 500 kVA DG are used to form a 4+1 system.

Redundancy Mode (1)

	N Solution (No Redundancy)	N+1 Solution	2N Solution
Topology			
Reliability level	The reliability is poor. The N solution meets the Uptime Tier Ⅰ requirements.	The reliability is favorable. The N+1 solution has one redundant DG and meets the Uptime Tier Ⅱ or Ⅲ requirements.	The reliability is high. The 2N solution has N redundant DGs and meets the Uptime Tier IV requirements.
DG maintenance	If any DG is being maintained, less than N DGs can be running.	DGs can be maintained one by one.	One group of N DGs can be maintained simultaneously.
Technical complexity	Technical complexity is low, and standalone running is applied.	Technical complexity is relatively high, and control logics need to be added to control the DG startup and stop.	Technical complexity is high, and the redundant N DGs can be standby or running simultaneously with the other N DGs.
Applicable scenario	Small-sized data center	Medium- and large-sized data center	Medium- and large-sized data center

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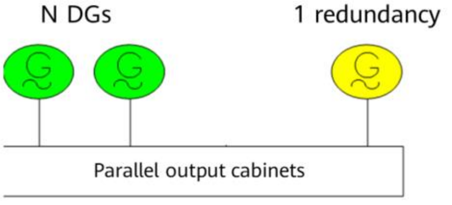
- Application scenarios of the N solution (no redundancy)
  - The DG configuration can meet the requirements of the system. When the mains supply fails, the N DG can supply power to key loads. However, the system has no redundancy, so it does not support online maintenance and has a single point of failure (SPOF). That is, if any DG stops running, the power requirement of N DG is not met. This solution applies to scenarios with low system availability, such as small-sized data centers. It meets the Uptime Tier I requirements.
- Application scenarios of the N+1 solution
  - The reliability of the N+1 solution is higher than that of the N solution. If the topology design is reasonable, the solution supports online maintenance. That is, if one DG is stopped as planned, the power requirement of N DG is not affected. This solution applies to medium- and large-sized data centers that require high reliability. The solution meets the Uptime Tier II requirements. If the line design is reasonable and online maintenance can be implemented, it will meet the Uptime Tier III requirements.

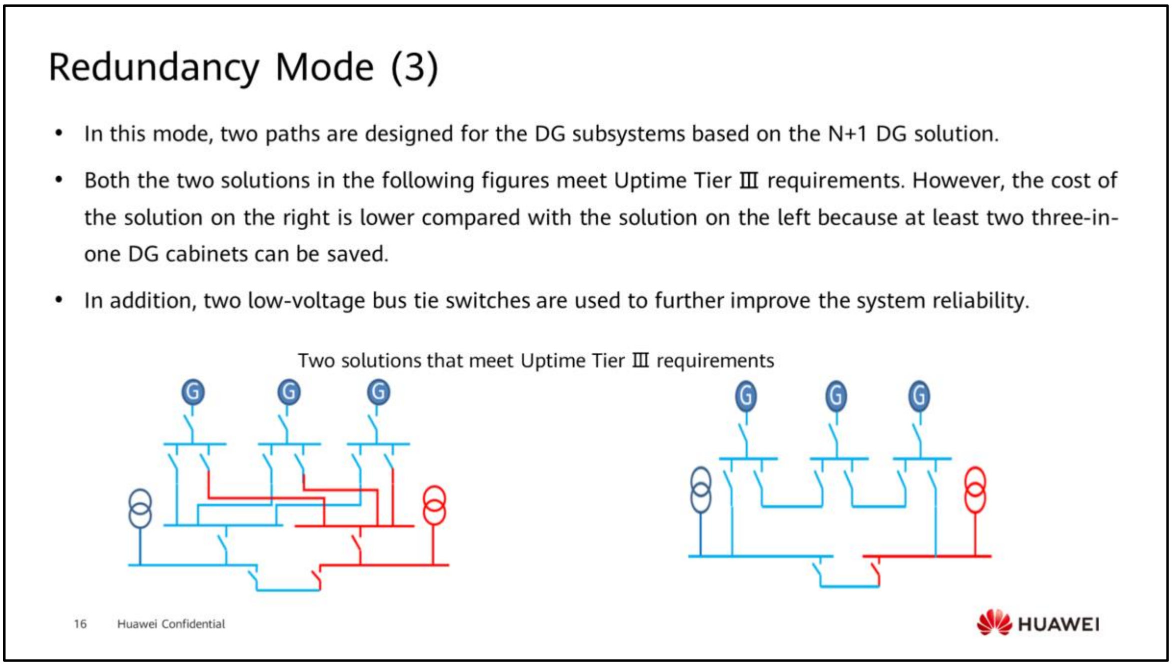
- Application scenarios of the 2N solution
  - The 2N solution has the highest reliability. Sometimes, the 2(N+1) mode is used, which is similar to the 2N mode. In the 2N mode, dual power supplies are provided. All key loads are powered by dual power supplies. Therefore, the 2N mode can meet the fault tolerance requirements. That is, any single point of failure in the DG system does not affect the power requirement of N DGs. This solution applies to large-sized data centers that require high reliability. If the design is reasonable, the system can meet the Uptime Tier IV requirements.

Redundancy Mode (2)

- How can the following N+1 redundancy mode meet Uptime Tier Ⅲ requirements through cable connection design?



- There are three control logics for a parallel DG system.
  - Logic 1: After receiving the power failure signal, all DG are started at the same time. That is, no matter how much the load is, the N+1 DG connected in parallel always run at the same time.
  - Logic 2: DG are started at the same time, and then cut off according to the load capacity.
  - Logic 3: After receiving the power failure signal, the system starts only one DG and determines whether to start other DG based on the load capacity.
  - The first control logic, that is, all DG are always online, is recommended for data centers. This mode prevents frequent DG startup and stop when the load capacity fluctuates rapidly. In addition, the internal resistance and impacts of harmonics can be reduced when multiple DG run at the same time, facilitating the stable running of the DG. The second control logic applies to scenarios where the load capacity changes slowly and this logic consumes least fuel. In the third control logic, DG are started in sequence, which is applicable to scenarios with small initial load and fixed load growth.



- On the premise that Uptime Tier III requirements are met, the solution on the right saves costs compared with the solution on the left. At least two three-in-one diesel generators and cabinets are not required.
- The low-voltage bus tie switch is also adopted in the above two segments of low-voltage bus, so that the system reliability is further improved.
- The low-voltage bus tie breakers are switched off when the two routes are normal. When one route has no mains supply, the mains input circuit breaker of this route is turned off first, and then the bus tie switch is turned on. In this way, one route bears all loads.

Contents

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High- or Low-Voltage DG Selection (1)

- DG are classified into low-voltage (0.4 kV) and high-voltage (10 kV) DG based on the output voltage. Except the output voltage varied with the DG configuration, the two types of DG have basically the same engine, control system, and technology.

Comparison between low- and high-voltage DGs

No.	Comparison	Low-Voltage DG (0.4 kV)	High-Voltage DG (10 kV)
1	DG cost	1	10% to 15% higher
2	Installation cost	Same	Same
3	Cooling mode	Same	Same
4	Noise control	Same	Same
5	O&M	Same	Same
6	Footprint	Basically the same	Basically the same
7	Grounding system	Not required	A ground resistance cabinet is required.
8	Efficiency	Same	Same
9	Startup time	Same	Same

Medium- or Low-Voltage DG Selection (2)

Comparison between low- and high-voltage DG

No.	Comparison	Low-Voltage DG (0.4 kV)	High-Voltage DG (10 kV)
10	Auxiliary switch cabinet	0.4 kV	10 kV
11	Power transmission medium	Low-voltage power cable or bus	High-voltage power cable
12	Power transmission cost	High	Low
13	Power transmission loss	High	Low
14	Power transmission distance	Near (less than or equal to 150 m)	Far (less than or equal to 2000 m)
15	Non-linear load bearing capability	The DG is directly connected to a load and is easily affected by a non-linear load.	In most cases, a transformer is used for connecting a load, and the transformer can eliminate part of the impact of a non-linear load on the DG.

Medium- or Low-Voltage DG Selection (3)

Comparison between low- and high-voltage DG

No.	Comparison	Low-Voltage DG (0.4 kV)	High-Voltage DG (10 kV)
16	Load power factor	The DG is directly connected to a load and is easily affected by the load power factor.	In most cases, a transformer is used for connecting a load to avoid that the output power of the DG is affected by an excessively low power factor.
17	Parallel operating	The parallel capacity is small because the DG is limited by the current of the low-voltage power distribution device.	High-power DG can be connected in parallel to form a large-capacity system.
18	Switching to the mains supply	ATS with a bypass are used, and this requires large current and multiple ATS, resulting in a large footprint and high costs.	A comprehensive control switch can be installed on the 10 kV bus to control the switchover, and this requires a small footprint and low costs.

Medium- or Low-Voltage DG Selection (4)

- Due to the performance limitation of low-voltage electrical equipment, the capacity of a single or parallel low-voltage DGs cannot exceed 2400 kW. If the total capacity of low-voltage DGs in a small- and medium-sized data center is less than 2400 kW and less than 10 DGs are connected in parallel, the 0.4 kV DG is preferred. Otherwise, the 10 kV DG is preferred.

Uptime Tier	Recommended DG Redundancy Mode	Remarks
Tier I	N	A single DG is recommended and the capacity cannot exceed 2400 kW.
Tier II	N+1 or 2N	If the total capacity of DG does not exceed 2400 kW and less than 10 DG are connected in parallel, the low-voltage DG solution is recommended. Otherwise, the high-voltage DG solution is recommended.
Tier III	N+1 or 2N	Same as above
Tier IV	2N	Same as above

Voltage Mode Selection

- The following table lists the voltage levels of the low- and high-voltage DG.

DG voltage level

Low Voltage (Three-Phase/Single-Phase)		High Voltage (Three-Phase)	
50 Hz	60 Hz	50 Hz	60 Hz
380/220	416/240	10500	12470
400/231	440/254	11000	13200
415/240	460/266	6300	13800
440/254	480/277	6600	3300
		6900	4160

- DG should be selected based on the local power supply modes. In China, the power supply mode is 220/380, 50 Hz.

DG Power Selection

- Determine the nominal power of the DG in a data center based on factors such as the mains reliability and data center reliability requirements. If the requirements are excessively high, for example, the consecutive power (COP) is used, the cost increases. If the requirements are excessively low, for example, the emergency standby power (ESP) is used, the reliability is decreased.
- Note:
  - For Uptime Tier Ⅲ and Tier Ⅳ data centers, COP DG are required.
  - For Uptime Tier Ⅰ and Tier Ⅱ data centers, LTP- or PRP- DG can be used.

- Output power ratings of DG:
  - COP: Continuous power (COP)-rated DG supply the maximum power continuously to constant loads for an unlimited number of hours annually. COP-rated DG are suitable for power plants.
  - PRP: Prime power (PRP)-rated DG supply the maximum power continuously to variable loads for an unlimited period of time annually. The 24-hour average load power is less than or equal to 70% of the PRP. PRP-rated DG often reserve extra speed adjustment power and can run at 10% overload. However, the average load rate, allowed full-load running time, and overload running time for different power plants vary. PRP-rated DG are applicable to industrial or civil engineering scenarios where the mains supply is unavailable or poor.
  - LTP: DG rated as limited-time running power (LTP) supply the maximum power for 500 hours annually. LTP-rated DG have no requirements on the load rate and are applicable to the areas with reliable mains supply.
  - ESP: Emergency standby power (ESP)-rated DG supply the maximum power to a variable load for 200 hours annually. The 24-hour average load power is generally less than or equal to 70% of the ESP. ESP-rated DG are applicable to common offices, real estate, and other places that do not have high reliability requirements.
  - When the preceding four types of power are calibrated for the same DG, the ratio of the calibrated power is about ESP:LTP:PRP:COP = 1000:920:850:780.

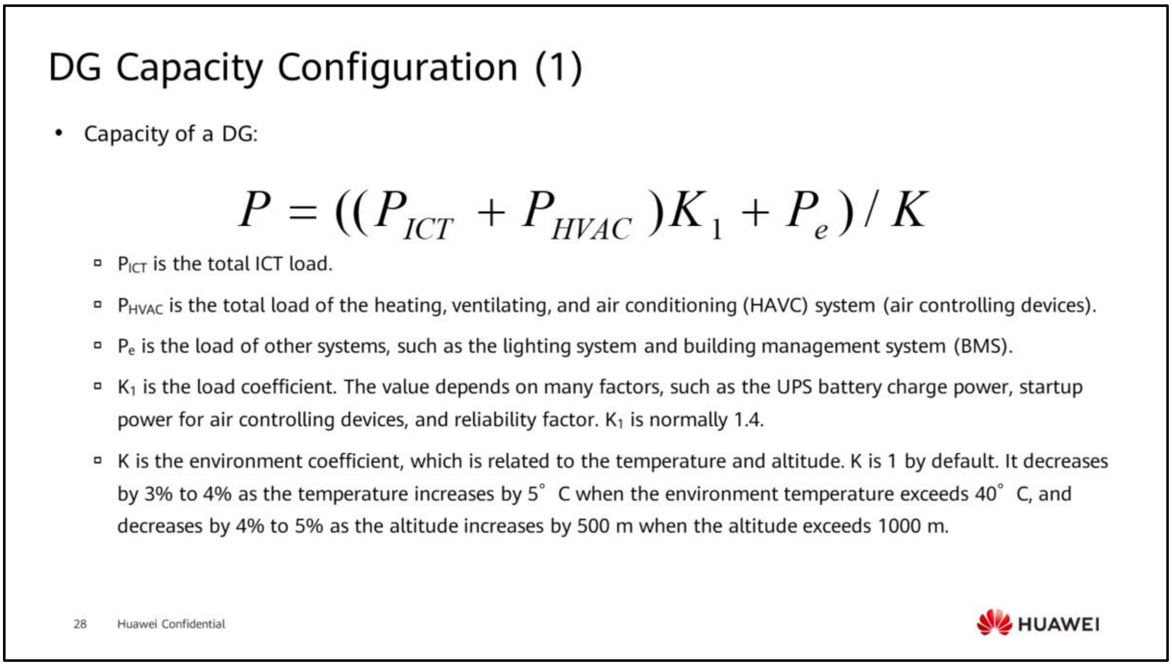
- The preceding definition is based on ISO 8528-1:2005. Generally, the nominal output power on the nameplate of a DG consists of the standby power, primary power, and continuous power. The standby power refers to the maximum power with which a DG can run continuously for 300 hours within the specified maintenance period and under the specified environment conditions. The DG should be able to run at the maximum power for 500 hours per year. The standby power is equivalent to the LTP in ISO standards. The prime power is the maximum power of a variable power sequence with which a DG can run for an unlimited number of hours each year in the specified maintenance period and under the specified environment conditions. The prime power is equivalent to the PRP in ISO standards. The consecutive power is the maximum power of a constant power sequence with which a DG can run for an unlimited number of hours each year in the specified maintenance period and under the specified environment conditions. The consecutive power is equivalent to COP in ISO standards. However, the definition and standards of power rating vary among different vendors. Therefore, you need to consult the vendor to determine during model selection.

- Generator power supply site:
- In Uptime Tier III or IV data centers, the engine generator system, its power path, and other auxiliary components shall meet the requirements for parallel maintenance and/or fault-tolerance performance verification tests.
- Runtime limit
- Engine generators at Uptime Tier III and IV data centers shall not have a limit on continuous operating time on the premise that the load meets the N requirement. Engine generators with limits on continuous operating hours are suitable for Tier I or II data centers. Only continuous operating power or derated prime rate meets the TIER III and IV requirements.

DG Selection Summary

- After the DG model is determined, the following information should be provided:
  - DG power: COP/LTP/PRP
  - DG voltage level: high/low voltage
  - DG power supply mode: 50/60 Hz, 400 V/480 V/11,000 V...

Contents



- The capacity is an estimation value.

DG Capacity Configuration (2)

- Determine the DG model, capacity, and quantity based on the list provided by the manufacturer.

Cummins DG capacity

50Hz	Model	Standby Load (kVA)	Standby Load (kVA)	Constant Load (kVA)	Constant Load (kVA)	Engine Model
Cummins	C650 D5A	650	520	590	472	KTA19G8
	C700 D5	706	565	640	512	VTA28G5
	C825 D5	825	660	750	600	QSK23G3
	C825 D5A	825	660	750	600	VTA28G6
	C900 D5	900	720	820	656	QSK23G3
	C1000 D5	1041	833	939	751	QST30G3
	C1100 D5	1110	888	1000	800	QST30G4
	C1100 D5B	1132	905	1029	823	KTA38G5
	C1250 D5A	1250	1000	1125	900	KTA38G9
	C1400 D5	1400	1120	1250	1000	KTA50G3
	C1675 D5	1675	1340	1400	1120	KTA50G8
	C1675 D5A	1675	1340	1500	1200	KTA50GS8
	C1760 D5e	1760	1408	1600	1280	QSK60GS3
	C2000 D5	2063	1650	1875	1500	QSK60G3

- Note: The preceding figure shows part of power segments.

Configuration Example

- According to the load statistics of an Uptime Tier III data center, the IT load is 700 kW, the power load is 800 kW, and the lighting load is 60 kW.
- According to the formula: $P = ((P_{ICT} + P_{HVAC})K_1 + P_e) / K$
- The total required power is calculated as follows: (700 + 800) x 1.4 + 60 = 2160 kW
- Because this is a Tier Ⅲ data center. Therefore, COP-rated DG is required. The following uses C1675 D5A as an example:
  - N solution: 2
  - N+1 solution: 2+1
  - 2N solution: 2 x 2

		Standby load (kVA)	Standby load (kW)	Constant load (kVA)	Constant load (kW)	
Cummins	C1400 D5	1400	1120	1250	1000	KTA50G3
	C1675 D5	1675	1340	1400	1120	KTA50G8
	C1675 D5A	1675	1340	1500	1200	KTA50GS8
	C1760 D5e	1760	1408	1600	1280	QSK60GS3

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- The reason why the active power is used for calculation is that the reactive power can be met in most cases.
- Only one model is used as an example. In actual model selection, parameters such as the cost and model size also need to be considered.

Contents

Fuel Tank Capacity Configuration (1)

- DG fuel storage requirements of data centers at all levels

Level / Standard	Tier Ⅳ	Tier Ⅲ	Tier Ⅱ	Tier Ⅰ
Uptime	12 hours	12 hours	12 hours	No specific requirements
TIA-942	96 hours	72 hours	24 hours	/

- Notes:
  - For a Tier Ⅲ or above data center, the fuel tank must be redundant. Except the fuel in the redundant fuel tank, the remaining fuel must be able to support 12-hour operation of N DG.
  - For a Tier Ⅲ or above data center, the fuel pipeline also needs to be designed in a similar way as the chilled water pipeline. The 2N design, loop design, or dual-pipe design can be adopted.

- For a Tier III or above data center, the fuel tank must be redundant. Except the fuel in the redundant fuel tank, the remaining fuel must be able to support 12-hour operation of N DGs.
  - Assume that there are three DGs in a 2+1 system. The system stores fuel for 12-hour operation. A total of 3000 liters fuel are required, and each DG requires 1000 liters. Therefore, at least two 2000-liter fuel tanks are required, and one of them is standby.

Fuel Tank Capacity Configuration (2)

- Fuel tank capacity calculation
  - V = g·t/γ/a = v·P·t/a
    - V: volume of the daily fuel tank (m^3); g: fuel consumption (kg/h) of the DG, which can be obtained from the product brochure.
    - γ: fuel density (kg/m^3), 810–860 kg/m^3 for light diesel; a: fullness coefficient of the fuel tank. Generally, the value is 0.90.
    - t: fuel supply time. Generally, the value is 3 to 8 hours. The value depends on the customer's requirements and is restricted by the specifications.
    - v: fuel consumption (L/kWh) of the DG, which can be obtained from the product brochure.
    - P: power (kW) of the DG.
  - In addition to the preceding calculation result, calculate the capacity of the daily fuel tank based on the diesel fuel consumption required for the trial operation in the normal refueling period.

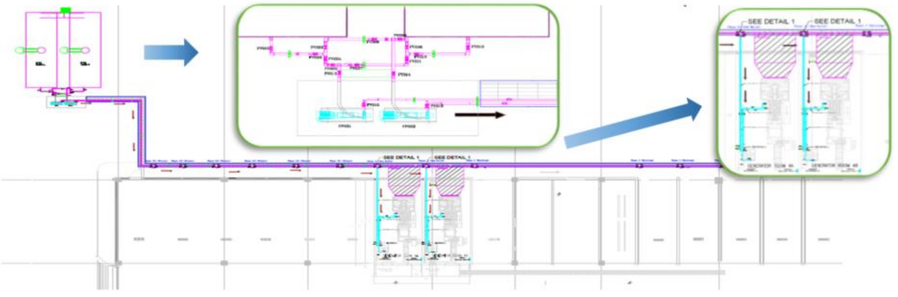
- The capacity of a fuel tank is designed based on the fuel consumption of the DG at full load. Generally, a less than 500 kW DG is equipped with a daily fuel tank that is installed at the bottom of the DG and it can provide fuel for the DG running for 8 to 12 hours at full load. An additional daily fuel tank needs to be installed for a big-power DG. When the customer requires an additional fuel tank, note that the capacity of the daily fuel tank in the DG room cannot exceed 1000 liters according to the fire protection regulations. The daily fuel tank of the standby DG is set to run at full load for 8 hours according to the communications industry standards. Therefore, a separate fuel tank room is required if the capacity exceeds 1000 liters, and fire extinguishing facilities are required according to the related fire protection regulations.
- V: Generally, the fuel consumption of a DG ranges from 0.2 L/kWh to 0.35 L/kWh. In the initial planning, 0.3 L/kWh can be used for capacity estimation.

Fuel Tank Capacity Configuration (3)

- If the fuel reserve of the daily fuel tank cannot meet the requirement for power backup time, a large fuel tank or underground fuel depot needs to be installed outdoors.
- Calculation of outdoor fuel tank capacity:
  - $V_{total\ tank\ volume} = V - V_{daily\ total\ volume}$
  - $V_{tank} = V_{total\ tank\ volume}/(N \cdot a)$
  - where:
    - $V_{total\ tank\ volume}$: calculated total capacity of outdoor fuel tanks (m^3); V: calculated total capacity (m^3).
    - V_{tank}: calculated capacity of the outdoor fuel tanks (m^3); N: number of fuel tanks.
    - a: fullness coefficient of the fuel tank. The value is usually 0.9 for the diesel fuel used for the data center.

Fuel Tank Pipeline Configuration (1)

- Uptime Tier Ⅲ application:
  - Similar to the chilled water pipeline design, the 2N, loop, or dual-pipe design can be adopted.
  - The fuel reserve must support 12-hour operation of N DG (daily fuel tank + reserve fuel tank).
  - For a Tier Ⅲ or above data center, the fuel tank must be redundant. Except the fuel in the redundant fuel tank, the remaining fuel must be able to support 12-hour operation of N DG.



In this solution, there are two sets of fuel pipes and fuel pumps, but the pipes and routes are not isolated.

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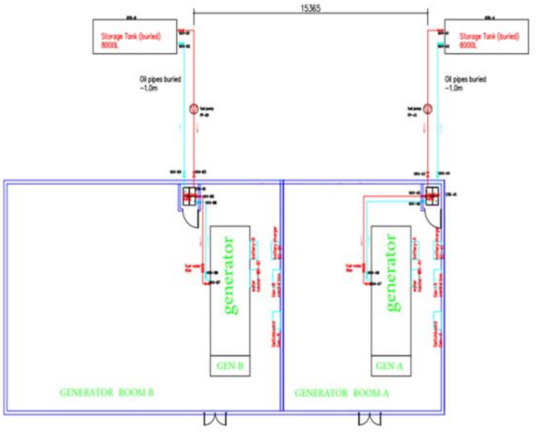
Fuel Tank Pipeline Configuration (2)

- Uptime Tier IV application:
  - Typically, Tier IV data centers adopt 2N DG solution. If a DG room is to be constructed, two DG must be physically isolated and not be placed in the same room.
  - The 2N pipeline design is the simplest, and the two pipelines are completely isolated. No pipes should be deployed between the two main fuel tanks. In addition, there must be some distance between the two pipeline systems so that the fault of one pipeline does not affect the other.

2N pipeline design



- After the fuel tank is configured, the DG planning is complete, and the other components are easy to configure.
  - Controller selection
    - If there is no specific requirement, select the controller provided by the DG manufacturer or a third-party controller. The controller needs to be compatible with the existing devices, and supports manual control mode and multi-language operations.
  - Parallel device selection
    - If multiple DG are running in parallel, select the corresponding parallel device.
    - For example, the Cummins DG is equipped with a parallel device by default. You only need to configure one parallel cabinet. A parallel cabinet and parallel device need to be installed for the Caterpillar DG to implement the parallel function.

- Other components
  - Select the soundproof canopy based on the customer's requirements. If the customer does not have specific requirements, the soundproof canopy is designed based on 85 dB per meter of the equipment room.
  - Select a startup battery string and battery charger to ensure the normal startup of the DG. The VLRA batteries are usually selected. The voltage of the startup motor is 12 V or 24 V. Select a compatible battery string. You can also configure batteries in 2N mode to meet reliability requirements.
- Other precautions
  - The DG must comply with local certification, such as the safety regulation certification and environment protection certification.
  - The following safety regulation and environment protection certifications are usually needed: CE and RoHS certifications in the EU, UL certification in the North America, and 3C certification in China.

Summary

- System Composition
- Planning Preparation
- Planning Method
  - Planning Method Overview
  - Networking Mode Selection
  - DG Selection
  - DG Capacity Configuration
  - Fuel tank configuration

Quiz

1. （T or F）The operation time of DG used in an Uptime Tier Ⅲ or above data center should not be restricted.
2. （T or F）The redundancy mode of DG used in an Uptime Tier Ⅲ or above data center should be N+1 or 2N and that the power supply paths of the DG support online maintenance or fault tolerance.

- 1. True
- 2. True

Thank you.

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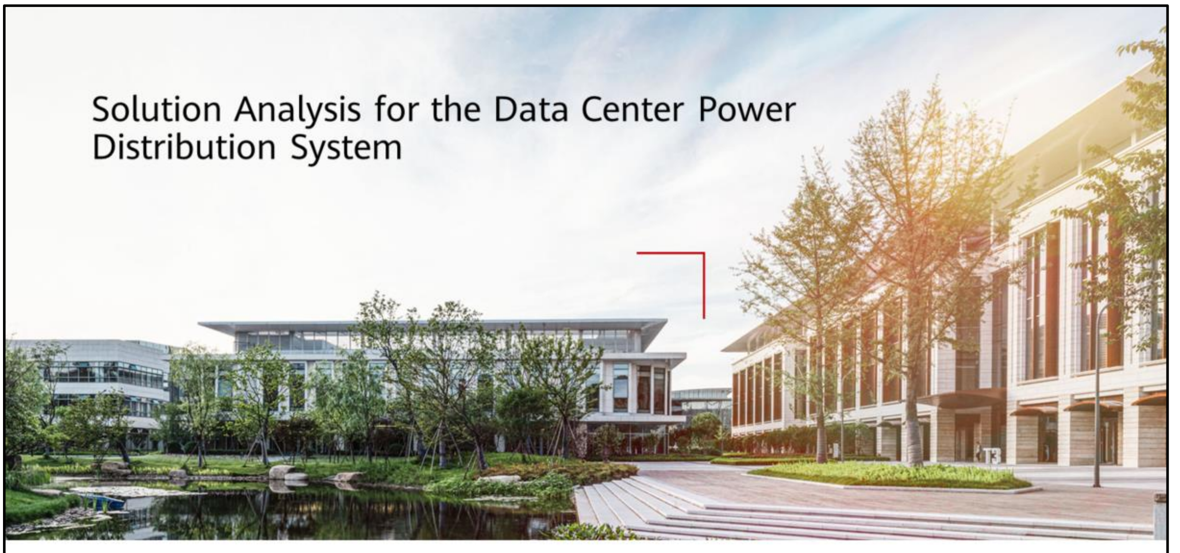
Solution Analysis for the Data Center Power Distribution System



Foreword

- The slides describe the typical power distribution solutions for different levels of data centers and their applications, including the working logic, application scenarios, advantages and disadvantages of these solutions. The slides also describe how to improve these solutions.

Objectives

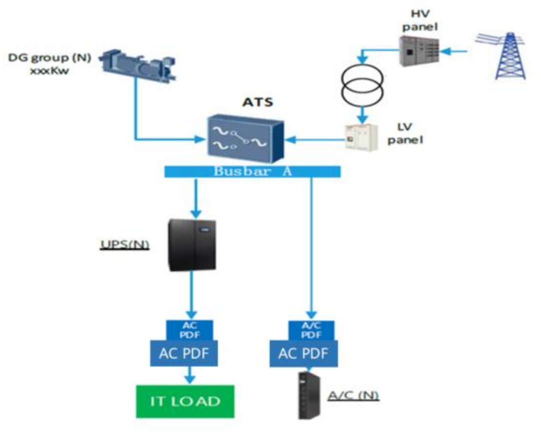
On completion of this course, you will be able to:

- Get familiar with the working logic of different power distribution solutions in a data center.
- Analyze the advantages of different power distribution solutions in a data center.
- Identify the disadvantages of different power distribution solutions in a data center.

Contents

Reference Solution for an Uptime Tier Ⅰ Data Center

- Single power supply and distribution route, diesel generator (DG), non-redundant uninterruptible power system (UPS)
- If any device on the power distribution route is faulty or overhauled, the service system may break down.
- This architecture is applicable to data centers used by small-sized enterprises that do not have specific requirements on service continuity.

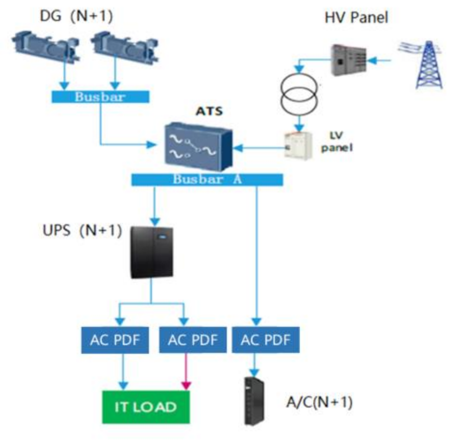


Power distribution topology of a Tier Ⅰ data center

- One mains input is used in all the solutions mentioned in the slides. The high-voltage mains input is not displayed.

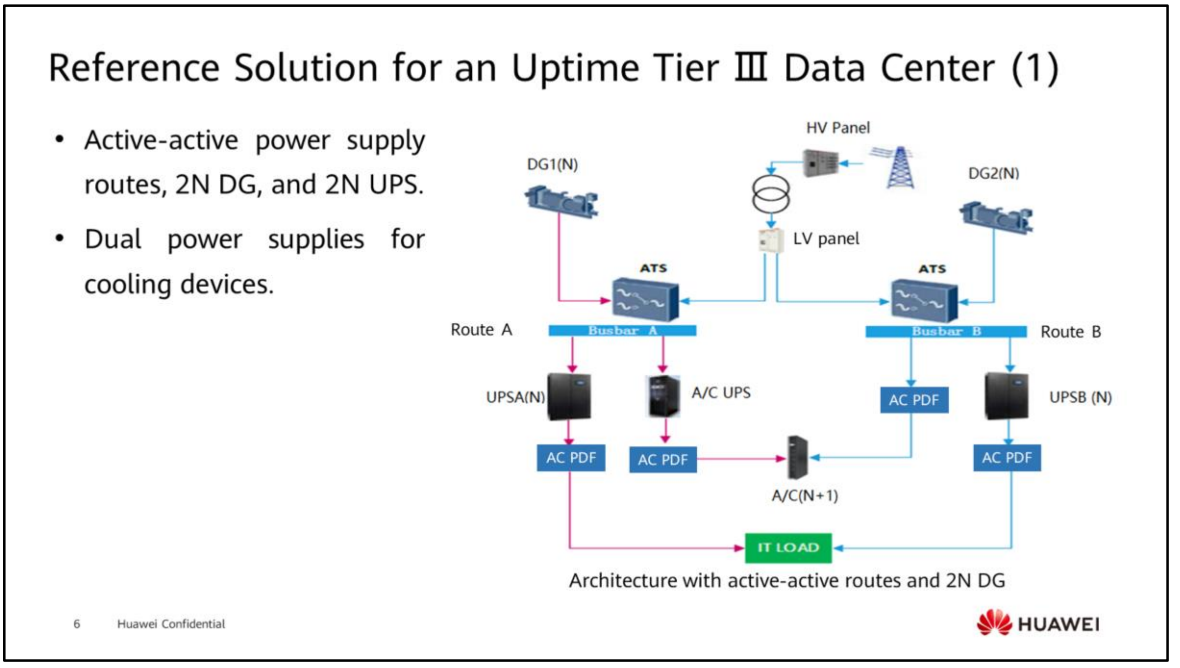
Reference Solution for an Uptime Tier Ⅱ Data Center

- Single power supply and distribution route, N+1 DG, UPS, and cooling devices.
- Faults and maintenance of key components do not affect the running of service devices.
- Faults and maintenance of the power supply and distribution route will affect the running of service devices.
- This architecture is applicable to data centers used by small- and medium-sized enterprises and aggregation sites of carriers that have no specific requirements on service continuity.



Power distribution topology of a Tier II data center

- If the customer has high reliability requirements and IT loads use dual power supplies, the power supply route from the UPS to the IT devices can adopt dual power supplies to improve system reliability. However, the topology is still at the Tier II level.

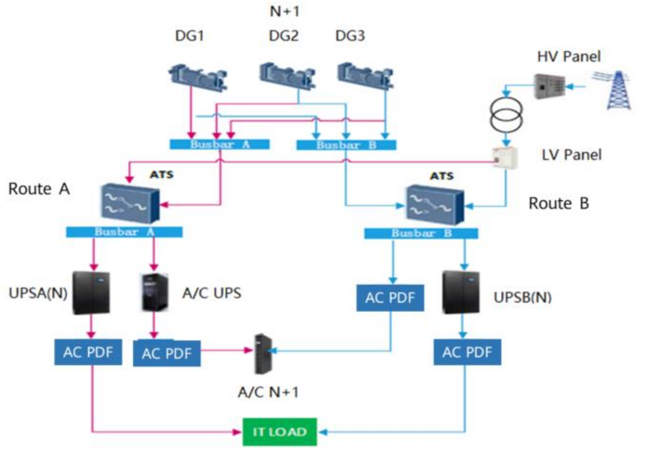


- The construction cost of Tier I/II equipment rooms is low, and the facility reliability is low. The facility of Tier IV equipment rooms is highly reliable, but the construction cost is high.
- Tier III equipment rooms have a good balance between construction costs and facility reliability and are widely deployed as important equipment rooms in various industries. The power supply architecture of a Tier III equipment room is also diversified.
- The following analyzes typical power supply topologies for Tier III data centers that are commonly used in the industry.
- Notes:
  - The Uptime standard does not require continuous cooling for Tier III equipment rooms. However, the construction certification has requirements on the temperature rise (the temperature change is less than or equal to 5° C/15 minutes) of the equipment room when the mains supply is disconnected and the DG is started. To ensure that the customer's service equipment does not break down, continuous cooling must be configured in the chilled water cooling scenario and direct expansion (DX) cooling scenario with the power density of 5 kW or higher per cabinet.

- Notes:
  - In the following recommended architectures, DX air conditioners are used in the cooling system for illustration purpose. In the chilled water scenario, continuous cooling is implemented by deploying a chilled water tank as well as chilled water pump and air conditioner indoor unit powered by the UPS.
  - One mains input is used in the example.
- This solution meets the Tier IV requirements in terms of the power supply architecture. The only difference lies in whether physical route isolation is required in the actual construction process.
- This solution is costly but highly reliable.

Reference Solution for an Uptime Tier Ⅲ Data Center (2)

- Active-active power supply routes, N+1 DG, and 2N UPS.
- Dual power supplies for cooling devices.
- Active-active parallel DG routes.

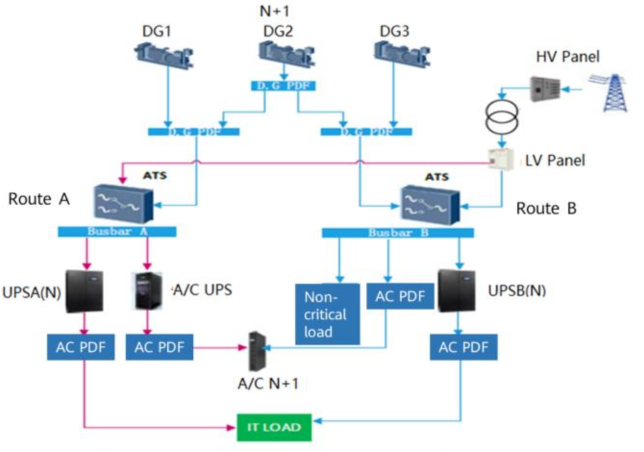


Type A architecture with active-active routes and N+1 DG

- The difference between this solution and the previous solution is that the DG is in N+1 mode, which can reduce the cost. However, the system still uses active-active routes.

Reference Solution for an Uptime Tier Ⅲ Data Center (3)

- Active-active power supply routes, N+1 DG, and 2N UPS.
- Dual power supplies for cooling devices.
- Backup DG shared by routes A and B.

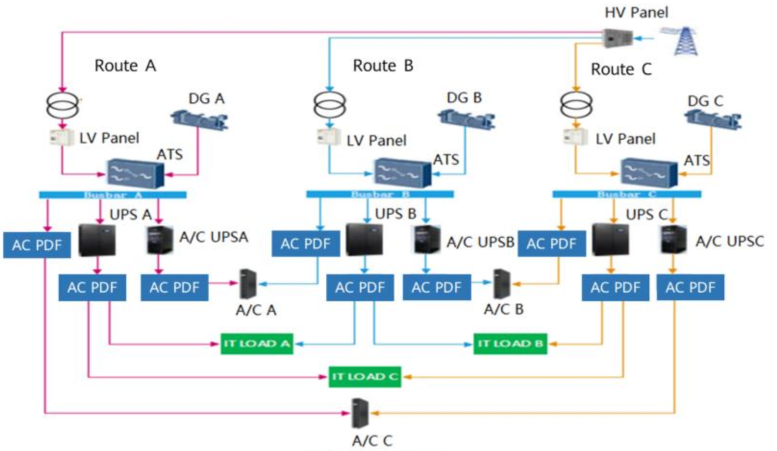


Type B architecture with active-active routes and N+1 DG

- This solution is basically the same as the previous solution. However, the internal architecture of the DG is optimized to meet the reliability requirements and reduce the cost.
- Working logic: DG 1 and DG 3 carry loads A and B respectively. DG 2 is a standby DG and does not work. If DG 1 or DG 3 is faulty, DG 2 starts. During the standby DG starts, the load is carried by the UPS.
- Compared with type A architecture (based on the topology analysis), this solution requires two fewer three-in-one DG parallel cabinets and two fewer output power distribution cabinets for each DG. If the system scale is large, hundreds of thousands of US dollars can be saved.

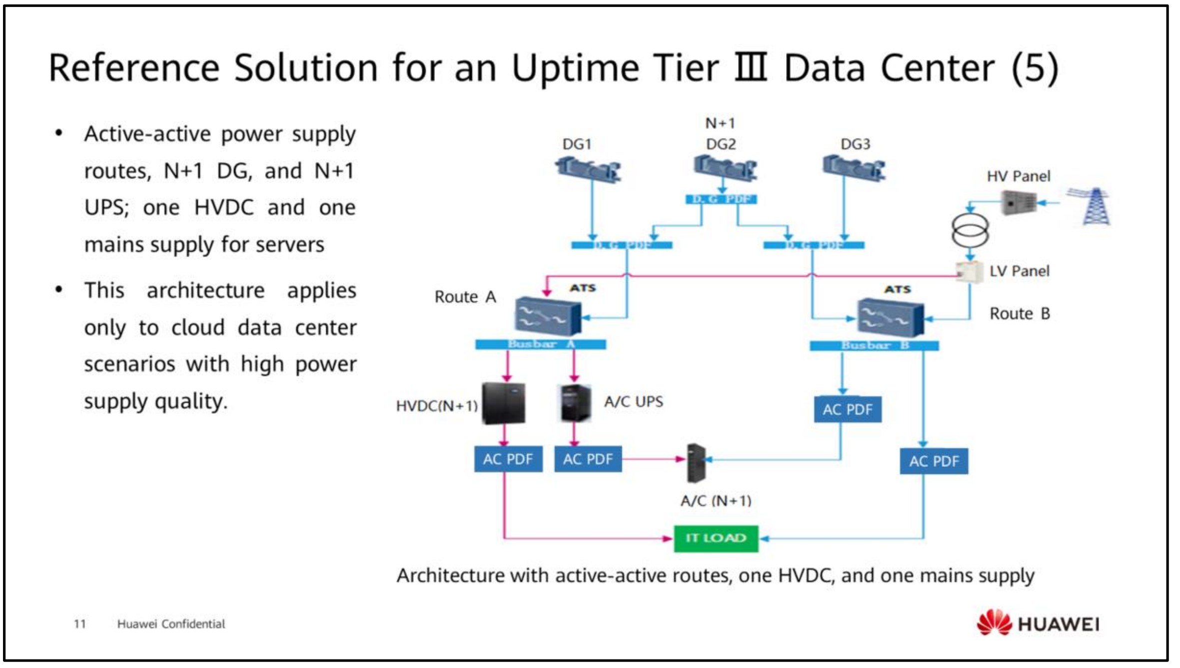
Reference Solution for an Uptime Tier Ⅲ Data Center (4)

- Multiple active power supply routes, DG and UPS route redundancy. The routes provide two power supplies for terminal devices in hand-in-hand mode.
- Complex O&M management, applicable to low-cost scenarios.



DR architecture

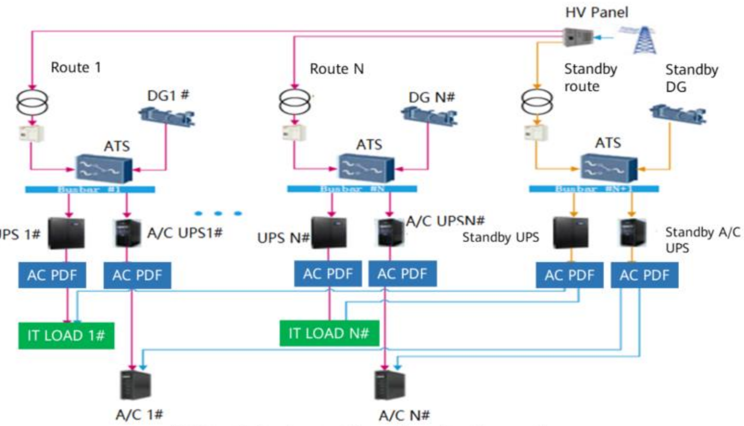
- In this solution, loads are divided into N (3 in this example) parts. The loads should be large enough to be divided into N parts. Therefore, this solution applies to large-sized data centers.
- Each part of loads adopts active-active routes, which ensures high load reliability. When one power supply route is faulty, its loads are switched to the other two routes, and the air conditioner on the faulty route uses single power supply. However, the cost of this solution is lower than that of the solutions 1 and 2 for Tier III data centers. According to preliminary calculation, the UPS redundancy is lower than 2N. The 2N solution requires N redundancy. In this solution, the total capacity of the UPS here is 1.5 N, and the redundancy is 0.5 N.
- The disadvantage is that the maintenance is complex and there are many loops. During maintenance, you need to determine which route (A, B, or C) the loads are from. In addition, when adding new servers, you need to evenly distribute the load to each route to avoid adding all loads to only one route.



- In this solution, the server needs to be customized to support one HVDC input and one mains input, and the mains quality must be good because the mains is directly supplied to the power module of the loads. If the mains quality is poor, the power module will be damaged. Mains in China, Japan, Europe, and the United States can meet the requirements, but the mains quality in Southeast Asia is poor.
- In addition, the data centers must be cloud data centers. In China, such data centers are generally used by China Mobile, China Unicom, and China Telecom as well as Baidu, Alibaba, and Tencent (BAT). The reliability of this power supply solution is relatively low and needs to be supplemented by the IT side. If some faults occur in the cloud data centers, processes and services are automatically migrated and virtualization technologies are used; therefore only some services will be affected by power failure.

Reference Solution for an Uptime Tier Ⅲ Data Center (6)

- Active-standby power supply routes, N+R DG, and N+R UPS.
- Single power supply for loads.
- Applicable only to cloud data centers.

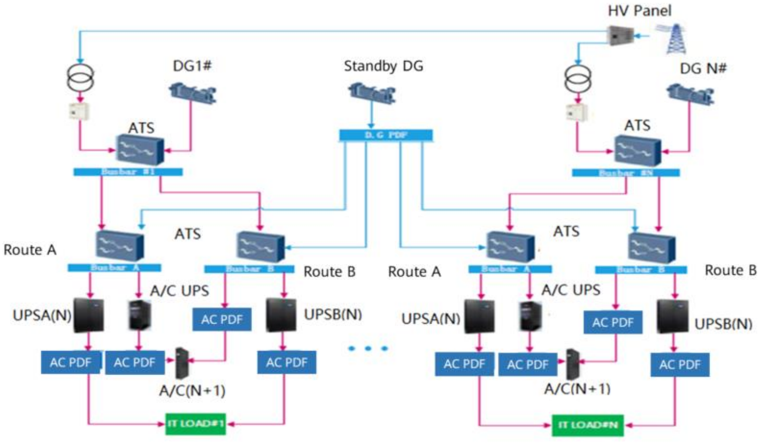


N+R architecture with active-standby routes

- The redundancy or backup mentioned in this solution is route-level backup. For example, the loads shown in the figure are divided into two parts (can be three, four, or N theoretically). Each part has an independent transformer, DG, UPS, and PDF to meet the load requirements. The route on the right is standby. The R is the standby route. You can determine the capacity of the standby route based on the actual requirements. The cost depends on whether only one load or all loads need to be backed up.
- This solution needs to be distinguished from the previous DR solution. Although the loads of the two solutions are partitioned, the entire power supply architecture is different. The power supply routes of the DR architecture are multiple active power supply routes, and the downstream loads use two power supplies, and the two power supply routes carry loads. However, in this solution, only the active route carries loads, and the other route is used as a backup and carries loads only during active route maintenance.
- This solution is also applicable to cloud data centers.

Reference Solution for an Uptime Tier Ⅲ Data Center (7)

- The loads are categorized into N identical modules. Each module is configured with independent 2N UPS, a DG, a transformer, and 2N power distribution routes.
- Each module shares the redundant DG.
- Applicable to 2 MW or higher data centers.



Architecture with pseudo active-active routes sharing the redundant DG

- In this solution, loads are evenly divided into N parts. Therefore, this solution is applicable to large-sized data centers. In 2 MW or higher data centers, loads need to be partitioned.
- Every N loads are configured with an independent DG, transformer, 2N UPS, and 2N power supply routes. For a Tier III data center, the DG must be redundant. Therefore, the DG in the middle is a backup DG shared by the entire data center. The DG is connected to route A of each load module, and route B is connected through the ATS.
- All the preceding topologies comply with the Uptime Tier III requirements. However, in actual application, there may be a slight change. For example, if the low-voltage power distribution bus has dual inputs, a bus tie switch needs to be added. However, the main architecture remains unchanged.

Comparison of Tier Ⅲ Power Supply Topologies

- Now we use an actual project model (300 cabinets, 1.7 MW) to compare the costs, reliability, and maintainability of different power distribution architectures.

Architecture	Reliability	Cost	Maintainability	Scenarios
Architecture with active-active routes and 2N DG	Highest	A	Easy maintenance	Recommended if only two DG are used in the project
Type A architecture with active-active routes and N+1 DG	5-Star	0.958A	Easy maintenance	/
Type B architecture with active-active routes and N+1 DG	5-Star	0.884A	Easy maintenance	Preferred for 2 MW or lower data centers
DR architecture	5-Star	0.790A	Complex maintenance	Preferred in scenarios with tight budgets
Architecture with active-active routes, one HVDC, and one mains supply	4-Star	0.856A	Easy maintenance	Cloud data centers with good power grid quality
N+R architecture with active-standby routes	3-Star	0.754A	Complex maintenance	Cloud data centers
Architecture with pseudo active-active routes sharing the redundant DG	4.5-Star	0.951A	Easy maintenance	Scenarios with power greater than 2 MW

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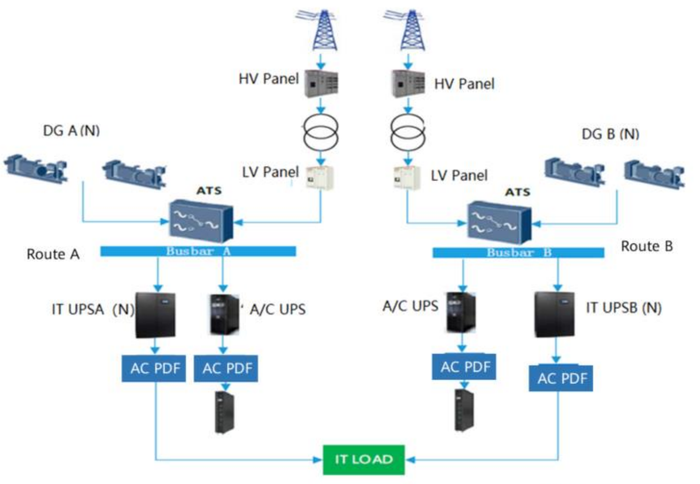
- Notes:
  - Assume that the high-voltage power distribution of each architecture, load power distribution, and the backup time of the project system are the same. The architecture cost comparison involves only the transformer, transformer output cabinet, DG, DG output cabinet and parallel cabinet, low-voltage switching cabinet, UPS, UPS input cabinet, UPS output cabinet, and mains PDF.
  - If the customer requires the single-side backup time be the same, the costs of the architecture with active-standby routes, architecture with active-active routes, architecture with one HVDC and one mains, and N+R architecture with active-standby routes can be further reduced because half of backup batteries are saved.
  - The pseudo active-active routes share the redundant DG, which is not applicable to scenarios with less than 2 MW power. Therefore, the cost is high for this project.
- Type A architecture with active-active routes and N+1 DGs requires fewer DG output cabinets and parallel cabinets. Therefore, the cost is further reduced, but the reliability remains unchanged. Only three DGs are required in this project. If the power is greater than 1.8 MW, there will be a DG price surge. Therefore, this architecture is preferred for 2 MW or lower data centers.

- DR architecture: The cost will be further reduced because the redundancy lowers, but the maintenance becomes complex. Therefore, the DR architecture is recommended only when the budget is tight.
- Active-active routes architecture with one HVDC and one mains routes: The cost is basically the same as that of the architecture of active-standby routes. The main difference is the contact switch.
- N+R architecture with active-standby routes: This architecture is least reliable because the redundancy of the backup is low. If the redundancy is high, the cost is high. In addition, the maintenance is complex, but it is simpler than the DR architecture. This architecture is recommended in cloud data centers.

Reference Solution for an Uptime Tier IV Data Center

- Active-active routes, 2N DG/UPS/cooling devices
- All devices and power distribution routes in the active-active routes are physically isolated (excluding service devices).
- A fault of any component on one route does not affect the normal running of the other route or service devices.



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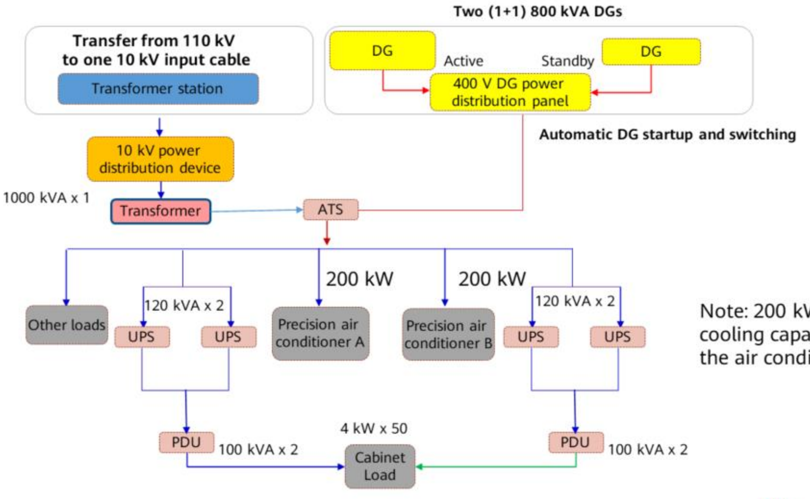
- The power supply architecture for a Tier IV data center uses active-active power supply routes, 2N redundancy of DG, UPS, and cooling devices, as well as continuous cooling of the cooling system (DX scenario: The air conditioners are configured with the UPS; water-cooled scenario: The chilled water tanks, chilled water pumps, and air conditioner indoor units are configured with the UPS). All devices and power distribution routes in the active-active routes are physically isolated (excluding service devices). A fault of any component on one route does not affect the normal running of the other route or service devices. This architecture is applicable to scenarios that have high requirements on service continuity, such as central data centers of banks and core equipment rooms of carriers.

Contents

Case 1 (1)

Power distribution solution for PL data center



Note: 200 kW is the cooling capacity of the air conditioners.

Case 1 (2)

- Discussion:
  - Which tier of requirements does the power supply solution meet?
    - Consider the following aspects:
      - DG configuration
      - Transformer configuration
      - UPS configuration
      - Power supply route for loads

  - How to improve the reliability of the power distribution solution by one tier?
    - No new main devices such as the UPS, transformer, and DG should be added, but the ATS and low-voltage power distribution frame (PDF) can be added.

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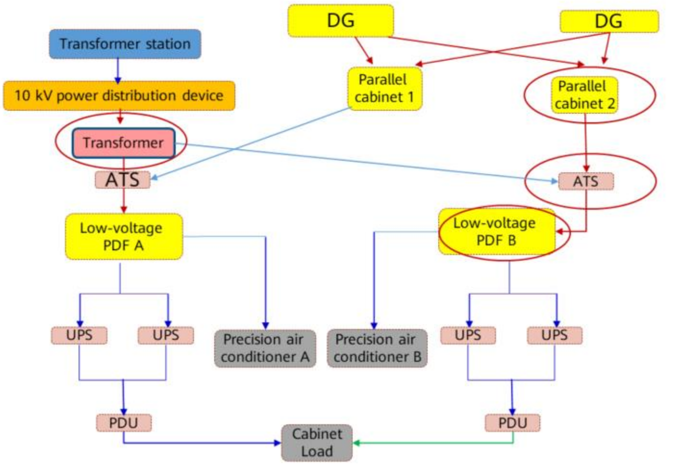
Case 1 (3)

- Which tier of requirements does the power supply solution meet: Tier Ⅱ
  - DG configuration: 1+1
  - Transformer configuration: N
  - UPS configuration: 2N
  - Power supply route for loads: pseudo dual power supplies
  - In conclusion, core components, such as the DG and UPS, meet the N+1 or higher requirements. The power supply route is pseudo dual power supplies. Although the transformer is configured in N mode, the Uptime standard does not have requirements on the mains.

Case 1 (4)

- Solution 1 example: Add the following configuration:
  - An ATS
  - A low-voltage PDF
  - A DG parallel cabinet
  - A transformer one-to-two PDF



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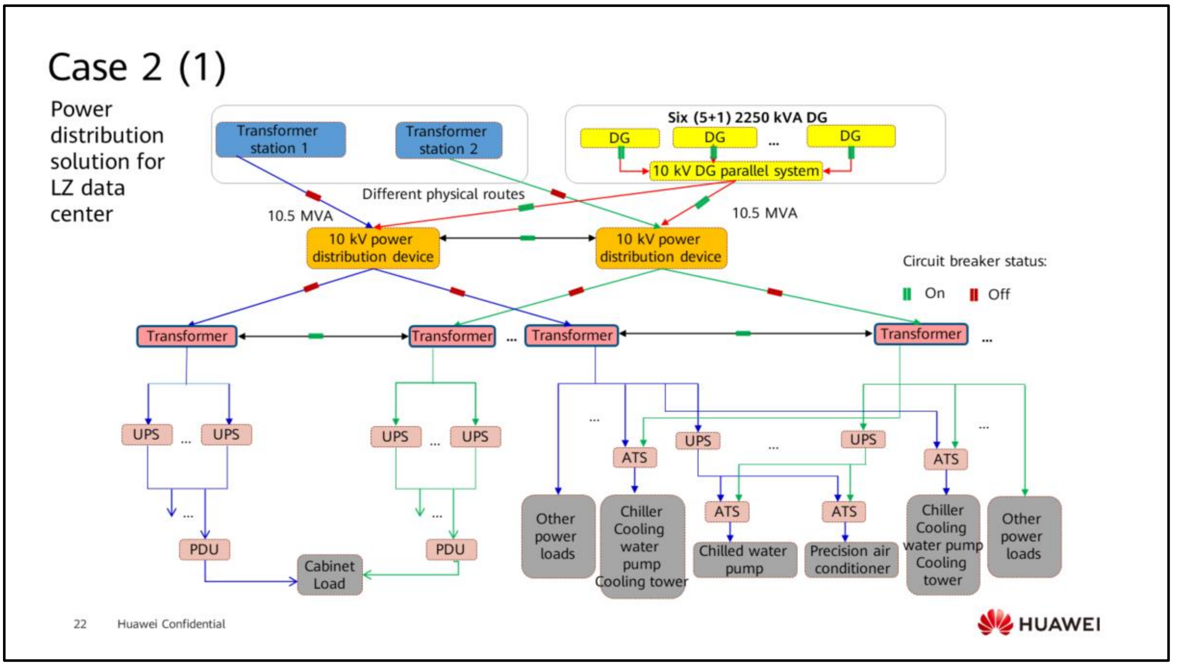


- High-voltage side:
  - The two 10 kV mains inputs use different physical routes, and the high-voltage power supplies are connected through bus tie switches, which further improves system reliability. The 10 kV high-voltage DG system is used. Note that the high-voltage DG is connected to the mains bus through a circuit breaker, and the low-voltage DG is connected to the mains bus through an ATS. The DG is configured in N+1 mode, but there is only one route. This is a risk point.
- Low-voltage side:
  - Power loads and IT loads are configured with independent transformers. Low-voltage bus tie switches are configured between routes A and B to improve system reliability.
  - IT loads are powered by UPS in dual-loop mode.
  - In terms of cooling, continuous cooling is also considered. The chilled water pump and air conditioners are configured with UPS. For the devices that use single power supply, the ATS is used to switch the route. The chiller, cooling water pump, and cooling tower use dual power supplies controlled by a terminal ATS.
  - Other power loads are powered by a single mains supply.

Case 2 (2)

- Discussion:
  - Which tier of requirements does the power supply solution meet?
    - Consider the following aspects:
      - DG configuration
      - Transformer configuration
      - UPS configuration
      - Power supply route for loads
  - What are the advantages and disadvantages of this solution?
  - How to add configurations to improve system reliability?

Case 2 (3)

- The power supply solution complies with the requirements for Uptime Tier Ⅱ data centers.
  - DG configuration: N+1 (5+1), there is only one DG route.
  - Transformer configuration: 2N
  - UPS configuration: 2N
  - Power supply route for loads: dual power supplies
    - In conclusion, except for the DG route, other routes meet online maintenance requirements. However, the data center tier is determined by the weakest route.

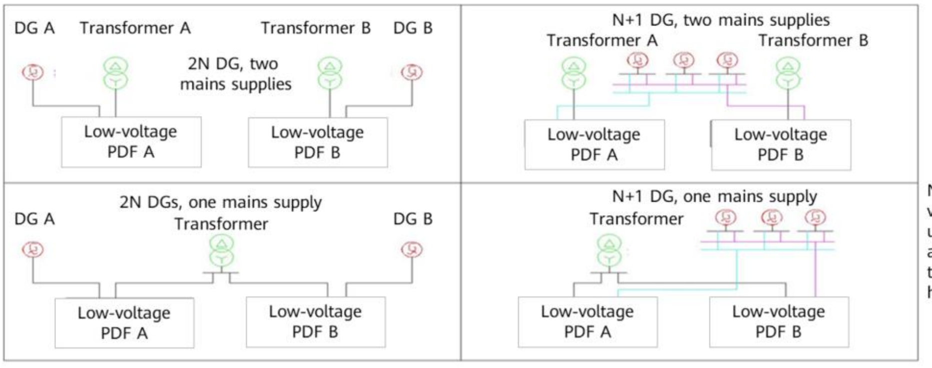
- After a parallel cabinet is added to the DG system, the architecture is similar to the Type A architecture with active-active routes and N+1 DG. This architecture is widely used in large-sized data centers.

Case 2 (4)

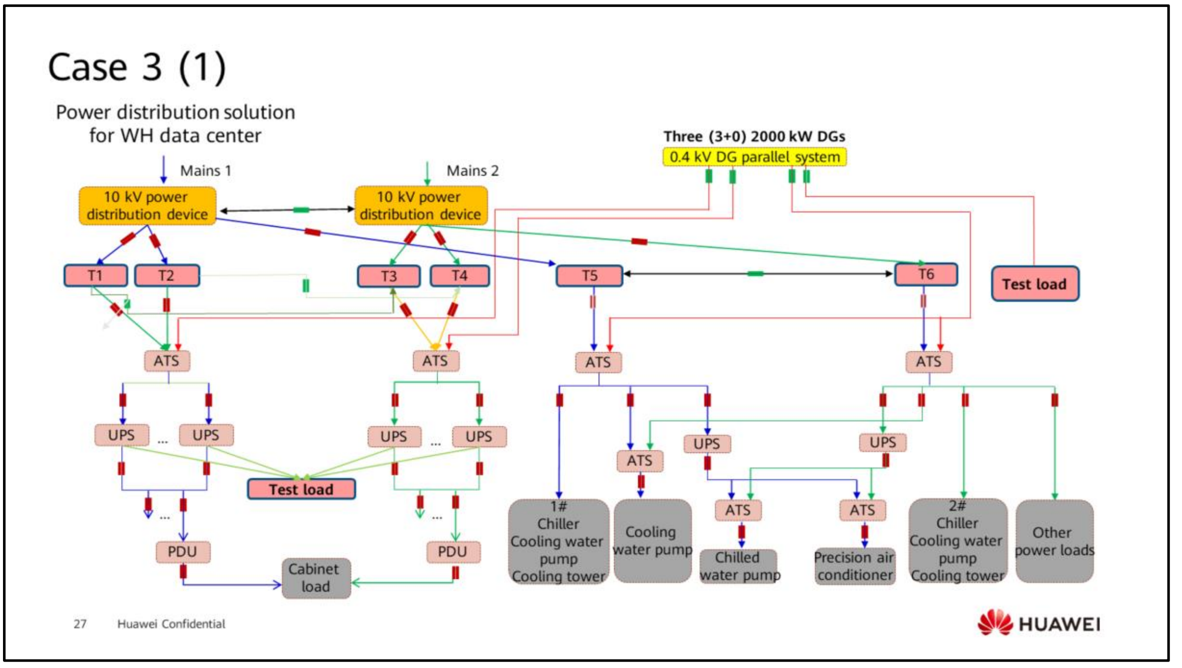
- Advantages:
  - Dual mains supplies in active-active mode are used. Bus tie switches are configured on the high- and low-voltage sides to improve the reliability of the mains.
  - The DG is configured in N+1 mode. When both mains inputs are faulty, the DG start, improving system reliability.
  - On the load side, the IT devices are powered by two routes, and the UPS is configured in 2N mode. The loads such as chillers and cooling towers are powered by two routes, which are controlled by a terminal ATS. IT loads and power loads are isolated to avoid mutual impact.
  - Chilled water pumps and air conditioners are also powered by two routes controlled by a terminal ATS. But one route is from an independent UPS to achieve continuous cooling.
- Disadvantage:
  - There is only one route on the DG side.

Case 2 (5)

- Add a DG parallel cabinet to form a dual-route system, improving the system reliability.
- Common DG configurations for Tier Ⅲ data centers



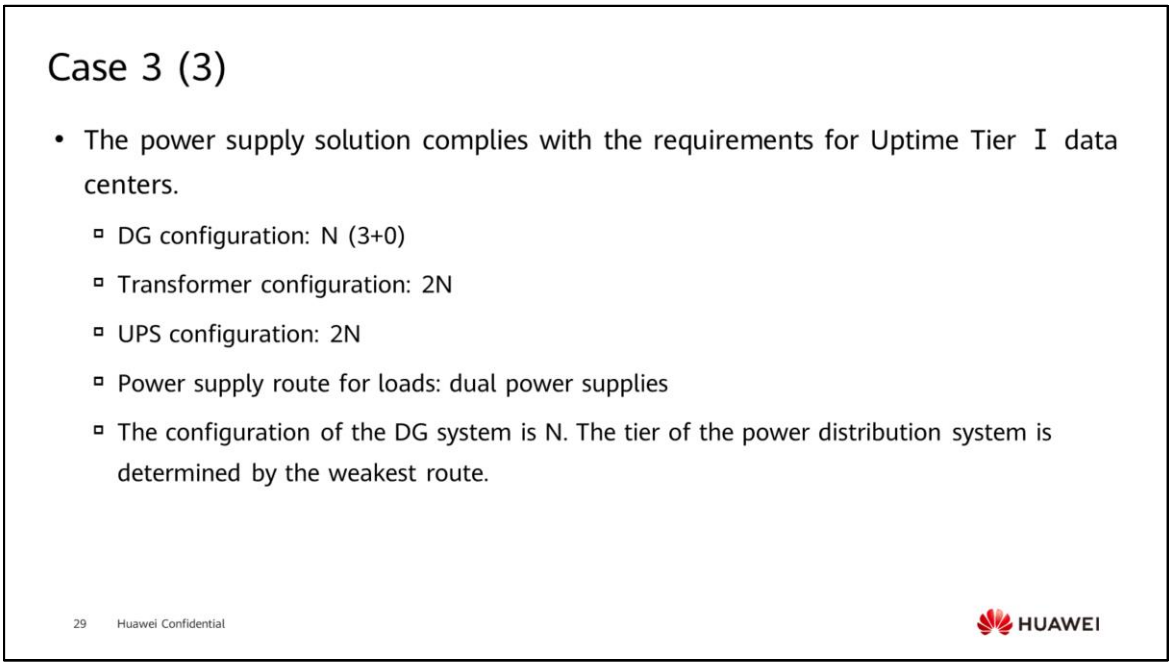
Note: Low-voltage DG are used here. The architectures are the same for high-voltage DG.



- Dual mains inputs. The low-voltage DG and mains are switched over by the ATS on the low-voltage side.
- Terminal load:
  - IT loads are powered by two power routes. Cooling loads are powered by two routes controlled by a terminal ATS. Continuous cooling is configured. Chilled water pumps and precision air conditioners are powered by two routes controlled by a terminal ATS. One route is from an independent UPS.

Case 3 (2)

- Discussion:
  - Which tier of requirements does the power supply solution meet?
    - Consider the following aspects:
      - DG configuration
      - Transformer configuration
      - UPS configuration
      - Power supply route for loads
  - What are the advantages and disadvantages of this power supply solution?
  - How to improve the system reliability?



- Although this solution complies with the requirements for Uptime Tier I data centers, it complies with class B requirements according to the Chinese GB standard. Because the mains quality in China is good, so the importance of DGs is weakened. Uptime is a global standard. The mains supply is poor in Southeast Asia, Africa, and Middle East. Therefore, the importance of DGs is highlighted.

Case 3 (4)

- Advantages:
  - Dual mains supplies in active-active mode are used. Bus tie switches are configured on the high- and low-voltage sides to improve the reliability of the mains.
  - The DG is configured in N mode. When both mains inputs are faulty, the DG start, improving system reliability.
  - On the load side, the IT devices are powered by two routes, and the UPS is configured in 2N mode. The loads such as chillers and cooling towers are powered by two routes, which are controlled by a terminal ATS. IT loads and power loads are isolated to avoid mutual impact.
  - Chilled water pumps and air conditioners are also powered by two routes controlled by a terminal ATS. But one route is from an independent UPS to achieve continuous cooling.
- Disadvantages:
  - N configuration on the DG side severely reduces system reliability.
  - Using a low-voltage DG causes complex power supply routes, excessive ATS applications, and complex control.

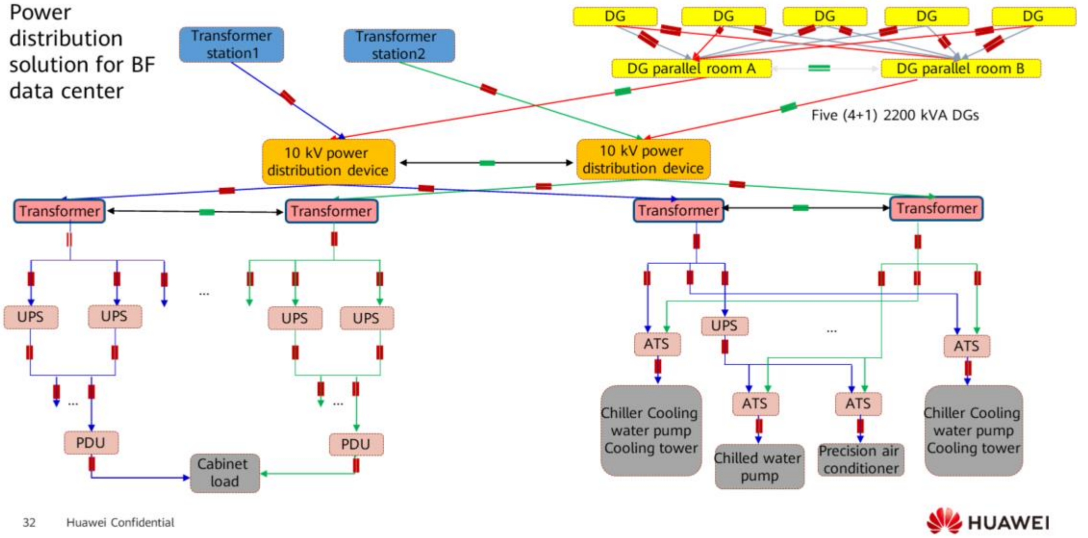
Case 3 (5)

- How to improve the system reliability?
  - Use high-voltage DG. In this way, the number of ATS is greatly reduced, and the control logic is simplified.
  - Change the configuration on the DG side to N+1 and add DG routes if necessary to improve system reliability.

- Pay attention to the differences between the high-voltage DG and low-voltage DG in actual applications.

Case 4 (1)

Power distribution solution for BF data center



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Case 4 (2)

- Discussion:
  - Which tier of requirements does the power supply solution meet?
    - Consider the following aspects:
      - DG configuration
      - Transformer configuration
      - UPS configuration
      - Power supply route for loads
  - What are the advantages of this power supply solution?

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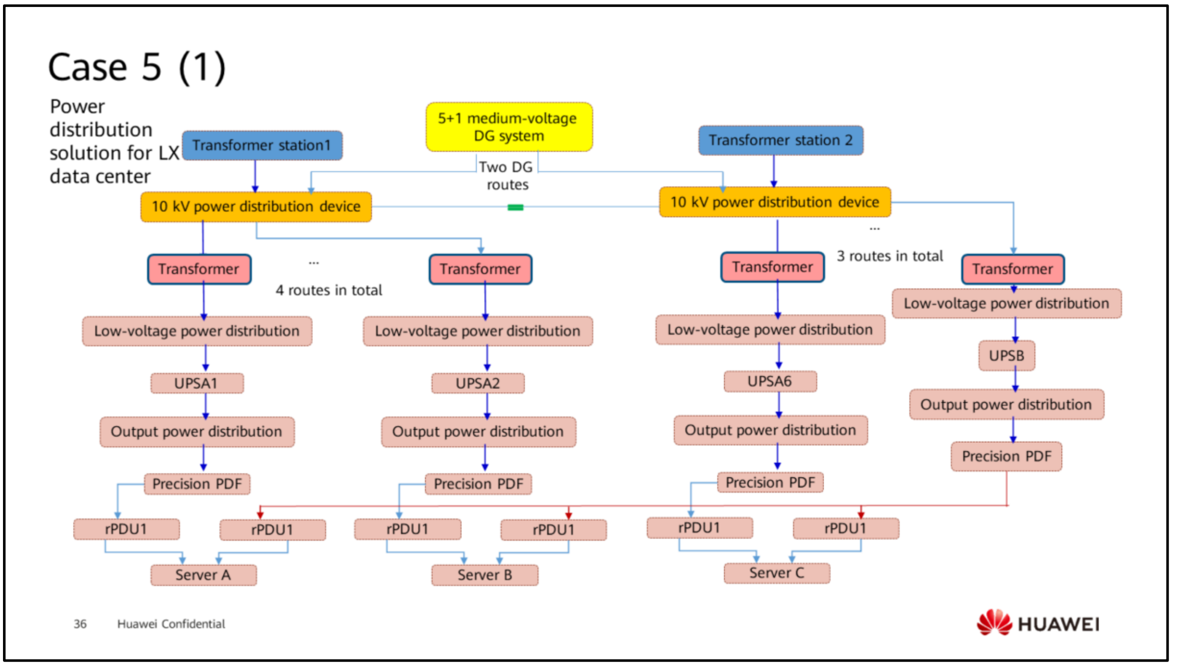
Case 4 (3)

- The power supply solution complies with the requirements for Uptime Tier Ⅲ data centers.
  - DG configuration: N+1 (4+1)
  - Transformer configuration: 2N
  - UPS configuration: 2N
  - Power supply route for loads: dual power supplies

Case 4 (4)

- Advantages:
  - Dual mains supplies in active-active mode are used. Bus tie switches are configured on the high- and low-voltage sides to improve the reliability of the mains.
  - The DG is configured in N+1 mode. When both mains inputs are faulty, the DG start, improving system reliability.
  - On the load side, the IT devices are powered by two routes, and the UPS is configured in 2N mode. The loads such as chillers and cooling towers are powered by two routes, which are controlled by a terminal ATS. IT loads and power loads are isolated to avoid mutual impact.
  - Chilled water pumps and air conditioners are also powered by two routes controlled by a terminal ATS. But one route is from an independent UPS to achieve continuous cooling.



- The system works in N+R route-level backup mode. A1 to A6 are active routes, and B is a standby route.
- The capacity of Route B can be 1 to N according to the budget or requirement.

Case 5 (2)

- Discussion:
  - Which tier of requirements does the power supply solution meet?
    - Consider the following aspects:
      - DG configuration
      - Transformer configuration
      - UPS configuration
      - Power supply route for loads
  - What are the advantages of this power supply solution?

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Case 5 (3)

- The power supply solution complies with the requirements for Uptime Tier Ⅲ data centers.
  - DG configuration: N+1
  - Transformer configuration: N+R
  - UPS configuration: N+R
  - Power supply route for loads: active-standby routes
- Advantages:
  - IT loads are powered by two routes (one active and one standby) and can be maintained online as planned.
  - Compared with the traditional UPS 2N configuration, this configuration reduces costs.

- Disadvantages: Although IT loads use dual power supplies, the power supplies are not active-active. The reliability is lower than that of the traditional UPS 2N configuration. The cost is reduced, but the reliability is also reduced.

Summary

- Typical Solutions
- Solution Application Analysis

Quiz

1. （T or F）The power supply architecture of a data center is as follows: dual mains supplies, 2N transformers, 2N UPS, and N+1 diesel generators. The diesel generators share one combiner cabinet, and the loads are cofigured with dual-paths power supply. The power supply solution of the data center meets the requirements of an Uptime Tier Ⅲ data center.

- 1. F

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Data Center Power Distribution Solution Optimization

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Foreword

- The slides describe how to optimize a data center power distribution solution. We have learned that a data center power distribution solution should be reliable and simple. In this training, we will optimize the data center power distribution solution from these two perspectives.

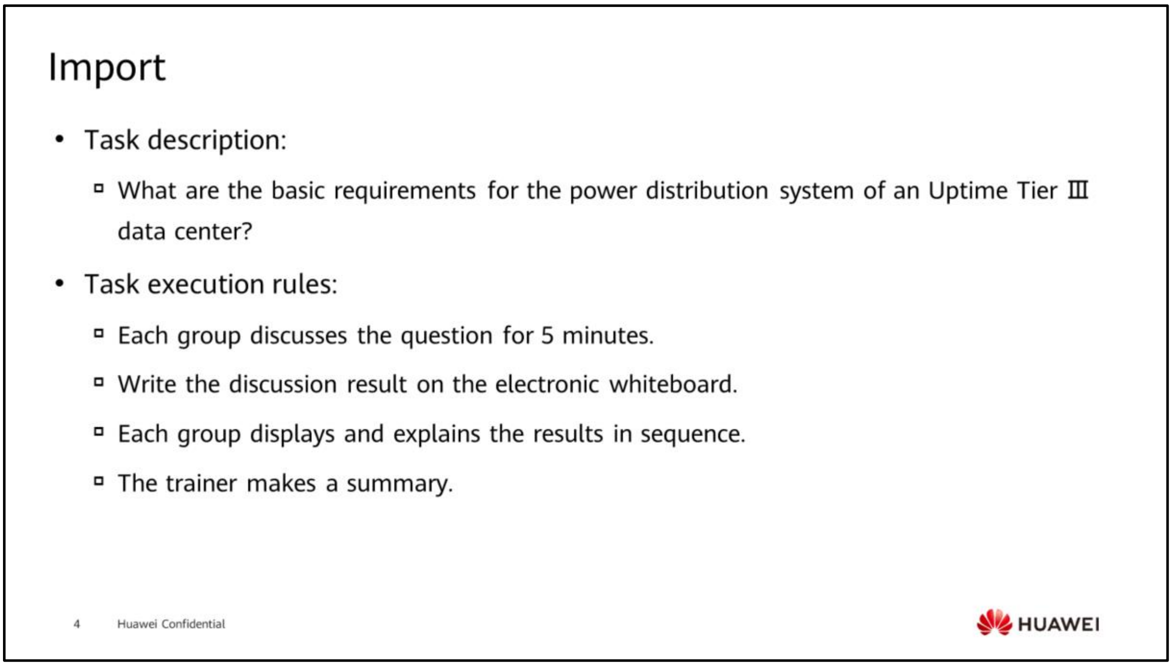
Objectives

On completion of this course, you will be able to:

- Get familiar with the operation modes of different power distribution solutions for data centers.
- Analyze the advantages and disadvantages of different power distribution solutions for data centers.
- Identify and optimize the weaknesses of different power distribution solutions for data centers.

Trainee Grouping

- Steps for trainee grouping
  - Before the training, the trainer prepares the same number of poker cards as the number of trainees. Every three cards have the same number.
  - Trainees draw lots before the training and those who draw the cards with the same number form a group.
  - If the number of trainees is excessive, the trainer specifies the group to which the excessive trainees belong.
  - Each group assigns its group name.



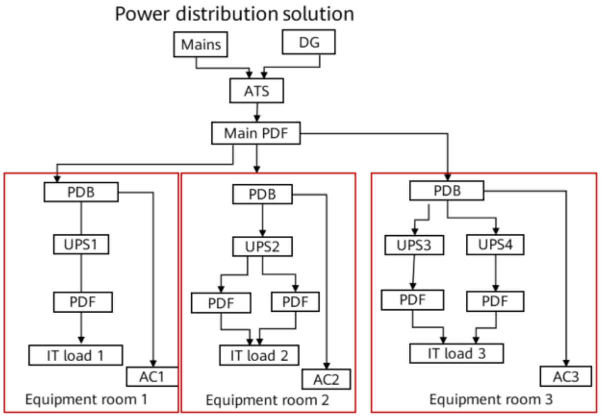
- The UPS system in the figure is not redundant.

Answer

- Data centers that can be concurrently maintained have redundant capacity components and multiple independent power distribution routes to serve critical systems. At any time, only one distribution route is required to serve the critical environment.
- All IT devices use dual power supplies and are properly installed to be compatible with the data center architecture topology. If the critical environment does not meet this specification, a transmission device such as a switch must be used.
- Onsite fuel reserve should support 12-hour operation of N diesel generators (DGs).

Case 1

- Carrier XX needs to reconstruct its data center to meet the Uptime Tier Ⅲ requirements.
- Engineer C is the power distribution solution designer of the general contractor. The figure on the right shows the original power distribution solution.
- In the solution:
  - There is one mains input and N DGs.
  - UPS 1 is configured in N mode, and IT load 1 uses single power supply.
  - UPS 2 is configured in N+1 mode, and IT load 2 uses dual power supplies.
  - UPS 3 and UPS 4 have the same capacity and each can support IT load 3. IT load 3 uses dual power supplies.
  - The air conditioners in all rooms are direct expansion air-cooled air conditioners with dual power inputs. The configuration is N+1.



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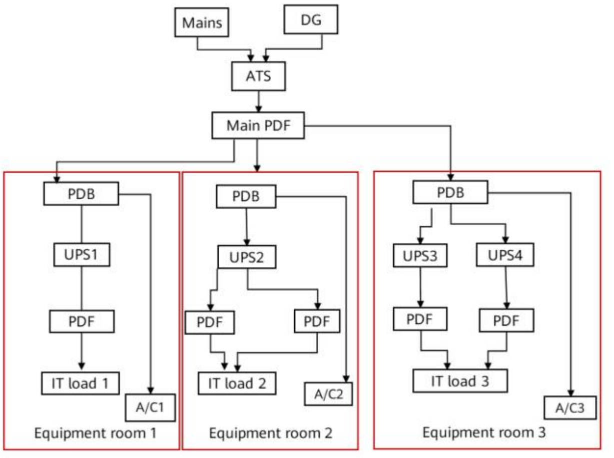
Task 1

- Task description
  - The original power distribution solution can meet the requirements of Uptime Tier ___ data centers. Specify reasons.
- Task execution rules
  - Each group discusses the question for 10 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.

Power distribution solution



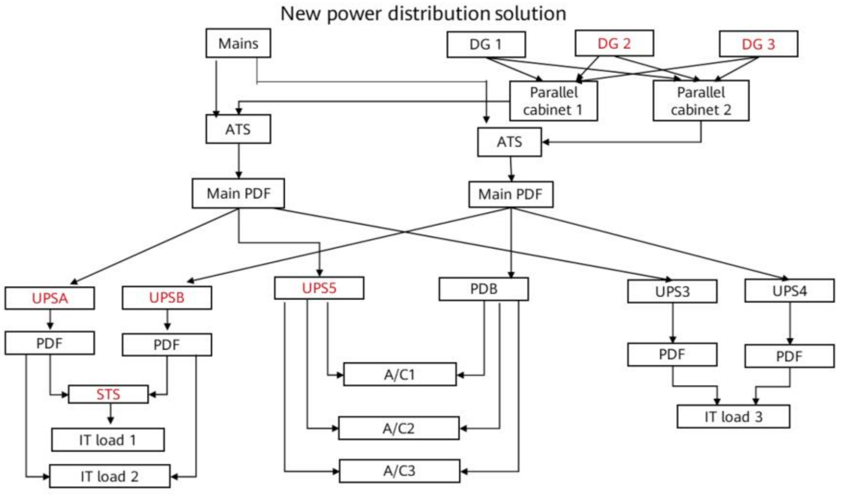
Answer to Task 1

- The original power distribution solution meets the requirements of Uptime Tier I data centers.
- Reason:
  - The DG is configured in N mode.
  - UPS 1 is configured in N mode, and IT load 1 is powered by a single route, which may cause a single point of failure.
  - The data center tier is determined by the weakest route. Therefore, this solution can only meet the requirements of Uptime Tier I.

Task 2

- Task description
  - After discussing with the customer, engineer C determines a new solution.
    - Considering the increase of services, one DG is reused and two new DGs are added to form 2+1 configuration. The mains supply is still one route.
    - The UPS system is configured in 2N mode. UPS 3 and UPS 4 are reused to supply power to loads in equipment room 3. UPS 1 and UPS 2 are replaced with new ones.
    - All air conditioners are reused, but continuous cooling is required. Add a set of UPS 5 to supply power to the air conditioners.
  - Based on the preceding information, change the original power distribution solution to a solution that meets the requirements of Uptime Tier Ⅲ.
- Task execution rules
  - Each group discusses the question for 15 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.

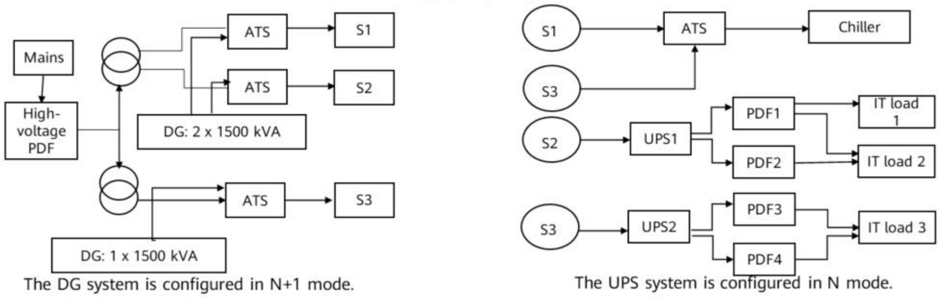
Answer to Task 2



Background of Case 2

- The XX data center needs to be reconstructed so that it can pass the Uptime Tier Ⅲ certification.
- Engineer Z from the general contractor is responsible for designing the power distribution system solution. Engineer Z provides the power supply topology as shown in the following figures.
  - Note: IT load 1 has a single power supply, and IT loads 2 and 3 have dual power supplies.

Power supply topology



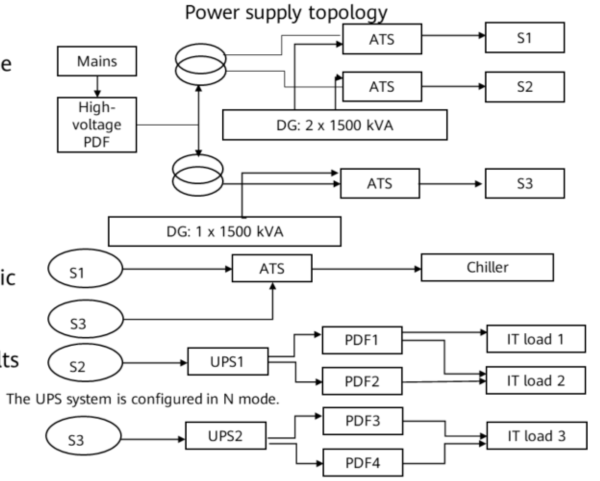
The DG system is configured in N+1 mode. The UPS system is configured in N mode.

- Note:
- This solution does not cover the mains input. The scope is from the transformer to the load. The upstream of the transformer is not displayed here.

Task 1

- Task description
  - Does the original solution meet the Uptime Tier Ⅲ requirements? Specify the reasons.
- Task execution rules
  - Each group discusses the question for 15 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.

Power supply topology



Answer to Task 1

- The original solution does not meet the Uptime Tier Ⅲ requirements.
- Reason
  - The power supply route does not meet concurrent maintenance requirements.
    - IT load 1 has a single power supply, and a single point of failure exists.
    - Although IT load 2 and IT load 3 have two power supplies, there is only one route from the UPS to the low-voltage PDF, and a single point of failure also exists.
  - Key capacity devices do not meet redundancy requirements.
    - The DG system is configured in N+1 mode, and the UPS does not have sufficient redundancy.

- The original power distribution solution can only meet the Uptime Tier I requirements.

Task 2

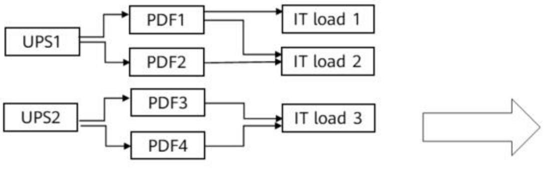
- Task description
  - Reconstruct the power distribution solution and make it meet the Uptime Tier Ⅲ requirements.
    - Step 1: Determine the power distribution reconstruction solution from the UPS to IT loads. The UPS system should be a dual-bus system. The PDFs are reused, and the number of circuit breakers is sufficient.
    - Step 2: Determine the power distribution reconstruction solution from the mains to the UPS. The DG system is reused and configured in 2+1 mode, the one mains input remains unchanged, and the transformer is reused.
- Task execution rules
  - Each group discusses the question for 20 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.

- Note: There is no standard answer for this solution. The answer is right as long as the configuration is reasonable and meets the Tier III requirements. The cost is not considered.

Answer to Task 2 (1)

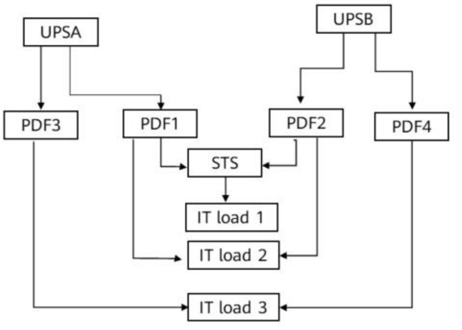
- Power distribution solution from the UPS to IT loads: 2N UPS configuration

Original power distribution solution



The UPS system is configured in N mode.

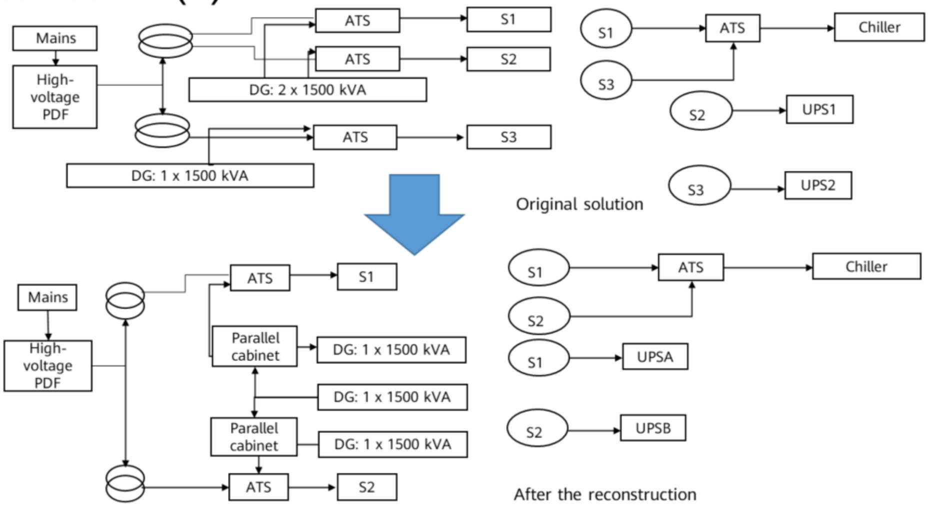
After the reconstruction



The UPS system is configured in 2N mode.

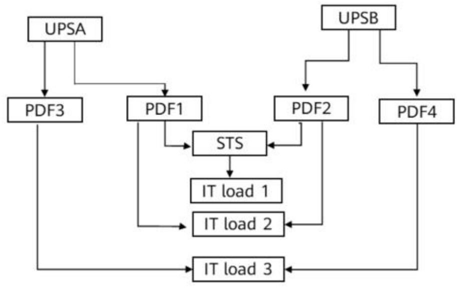
Answer to Task 2 (2)

Power distribution solution from the upstream mains to the UPS



Task 3

- Task description
  - Determine an appropriate UPS and battery configuration solution based on the power distribution solution and load capacity in the previous task.
    - Note:
      - The capacity of IT loads 1, 2, and 3 is 250 kW, 500 kW, and 450 kW.
      - The capacity of a single UPS can be 100 kVA, 200 kVA, 300 kVA, 400 kVA, 500 kVA, or 600 kVA. The output power factor is 1, the IT load power factor is 0.9, and the battery backup time is 15 minutes.
      - The battery capacity does not need to be calculated.



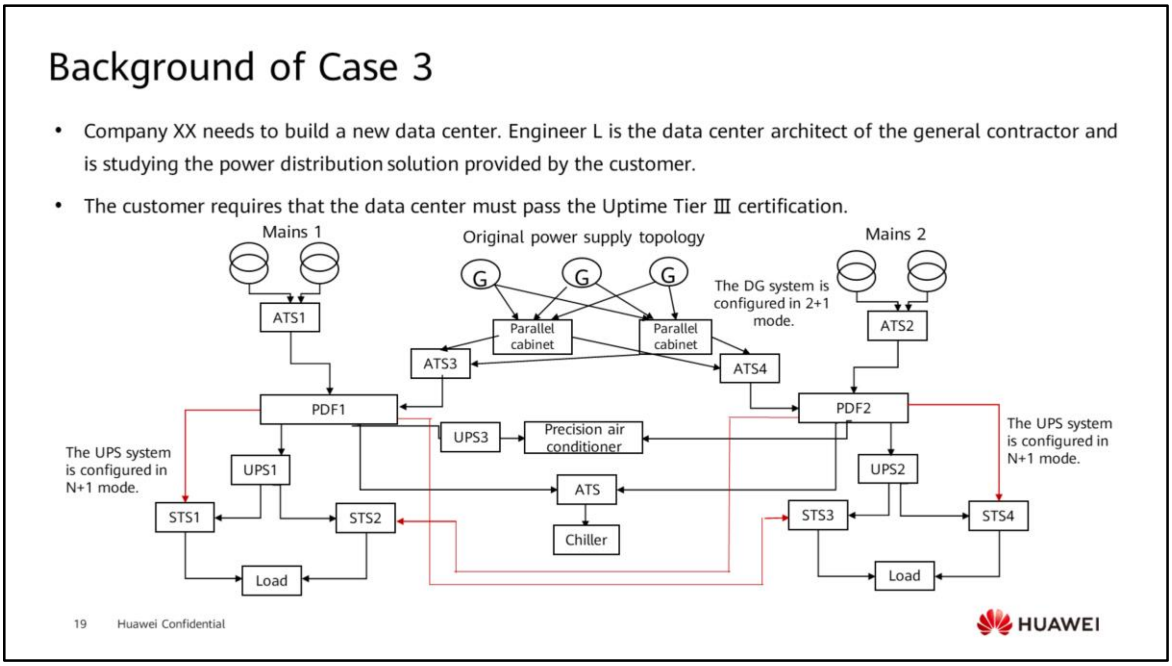
- Task execution rules
  - Each group discusses the question for 15 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays the results and
  - explains the calculation process in sequence.
  - The trainer makes a summary.

- Note: There is no standard answer for this task. The answer is right as long as the configuration is reasonable and meets the Tier III requirements. The cost is not considered.

Answer to Task 3

- UPS configuration
  - UPS capacity = (250 + 500 + 450)/0.9 x 1.2 = 1600 kVA.
  - Two sets of 3 x 600 kVA or two sets of 4 x 500 kVA UPSs can be selected.
  - Two sets of 3 x 600 kVA UPSs can be selected to reduce costs.
- Battery configuration
  - Each UPS is connected to separate batteries. The backup power of each UPS is calculated as follows: (250 + 500 + 450)/3 = 400 kW. The backup time is 15 minutes with constant power.
  - If either route A or route B is faulty, the backup time can still meet the requirements.

- It is recommended that a maximum of four UPSs be connected in parallel.



- This solution does not cover the mains input. The scope is from the transformer to the load. The upstream of the transformer is not displayed here.
- Mains 1 and 2 come from different transformer stations.

Task 1

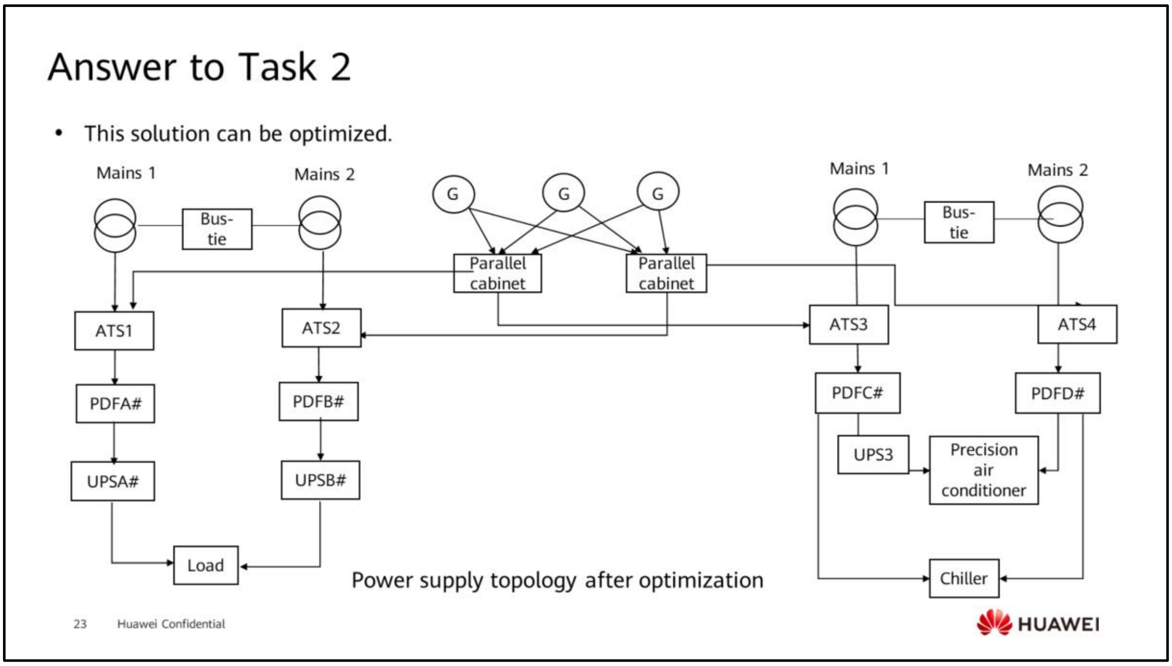
- Task description
  - Discuss whether the power supply topology meets the Uptime Tier Ⅲ requirements and describe the basis.
- Task execution rules
  - Each group discusses the question for 15 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.

Answer to Task 1

- The power supply topology complies with the Uptime Tier Ⅲ requirements.
- Reason:
  - The DG is configured in N+1 mode, and N is 2.
  - Power load: The precision air conditioner supports continuous cooling. One route is from the UPS, and the other route is from the mains. Chillers use dual power supplies controlled by an ATS at the end.
  - IT load: Two power supplies are provided. The UPS is configured in N+1 mode. The two inputs of the IT loads are from two STSs respectively. One of the two STS inputs is from the UPS, and the other is from the mains. The mains are from different transformers, improving reliability.
  - In conclusion, the key capacity facilities are configured in N+1 mode. In addition, the dual power supply routes are used, which supports concurrent maintenance and meets the requirements of Uptime Tier Ⅲ data centers.

Task 2

- Task description
  - Discuss whether the solution can be optimized without affecting the data center tier (Uptime Tier Ⅲ). If yes, draw the optimized power distribution diagram and explain the reasons.
  - Requirements: The DG system is still configured in 2+1 mode, and the UPS is in 2N mode.
- Task execution rules
  - Each group discusses the question for 30 minutes.
  - Write the discussion result on the electronic whiteboard.
  - Each group displays and explains the results in sequence.
  - The trainer makes a summary.



- Note:
- There is no standard answer. The answer is right as long as it is reasonable.
- There are two mains inputs. The transformers and UPSs are configured in 2N mode. A bus tie switch is added between transformers to improve reliability.
- IT loads and power loads are configured separately to minimize mutual impact.

Answer to Task 2

- Disadvantages of the original solution:
  - Excessive redundancy and use of the ATS and STS greatly increase the cost and complicate the operation and maintenance.
  - There are multiple mains and transformers, but the IT loads and power loads are not separated.
- Optimization
  - Separate IT loads and power loads, and ATS1 and ATS2 at the downstream of the transformers do not need to be configured.
  - All loads use dual power inputs. All STSs can be omitted by optimizing the UPS solution.

Summary of Task 2

- Although this architecture fully meets the requirements of Uptime Tier Ⅲ, it is too complex and difficult to maintain. In addition, too much redundancy is used, resulting in high costs.
- Uptime Tier Ⅲ requirements are not rigid, but flexible.
- The core requirement of Uptime Tier Ⅲ is as follows:
  - "All power distribution devices are concurrently maintainable without affecting the normal running of the data center." This requirement is result-oriented and does not require a specific power distribution architecture. The core requirement can be met as long as concurrent maintenance is realized.

Summary

- In this chapter, we have learned how to analyze the power distribution solution of data centers on the live network, including new data centers and reconstructed data centers, from two aspects: reliability and simplicity.
- First, ensure that the solution is reliable. On the premise that the reliability requirements are met, make the solution as simple as possible. If the solution is too complex, the O&M work will be complex, and the system reliability will be affected in another way.

Thank you.

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每个组织，构建万物互联的智能世界。

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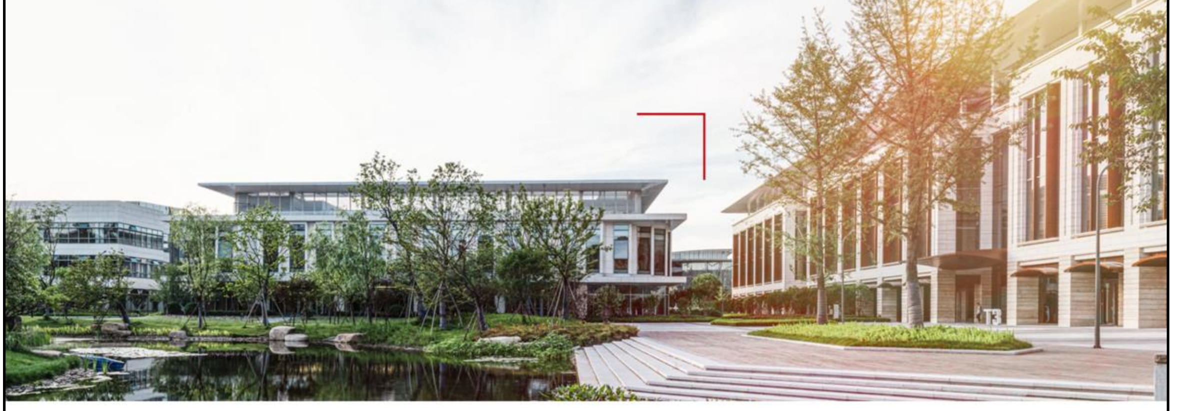
Data Center Cooling System Planning



Foreword

- A data center construction project can be large or small, new or refurbished, and complete or partial.
- The project may involve changes in the physical area of the equipment room, equipment layout, or electrical capacity, power density increase, and redesign of the power or cooling architecture. Regardless of the scale or nature of the project, the success of a project depends not only on the procurement and installation of physical system equipment, but also on the entire planning and design process from project concept to commissioning.
- This course describes the process and implementation of the cooling system project planning, including the planning process, precautions, and requirements.

Objectives

On completion of this course, you will be able to:

- Master the cooling system planning process of a data center.
- Master the requirement planning of a data center cooling system.
- Master the cooling system planning of a data center.

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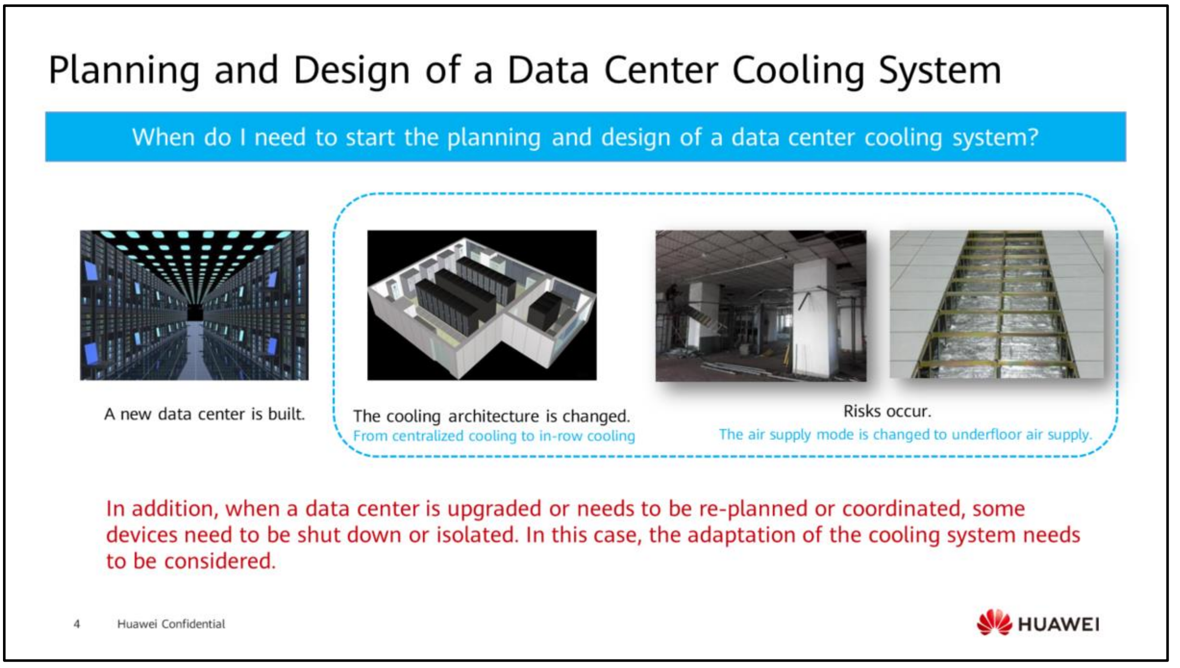
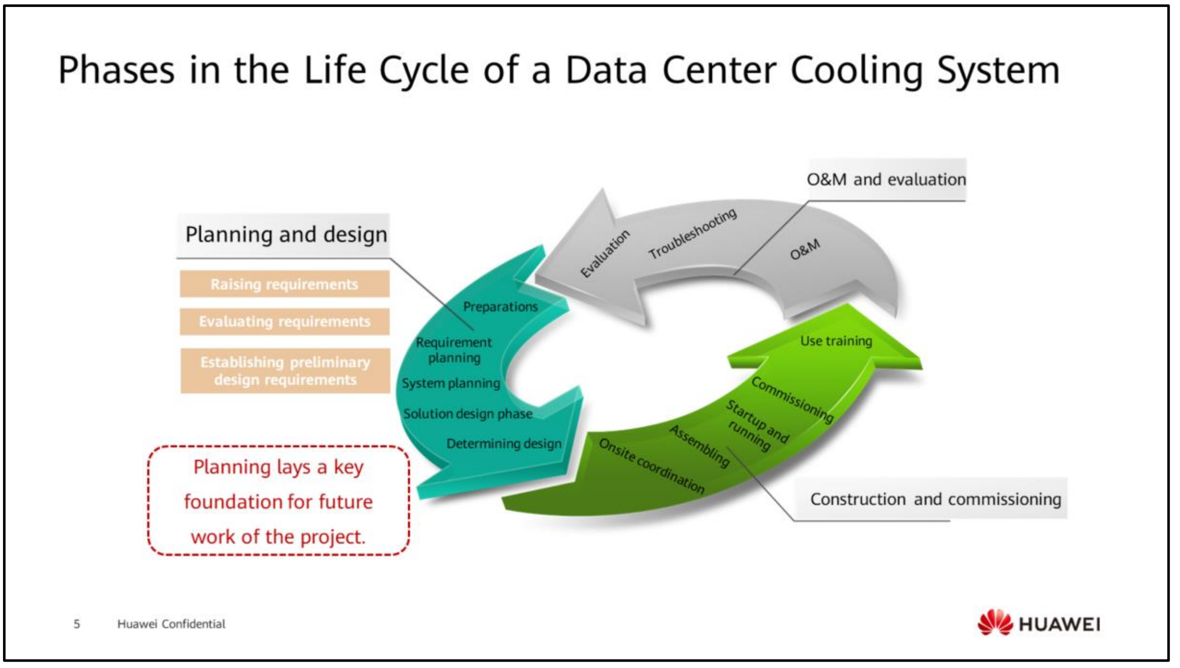


- Many scenarios are involved. Main scenarios include construction and reconstruction. Other cases are special and need to be analyzed based on actual conditions.



- Planning is the most likely to cause confusion, misunderstanding, and communication errors. The mistakes made in the planning phase will be further amplified and spread in the subsequent construction phase. Typical consequences are delay, restart, cost overruns, time waste, and frustration, which will ultimately affect system performance.

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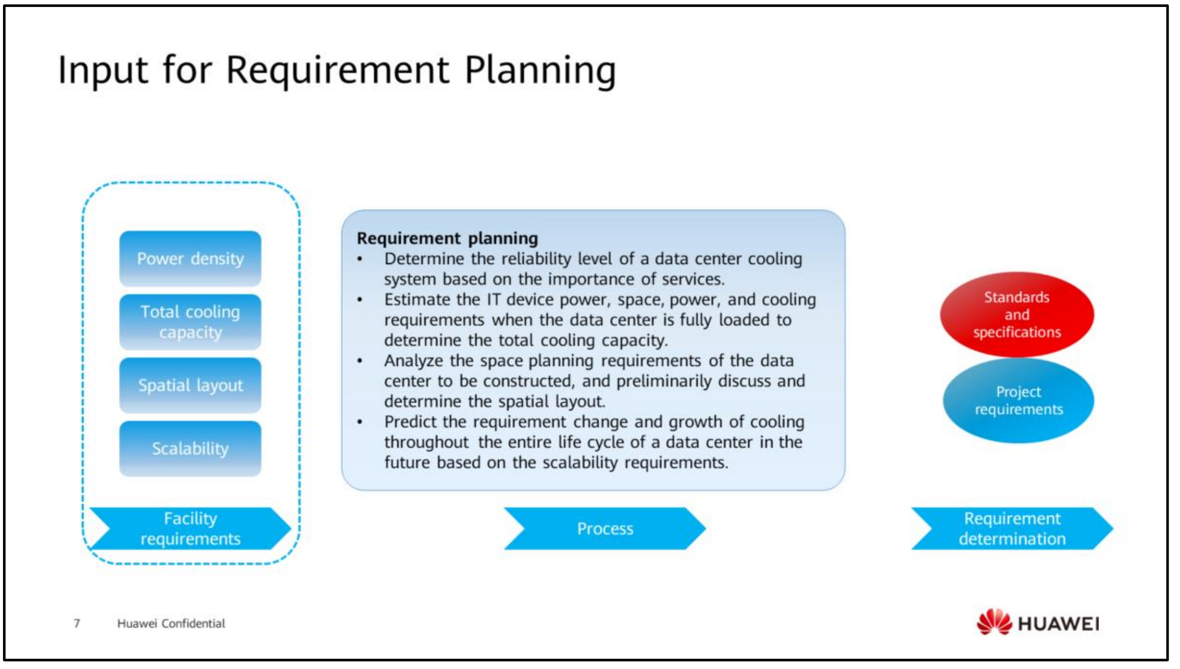
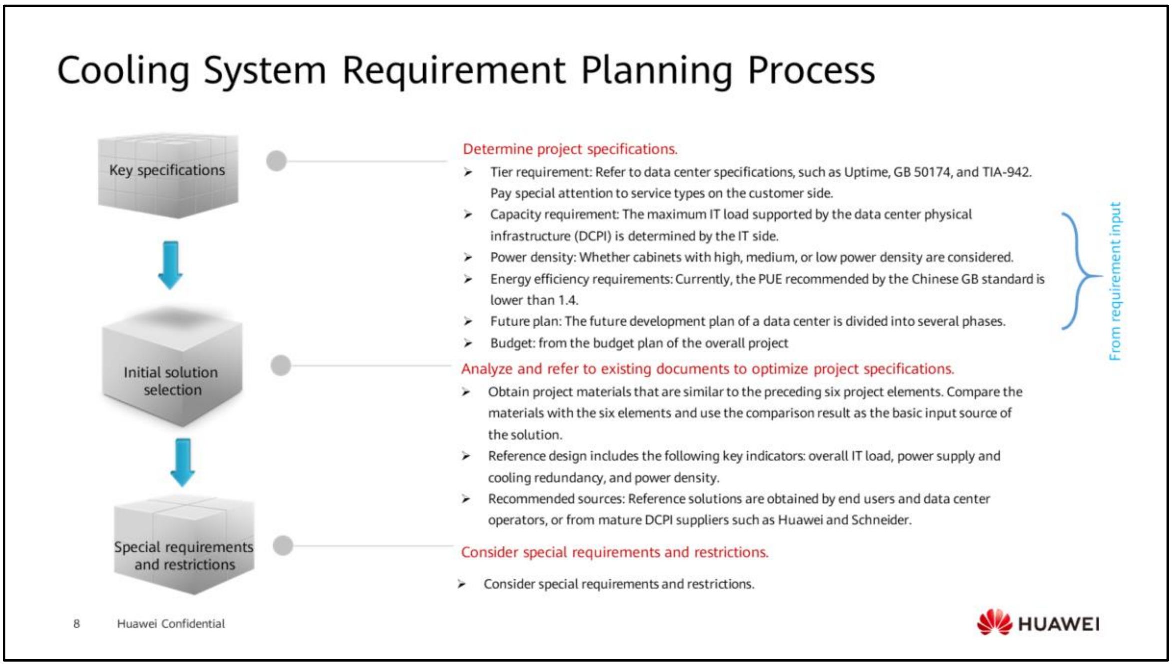


- The final requirement consists of the following elements:
  - Standard requirements usually appear in the form of standards and specifications (main components of data center specifications). Examples of standard requirements include special regulatory compliance standards, subsystem compatibility, safety, or best practices that need to be publicly explained to engineers or installers.
  - Project requirements define the details of project execution for users.



- Determine project specifications: Hold meetings with related personnel and other personnel who understand the core service requirements and objectives to determine macro objectives of the data center project and determine basic requirements for the DCPI.
- Initial solution selection: Obtain some basic specifications from previous mature projects in the industry in advance as a reference, use them as the basis of the solution, and then adjust the solution based on the preferences or restrictions of specific users.
- Consider special requirements and restrictions: Special requirements refer to customers' special requirements. Restrictions are determined by the environment and are not controlled by the data center designer. Restrictions include facility restrictions, regulatory restrictions, or unchangeable service requirements. Professional consultants are required to assess whether decisions affecting the physical location of facilities comply with related national and regional standards.

- The industry suggests that the final requirements consist of the following elements:
  - Standard requirements, which do not change with the project. Standard requirements usually appear in the form of standards and specifications (main components of data center specifications). Examples of standard requirements include special regulatory compliance standards, subsystem compatibility, safety, or best practices that need to be publicly explained to engineers or installers.
  - Project requirements define the details of project execution for users. These include special deadlines, allocation or limitations of human or equipment resources, and mandatory special procedures or other management processes that must be followed by suppliers or the project.
- Requirement planning must be performed by the customer. The planned budget is the project budget, excluding the operating expense (OPEX) budget.
- Preference refers to expectations that users may change or adjust after considering (or re-considering) costs and results. Sometimes, user preferences change after the user gets new information.
- Restrictions are conditions that cannot be overcome or will incur great costs or cause unacceptable consequences if not observed. Restrictions are pre-existing conditions that are difficult or impossible to change.

System Planning Analysis Input of a Data Center

System planning

- All contents of requirement planning must be provided. The selected cooling system must meet the requirements for cooling space, power supply, safety, floor load, grounding, and electrical protection.
- The system planning involves the layout and technology selection of the computer room area, support area, auxiliary area, and other areas.
- Plan the phased principle and subsequent implementation plan. The subsequent implementation should not affect the operation of completed areas.

Based on comprehensive analysis and evaluation of multiple factors, adjust and modify the plan and complete the planning of the cooling system type, overall layout, and preliminary plane partition of a data center.

Cooling System Planning Process

1

- Obtain and prepare for tasks.
  - Task scenario analysis
  - Floor plan
  - Modular layout planning
  - Typical layouts and requirements of different levels

2

- Determine the system solution.
  - Cooling source solution planning
  - Energy-saving solution planning
  - Indoor unit solution planning
  - Humidity measurement and control planning
  - Fresh air system solution planning

3

- Check the detailed planning data of the system.
  - Cooling load determination
  - Indoor unit determination
  - Feasibility study solution output

Feasibility study report output

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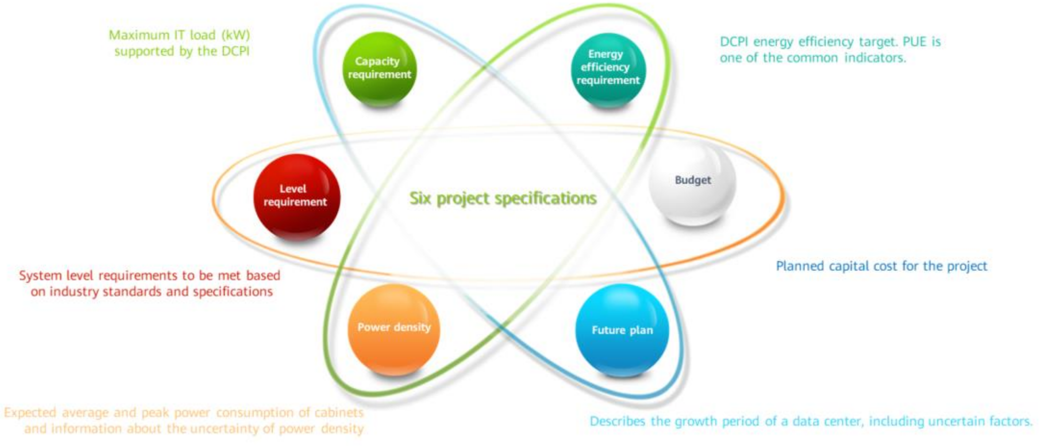
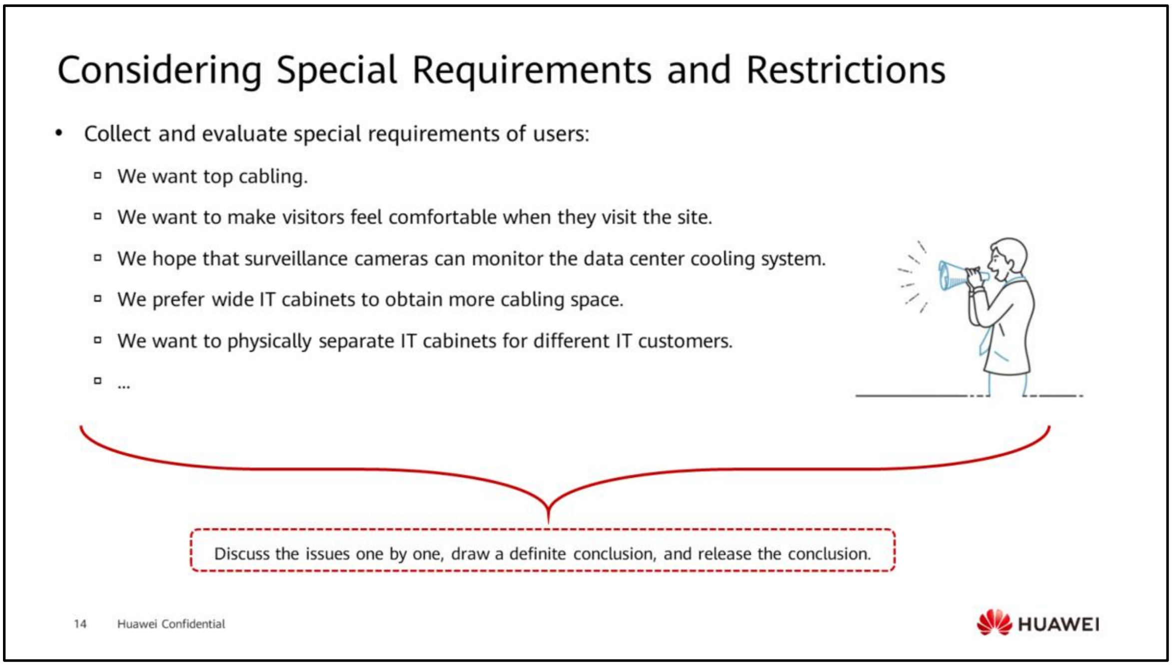
Determining Key Planning Specifications that Affect the Cooling System

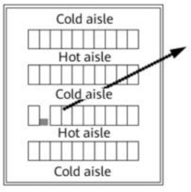




- In most cases, multiple modifications are required to determine the final user preferences and restrictions. This task is completed when preferences and restrictions are adapted to system concepts and summarized as conceptual adjustments, validated preferences, and validated restrictions. If user preferences and restrictions are synchronized with the previous task, the process and task can be completed more quickly. Note that many restrictions cannot be determined before the location is selected. This may require the previous task of developing system concepts to be performed before you can collect restrictions.
- The main idea here is that user preferences and restrictions should be adjusted to fit the system concepts that have been chosen.

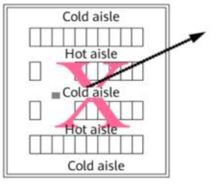
Considering Special Requirements and Restrictions

- Restrictions
  - Physical properties of facilities (ceiling height, floor bearing capacity, geometric shape of the equipment room, existing columns or walls, rooftop installation requirements for outdoor equipment, and onsite pipe routing requirements)
  - Local laws or regulations
  - Physical properties of the transportation passage (such as the bearing capacity of the elevator for transporting equipment to the equipment room)



Deployment scenario 1

In this example, one cabinet position is occupied.
A column can occupy a maximum of three cabinet positions based on the column dimensions and the position of the column in the cabinet row.



Deployment scenario 2

Removing several cabinets in the middle of the cabinet row will cause mixing of cold and hot air.

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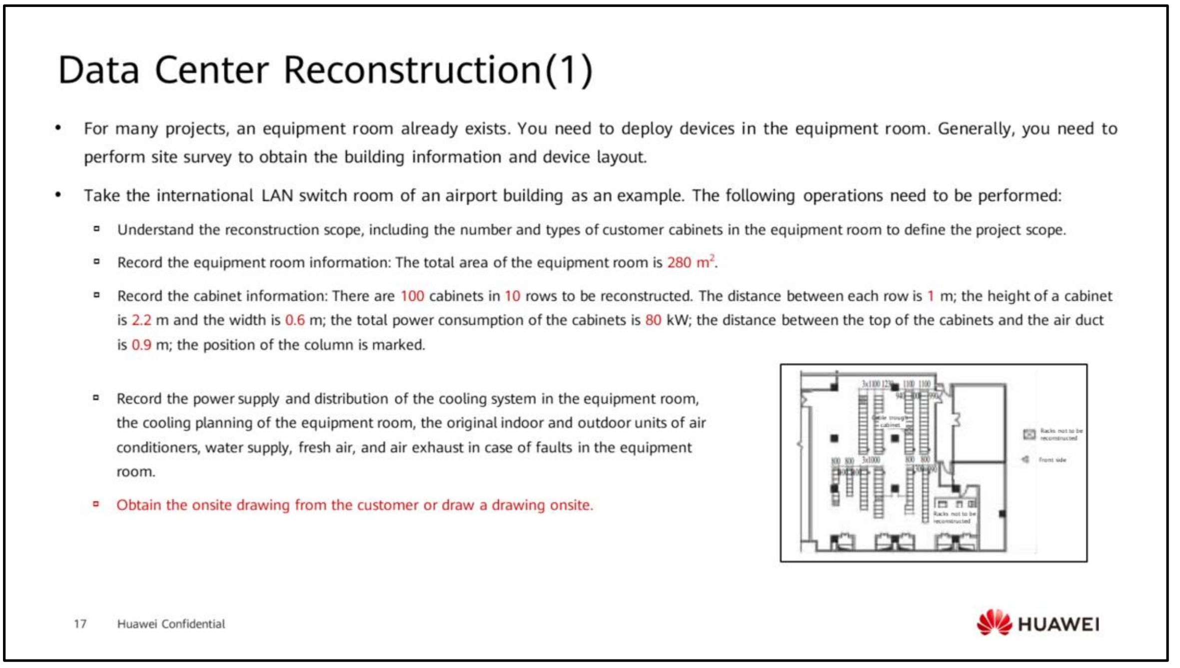


- Purpose: To calculate the load of the air conditioning system, determine the system mode, plan the device installation position, and plan the pipe layout. The device power must be the actual power of the cabinet. If nameplate power is used, the calculated cooling load will be higher than the actual value.

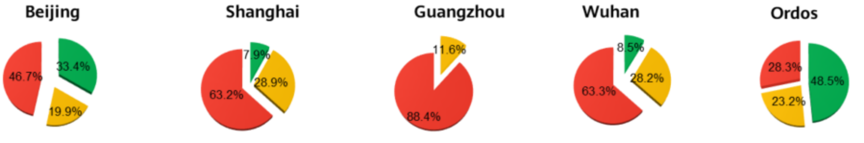
Data Center Reconstruction(2)

- After selecting a solution, you need to perform the following operations:
  - Obtain geographic and climatic information.
  - Calculate cooling load (cooling loss).
  - Obtain the cooling capacity of indoor units.
  - Consider measurement tolerance and energy consumption.
  - Determine the pipe routing mode of the indoor units of air conditioners.
  - Confirm other requirements, including heater (dehumidifier), humidifier, teamwork control, fire extinguishing linkage, water leakage interruption, DCIM remote monitoring and control, and maintenance space.

Impact of Site Selection on a Cooling System - Climate(1)

Climate

A data center requires cooling throughout the year. In areas where the ambient temperature is low throughout the year, free cooling can be used to reduce the compression cooling time, saving energy and reducing costs. However, the cost of heating and humidification may increase in very cold areas. Comprehensive analysis needs to be performed for different areas.



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Impact of Site Selection on a Cooling System - Climate(2)

Direct ventilation free cooling days

Area	Indicator		Requirement
	Key Indicator	Auxiliary Indicator	
Severe cold area	Average temperature in the coldest month: ≤ –10°C	Number of days when the daily average temperature is lower than or equal to 5°C: ≥ 145 days	Heat preservation requirements in winter must be fully met. Generally, protection measures against heat in summer can be ignored.
Cold area	Average temperature in the coldest month: 0°C to –10°C	Number of days when the daily average temperature is lower than or equal to 5°C: 90–145 days	Heat preservation requirements in winter should be met. Protection measures against heat in summer in some areas should be considered.
Mild area	Average temperature in the coldest month: 0–13°C; average temperature in the hottest month: 18–25°C	Number of days when the daily average temperature is lower than or equal to 5°C: 0–90 days	Heat preservation requirements in winter in some areas should be met. Generally, protection measures against heat in summer can be ignored.
Areas with hot summer and cold winter	Average temperature in the coldest month: 0°C to –10°C; average temperature in the hottest month: 25–30°C	Number of days when the daily average temperature is lower than or equal to 5°C: 0–90 days; number of days when the daily average temperature is greater than or equal to 25°C: 40–110 days	Protection measures against heat in summer must be taken. Heat preservation in winter should be considered based on requirements.
Areas with hot summer and warm winter	Average temperature in the coldest month: > 10°C; average temperature in the hottest month: 25–29°C	Number of days when the daily average temperature is greater than or equal to 25°C: 100–200 days	Protection measures against heat in summer must be taken. Generally, heat preservation in winter can be ignored.

Impact of Site Selection on a Cooling System - Air Quality

Air quality

The corrosion mechanism of air contaminants on IT equipment is complex. Corrosion is usually caused by multiple contaminants. International standards for the pollution degree are often set using silver and copper test bars (measuring the thickness of corrosives every month, which is usually 200 angstroms using silver bars and 300 angstroms using copper bars).

The site must be away from **dust, oil fume, harmful gas,** or **corrosive, flammable, or explosive** materials. (**Sea** and **landfills** are also sources of corrosive materials.)

Occasional air pollution may also cause damage to servers.

Exercise caution when selecting direct ventilation free cooling. Even if there is no contaminant temporarily, the air quality may be affected in the future. Mountain fires, autumn harvests, salt fields, hazardous chemical explosions can all be sources of pollution.

Impact of Site Selection on a Cooling System - Environmental Factors

- Do local utility conditions, such as electricity, water supply and drainage, communications, diesel, and heat, meet the requirements of a data center?
- Are there any building restrictions, noise restrictions, contaminant emission restrictions, and other local government restrictions?
- Is there an annual power outage maintenance time period that is not recognized by the planned maintenance?

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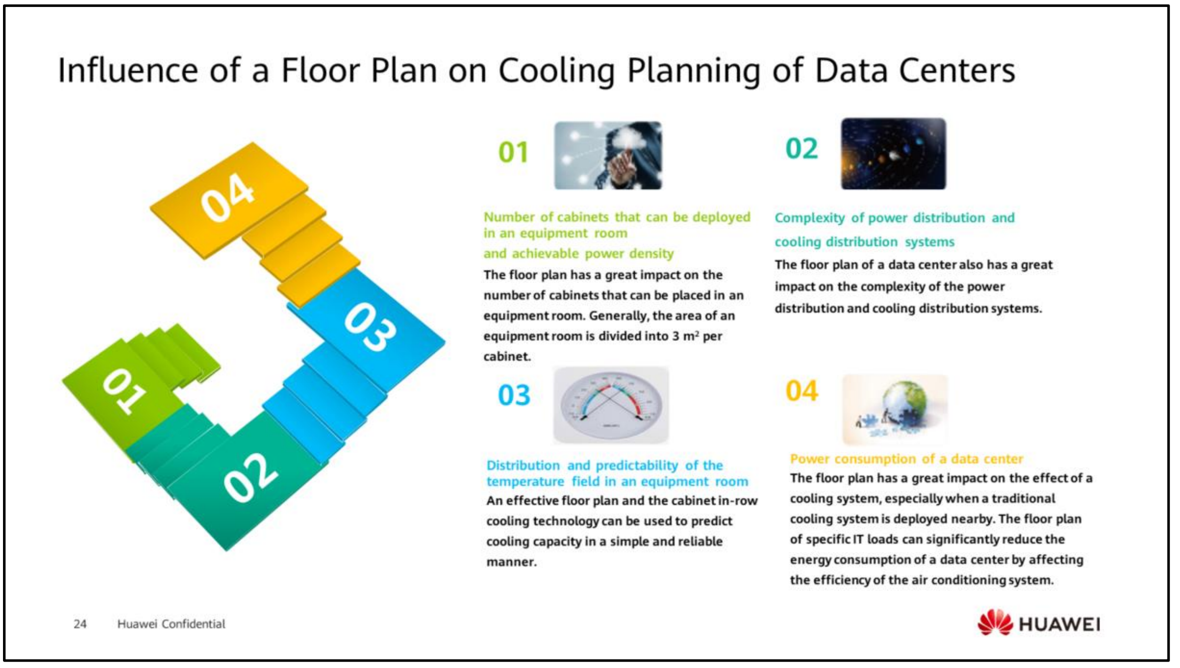
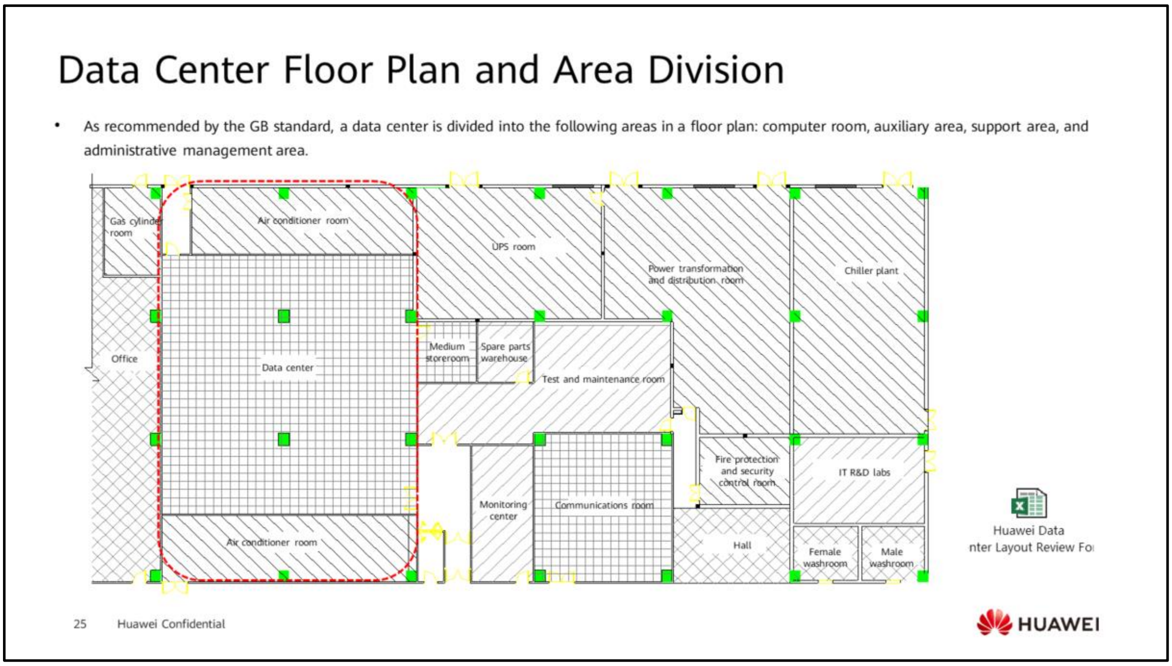


- Why do we need to consider the floor plan in the initial planning phase instead of the detailed design phase? The reasons are as follows:
- It is recommended that the data center power density be determined based on the cabinet row. Therefore, the cabinet row layout must be determined before the power density specifications are formulated.
- Planning based on the cabinet row or cabinet row group produces the best effect. Therefore, the cabinet row layout must be determined before an effective phase plan is formulated.
- The grid of the raised floor and the keel of the suspended ceiling must be aligned with cabinets. Therefore, you must determine the cabinet row layout before positioning the grid and keel.
- The criticality and availability of different areas in a data center depend on the actual situation. The cabinet row layout must be determined before a multi-level criticality plan is made.
- Achievable power density
- The floor plan of a data center has a great impact on the power density that can be achieved. In some cooling architectures, if the floor plan is poor, the allowable power of a specific cabinet will be reduced by more than 50%, which greatly affects the performance of a modern data center. The application of new technologies in modern data centers poses great pressure on the design capability of data centers. In many data centers, users want to build areas with different power densities. The division of these density areas depends on the device layout. Therefore, the floor plan is a key tool for describing and

determining the data center density.



- The division of the data center area determines the application scope and system mode of air conditioners. This section focuses on the layout of air conditioner areas. The typical air conditioner layout is shown in the preceding figure. Air conditioner rooms are deployed on two sides and physically isolated.

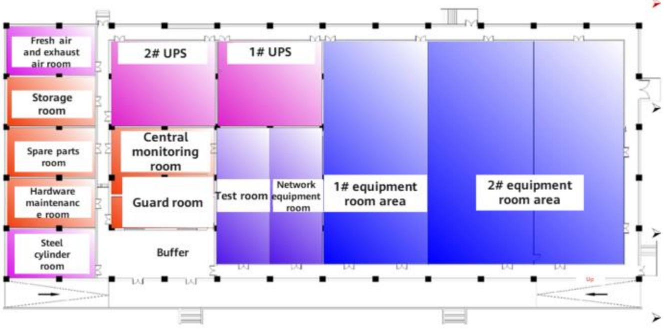
Influence of a Floor Plan on a Cooling System

- Affecting the building structure layout of a cooling system
  - The equipment room layout of a new or reconstructed data center must be determined, including the positions of walls, doors, windows, supportive columns, observation windows, and major water and electricity connections. If a raised floor is used in the equipment room, the height of the floor and the location of the escalator or elevator at the entrance should also be considered. In addition, other conditions inside the equipment room, such as fresh air, air exhaust in case of faults, and floor drain, also need to be marked and considered.
- Affecting the device layout of a cooling system
  - The device layout includes the positions for IT, power distribution, and cooling devices. IT device positions can be defined as cabinet positions, without considering specific devices in cabinets. However, the shape of devices such as large enterprise servers is different from that of common cabinets, which have different impact on the structure layout. Therefore, different measures must be taken for such devices. In addition, the characteristics of the airflow path must be considered when IT devices are laid out.

- The measurement value of an equipment room is based on the floor tile. The width of a floor tile is 600 mm or the width of a standard cabinet.
- The airflow of common IT cabinets is from the front to the rear. However, the airflow mode of some devices is different, for example, from the front to the top. During device layout, power and cooling devices must be considered. However, many new power and cooling devices can be installed on cabinets or designed to be installed on cabinet rows, which simplifies the layout.

Floor Plan Example

- Identify major issues and set core areas and non-core areas.
  - Core areas: areas that need to be focused on during planning, including the core area of a data center, power supply and distribution system, cooling system, and monitoring system.
  - Non-core areas: operation center, data center office, unloading platform, and warehouse



- Classify equipment rooms and clearly define the power density. Equipment rooms are classified into high-load, medium-load, and low-load equipment rooms based on the deployment and power consumption density of data devices inside. Mark the three types of equipment rooms.
- Reduce the impact of the environment on equipment rooms. For a new equipment room, the direction of external walls can be considered. The equipment room can be designed on the east or north side of a building, and passages such as corridors can be reserved on the opposite side.
- Design an appropriate area of equipment rooms. An equipment room of a large data center should not be square, but be rectangular. The economic area is 500–800 mm^2.
- Properly deploy devices.

Layout Principles for a Cooling System

- The core area should be compactly deployed based on the following considerations:
  - Security: Physical deployment in the core area protects the area from risks that may cause damages.
  - Easy O&M:
    - The cooling system layout should consider the following items in sequence based on the heat transfer direction of servers in the data center: air conditioner indoor unit, water pump room (can be ignored for an air-cooled DX system), and air conditioner outdoor unit platform (chiller platform).
    - Power supply for the cooling system: Select an appropriate system based on the equipment room level and reliability requirements to facilitate maintenance and isolation.
  - System economy: A compact and reasonable system layout shortens the distribution path of the power distribution and cooling systems, reduces the length of bus cables and pipes, and saves costs.

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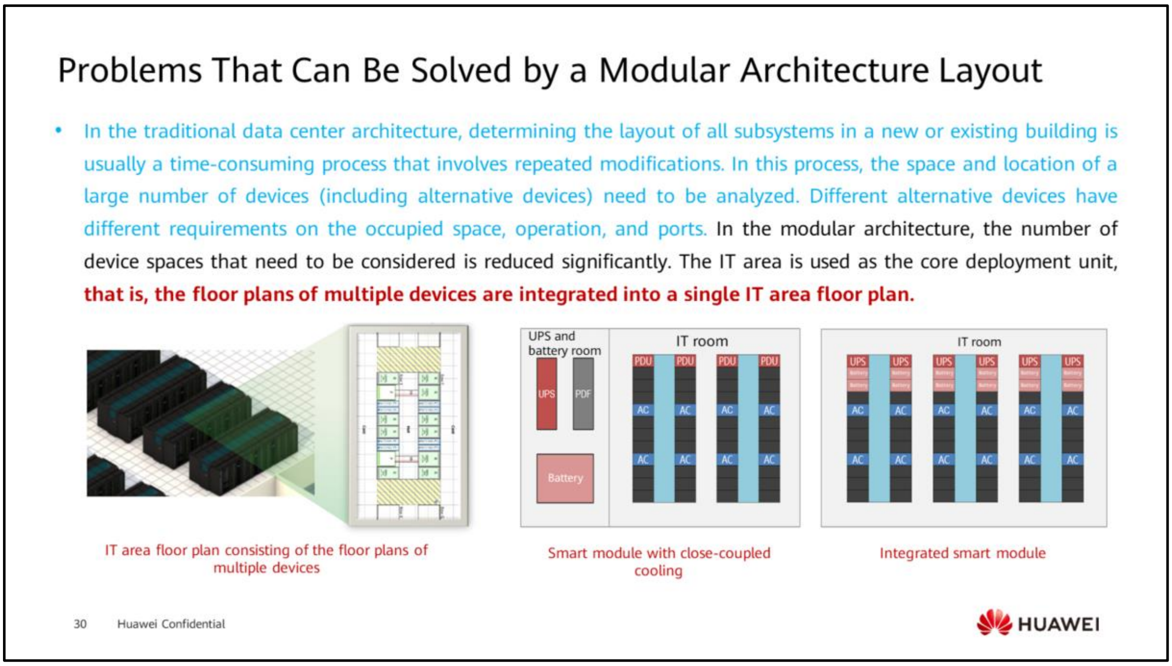


- Several reports recently released by Gartner, a well-known consulting firm, show a trend: The design of the first two generations of data centers cannot meet current and future requirements. New data centers should no longer be a static structure, but a dynamic organism that can evolve with the change of servers and storage infrastructure. Therefore, Gartner recommends that a new data center should adopt flexible, modular, and virtual design.
- A controversy about the modular architecture is that it is limited by the system floor plan. If the layout of the IT area or other subsystems is not flexible, the system may fail to fully utilize the available space. Users often need to place data centers in existing spaces of various sizes and shapes. Although there are many examples showing that standardized IT areas cannot make full use of ground space, experience shows that this problem is not serious.

Planning a Data Center Project Using the Modular Method

I. **Determine the main specifications of the overall design solution, such as the data center, power capacity, future plan, and power density.**

II. Select an existing standard modular architecture that best meets various requirements based on **IT specifications.**

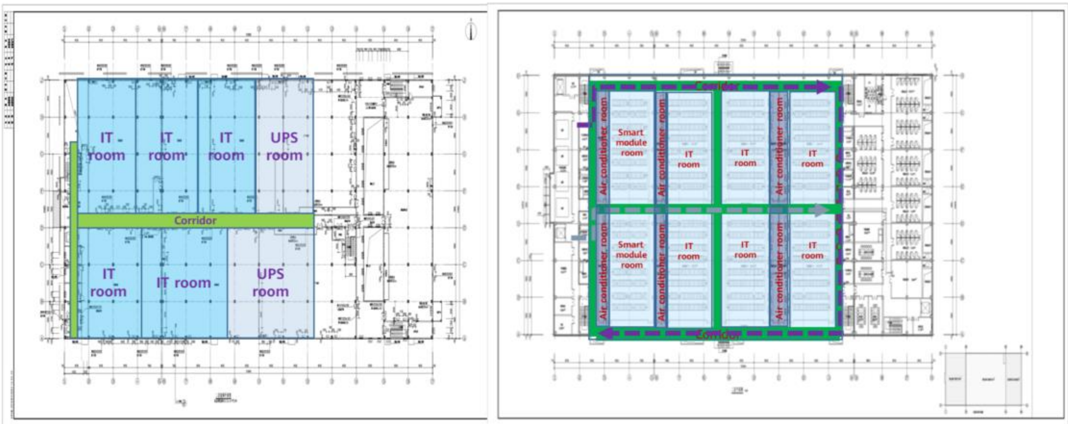
III. Determine the special restrictions of the project, such as the existing physical space, power supply, or cooling subsystem.

IV. Determine the modules and other options required to meet the IT specifications based on the restrictions and selected architecture.

V. **Verify that these modules can be deployed under the current project restrictions.**

VI. If the selected architecture cannot be used due to restrictions, consider other alternative solutions within the architecture or alternative architectures, or try to adjust restrictions to select the final architecture.

Floor Plan Comparison



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- Compare the two modes when power is the same.

Huawei Ulanqab Cloud Modular Data Center

- To maintain stable growth, make structural adjustments, and improve living standards, Ulanqab seizes the opportunity of coordinated development of the Beijing-Tianjin-Hebei region and rapid growth of the cloud computing industry, and introduces and supports cloud computing and related industries as strategic industries.
- In Chahar Economic and Technological Development Area, Huawei has planned an information industry park covering an area of 13 square kilometers to expand the cloud computing service market, provide high-quality cloud computing services for enterprises and institutions in and outside China, and facilitate the rapid development of the cloud computing industry in Ulanqab.
- Cloud migration of information application systems of municipal departments is being actively carried out. Currently, 34 service systems have been migrated to the cloud and rolled out.
- The mild climate, stable geology, and low energy costs make Ulanqab very suitable for building data centers.

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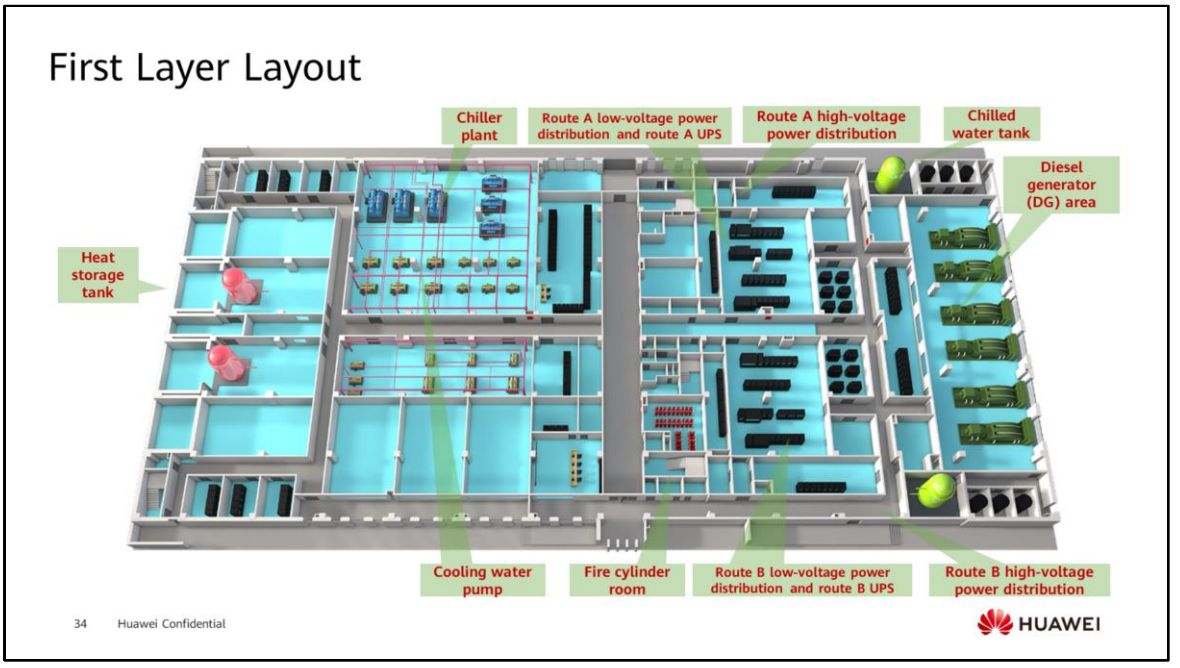
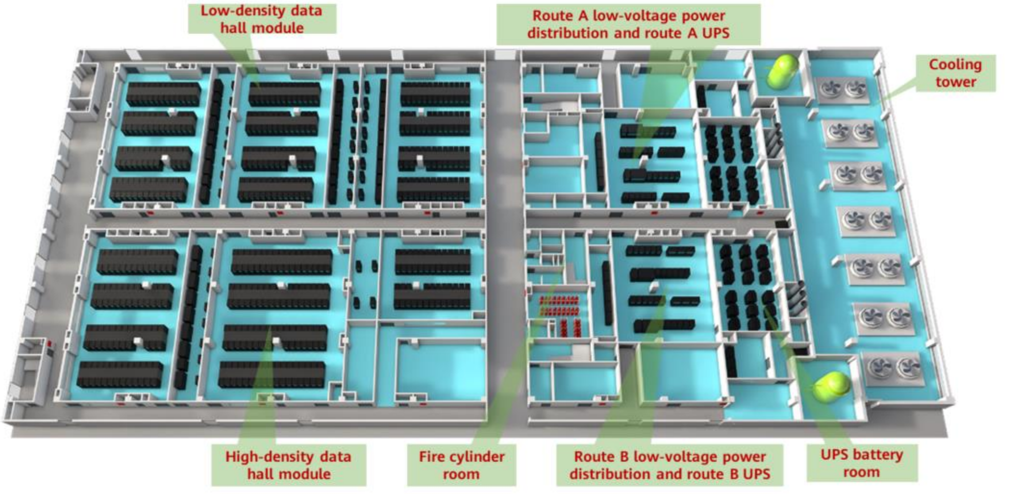
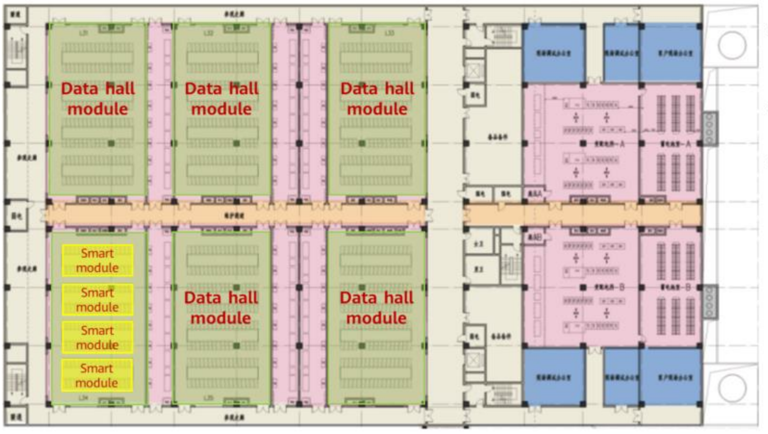


- The data center has two layers. The first layer is the support area, where facilities such as the chillers, fire extinguishing system, and high-voltage power distribution room are deployed.

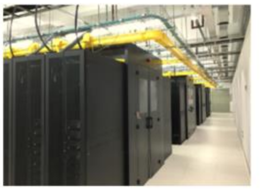
Standard Layer Layout



Modular Data Center



- Twelve data halls, six on each layer. The area, shape, and facilities are unified and can be used and expanded by module.
- Every two data halls form a group and share a maintenance channel.
- The data hall uses the **smart module** combination, which can be quickly expanded and reserved.



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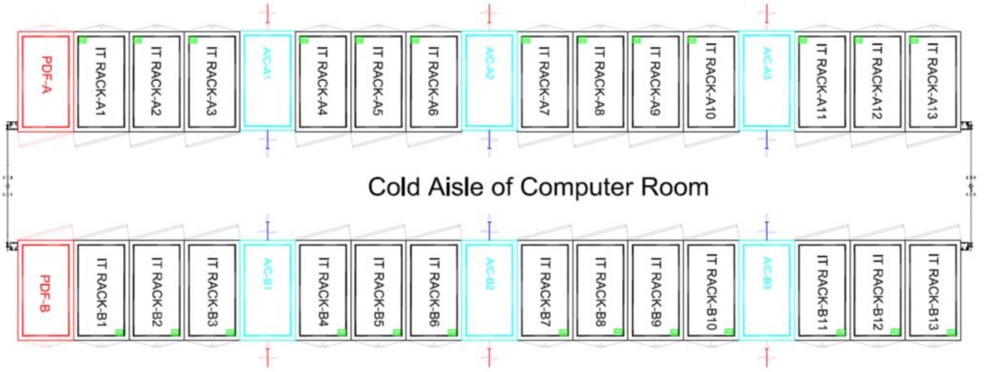
Typical Layout of Cold Aisle In-row Air-Cooled Air Conditioner Indoor Units

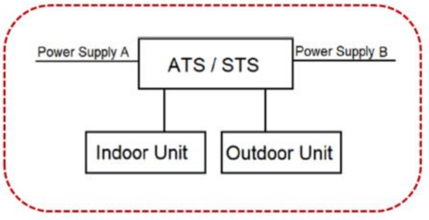
- Tier III: N active air conditioners + 1 standby air conditioner

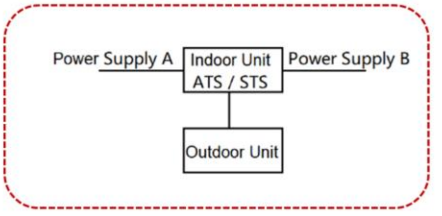


- In a typical in-row solution, PDFs are deployed and occupy cabinet positions.

Power Configurations for Cold Aisle In-row Air-Cooled Air Conditioner Indoor Units

- Power supply A comes from power distribution route A, and power supply B comes from power distribution route B (power supplies A and B are turned on at the same time).
- Each air conditioner is configured with an ATS/STS.
- The ATS/STS can switch power supplies A and B to the indoor and outdoor units.
- The power supplies of the indoor and outdoor units should come from the same power supply device and be on the same layer.

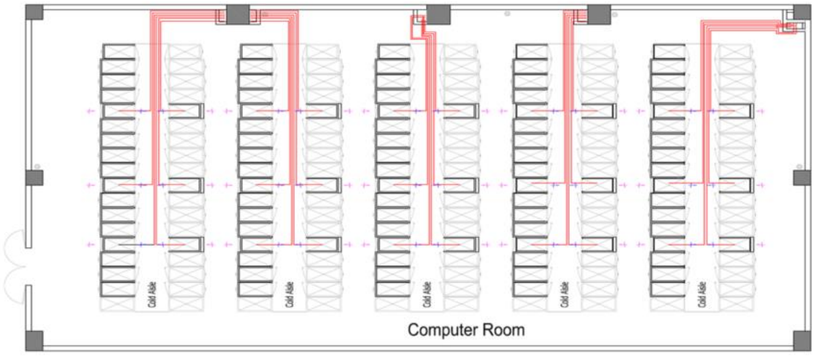




- A power failure during the ATS switchover in a Tier III configuration is only an operation event, not a fault.

Typical Layout of Tier IV Cold Aisle In-row Air-Cooled Air Conditioner Indoor Units

- Tier IV: 2N (Half of the indoor units operate to meet the cooling requirements.)



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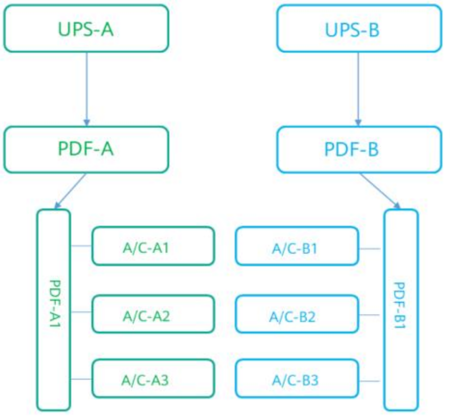
- Tier IV requirements: fault tolerance, partition isolation, continuous cooling, and automatic response
- The gas pipe and liquid pipe of an air conditioner are secured on a steel base and can be isolated separately.

Power Configurations for Tier IV Cold Aisle In-row Air-Cooled Air Conditioner Indoor Units

- In a 2N active system, there are N (three) air conditioners in each aisle of the Tier IV system.
- Routes A and B are operating at the same time.
- Each aisle can bear all cooling loads in the critical environment to meet continuous cooling requirements.
- The power supplies of the indoor and outdoor units should come from the same power supply device and be on the same layer.
- The air conditioner has a single power supply. The indoor unit can have no ATS/STS.



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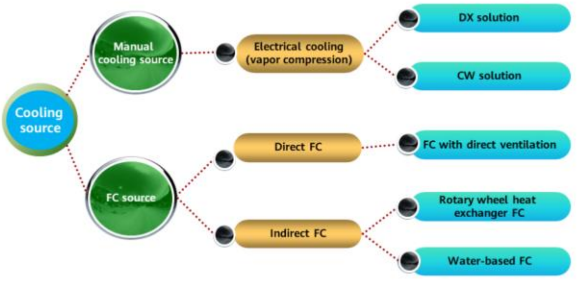
2. **Implementation of the Data Center Cooling System Planning Process**
   - System Planning
     - Reconstruction
     - Floor Plan
     - Modular Layout Planning
     - Cooling Source Solution Planning
     - Energy-Saving Solution Planning
     - Indoor Unit Solution Planning
     - Humidity Measurement Control and Fresh Air System Planning
     - Load Calculation and Indoor Unit Solution Determination

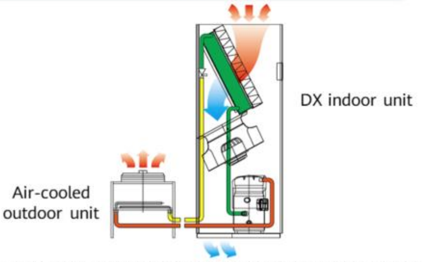
Cooling Source Solution Planning for the Cooling System

- Classification of cooling source systems
  - Any substances with cooling and dehumidification functions can be used as cooling sources for air conditioners on condition that the substances are safe, economical, and environmentally friendly. In general, there are two types of cooling sources for air conditioners: free and manual cooling sources.
  - Manual cooling source solutions: DX cooling solution and CW cooling solution; FC source solutions: direct ventilation, rotary wheel heat exchange, and water-based heat exchange



Data Center Cooling System Solution – DX Air Conditioning System

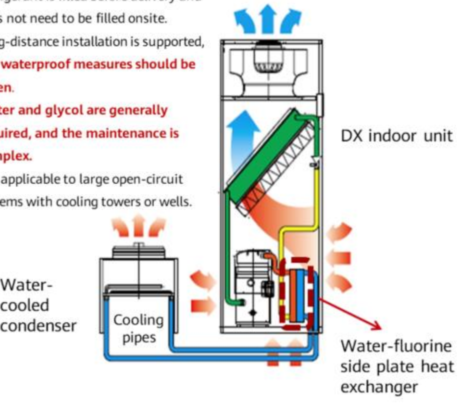
DXA

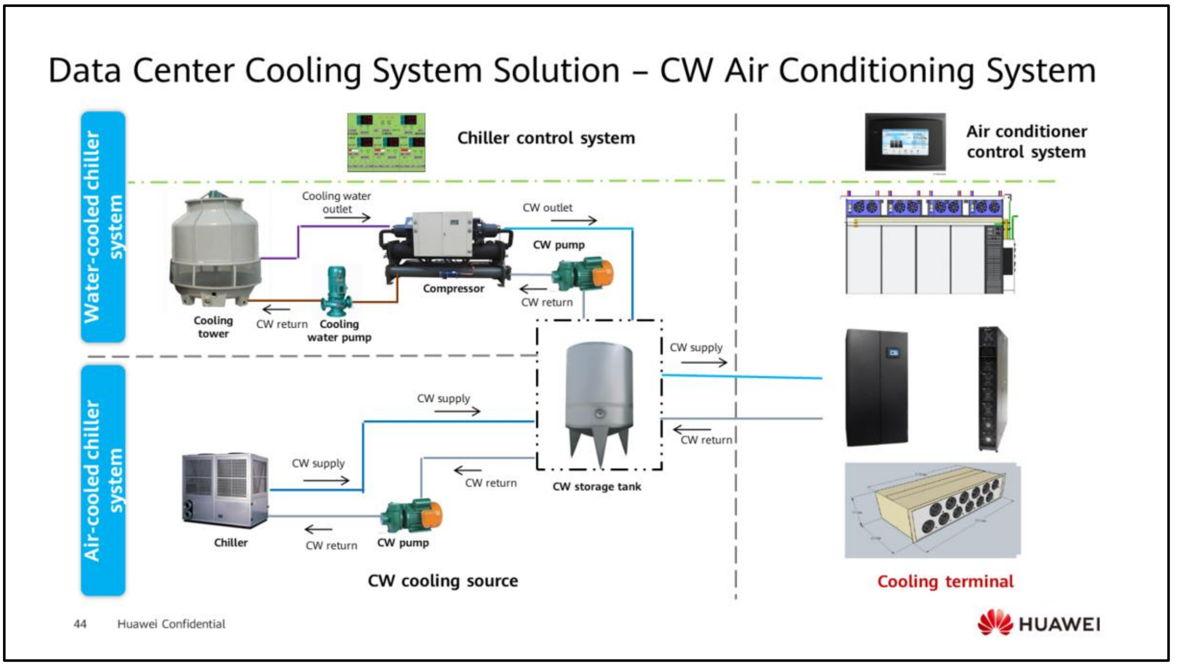


- Easy to install, no need for water system energy-saving construction and maintenance costs
- Relatively small and independent cooling cycle, easy to maintain
- Applicable to areas with insufficient water sources and places without cooling water systems
- **Not applicable to large data centers due to lower cooling energy efficiency than that of chillers**
- **The installation distance cannot be too long. Otherwise, the cooling loss is large.**

DXW

- Refrigerant is filled before delivery and does not need to be filled onsite.
- Long-distance installation is supported, **but waterproof measures should be taken**.
- **Water and glycol are generally required, and the maintenance is complex.**
- It is applicable to large open-circuit systems with cooling towers or wells.

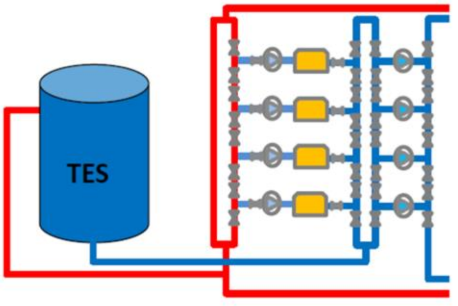




- Water-cooled chiller system:
- Consists of the air conditioner, CW pump, water-cooled chiller, cooling water pump, cooling tower, water tank, and other related components.
- Air-cooled chiller system:
- Consists of the air conditioner, CW pump, air-cooled chiller, water tank, and other related components.

Air Conditioner Cooling Source Solution – Continuous Cooling

- To ensure that the computer room and UPS room that generate much heat can maintain a stable temperature, necessary measures must be taken for the cooling and air conditioning system to provide continuous cooling, so that cooling for systems will not be interrupted due to events such as mains outage and chiller restart.



Class A uninterruptible cooling system with a chilled water tank

- According to the white paper on the continuous cooling system for high-density data centers discussed by the Uptime Institute, the cooling system is classified into classes A, B, and C. Class A is the uninterruptible cooling system; class B is the continuous cooling system; class C is the interruptible cooling system. The figure on the left shows the class A uninterruptible cooling system.

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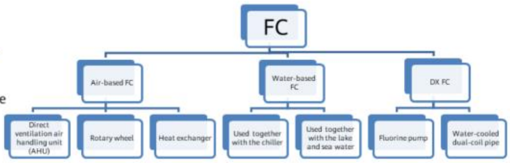
Data Center Cooling System Solution – FC

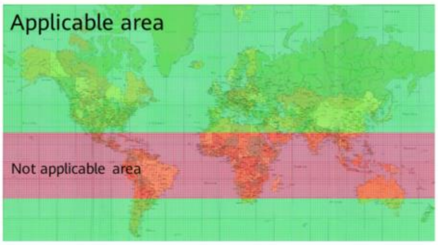
Advantages:

- Directly uses the cooling capacity of the outdoor cooling source, resulting in **ultra-low energy consumption**.
- Makes full use of the seasonal temperature difference of air and water sources.
- Has many mature cases in the industry.

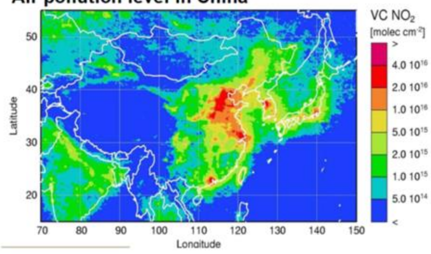


Disadvantages:

- Indirect FC is complex and **prone to single points of failure**.
- Not applicable to **tropical/subtropical areas.**
- Excessive **air conditioning pollution** increases IT equipment security risks.



Air pollution level in China



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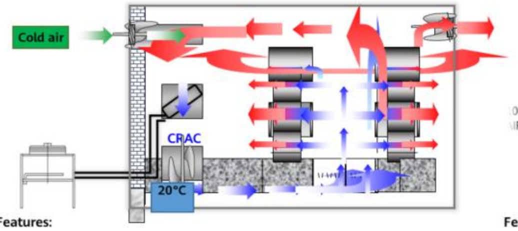
Data Center Cooling System Solution – Direct Ventilation FC

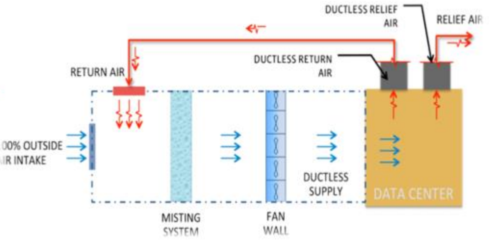
Mechanical cooling + direct ventilation hybrid cooling



Features:

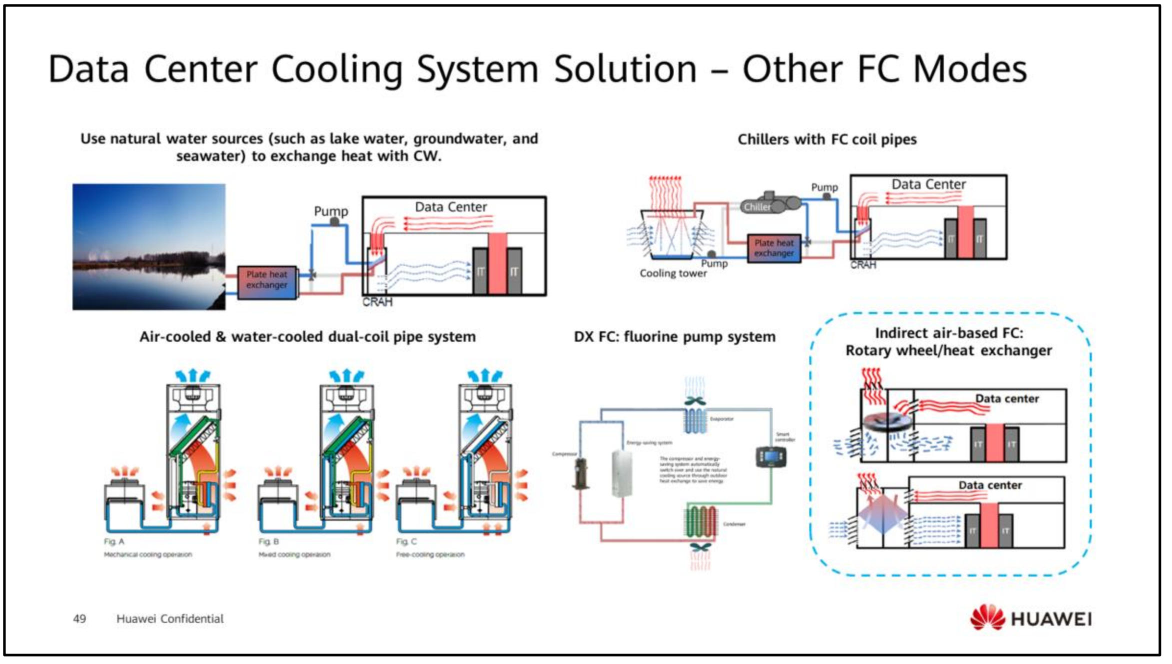
- Multiple control modes, making full use of FC sources and saving energy
- Supports underfloor air supply. The indoor air conditioner is basically the same as a common air conditioner.
- Supports DX and CW mechanical cooling backup.
- **The project is complex and has high requirements on the building height and outdoor air quality.**
- **High restrictions on areas, applicable to areas where the annual average temperature is lower than 20°C**

Direct ventilation FC



Features:

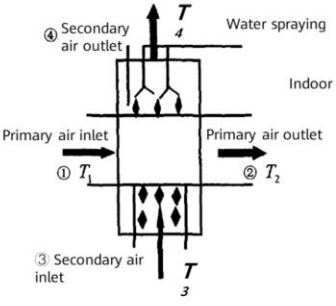
- Makes full use of FC sources, improving efficiency and saving energy. The PUE is close to 1.
- Easy O&M
- **No mechanical cooling backup**
- **The project is complex and has high requirements on the building height and outdoor air quality.**
- **Fails to meet the Tier III standards.**

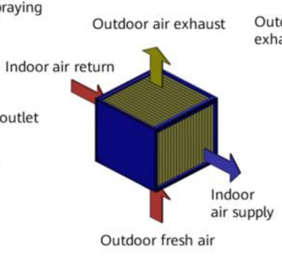


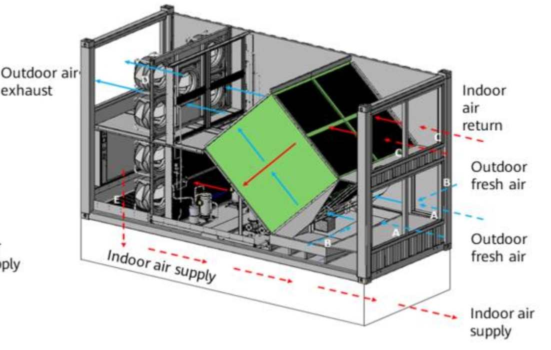
- Heat exchange between natural water sources and CW: has high requirements on the quality of water sources and has risks of environmental damage.
- Air-cooled chiller FC: applied in some scenarios.
- Air-cooled & water-cooled dual cooling sources: applied in some scenarios.
- Fluorine pump FC: applied in some scenarios.

Air Conditioner Energy-Saving Solution – Evaporative Cooling Solution

- Uses an air-to-air heat exchanger to lower the indoor temperature through the outdoor low-temperature cooling source.
- Fully utilizes the difference between dry and wet bulb temperatures to prolong the free cooling time by using the spraying system.
- Starts mechanical cooling for auxiliary cooling when the cooling capacity provided by free cooling is insufficient.







Key Points for Selecting an Energy - Saving Solution

- Data center scale and capacity
  - Total cooling load of the cooling source, building footprint, and building floor height
- Surrounding environment conditions
  - Air temperature and quality, whether there is waste heat and industrial waste heat, whether the power supply is sufficient, and whether there is a renewable cooling source
- Building installation environment
  - Whether there is a basement, whether there are open spaces outdoors and on the roof, and whether there is a device layer
- Performance requirements
  - PUE requirements, continuous cooling requirements, reliability level requirements, and control policy complexity
- Economy requirements
  - If two or more solutions are available, you need to analyze the initial investment and OPEX.

Contents

Key Points of Indoor Unit Solution Planning

Indoor unit types of in-room, in-row, and in-cabinet cooling

- Indoor unit type selection and recommendation
- Indoor unit type comparison

Indoor unit layout

- Layout scenario
- Energy-saving mode

Selection of the airflow organization mode of the indoor unit

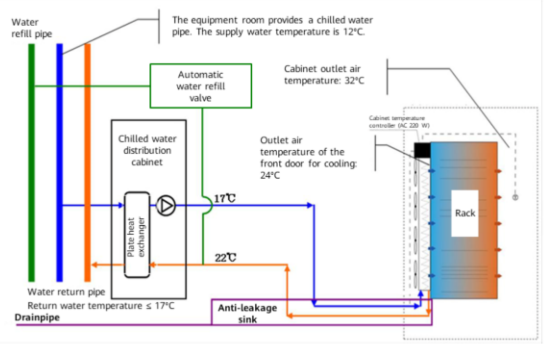
- Selection of air supply modes
- Selection of air return modes

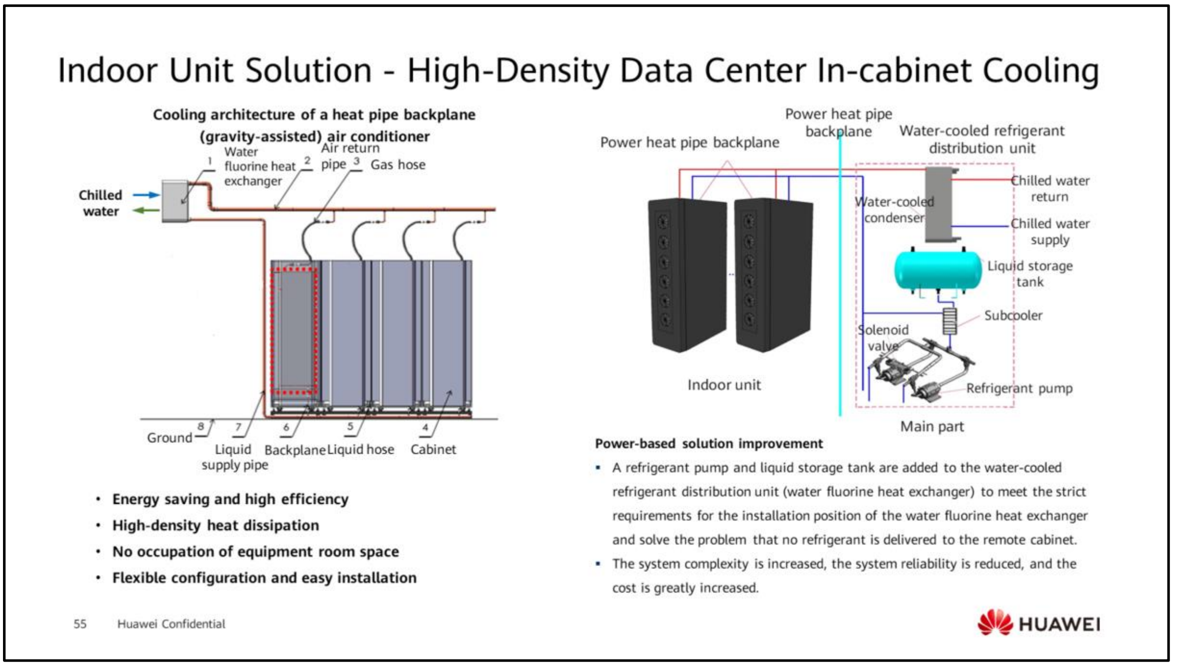
Underfloor air supply

- Characteristics of underfloor air supply
- Optimization scheme of underfloor air supply

Indoor Unit Solution - High-Density Data Center In-cabinet Cooling

- Chilled water backplane air conditioner
  - The indoor unit of the heat exchange system is combined with the cabinet door, and the cooling source is close to the heat source, achieving high cooling efficiency.
  - The indoor units of the entire air conditioning system are distributed on the front door of each cabinet and do not occupy extra space of the equipment room. This improves the space utilization of the equipment room.
  - Cold aisles are formed inside cabinets and hot aisles are formed outside cabinets. The cooling capacity is concentrated on target devices without loss.
  - The heat exchanging capacity of each cabinet is greater than or equal to 10 kW and can be adjusted based on the internal load.
  - The cabinet integrates the air conditioner, power supply, and monitoring systems, which are completely modular.





- Cooling architecture of a heat pipe backplane (gravity-assisted) air conditioner
  - This air conditioner type prevents water from entering the cabinet area and eliminates water leakage risks.
  - High plane usage of the computer room (doubtful)
  - There are a large number of indoor units (backplanes), pipes, and connectors, and the O&M workload is heavy.
  - Refrigerant is delivered by gravity, and there is a risk that the remote cabinet has no available refrigerant.
  - Requirements on the installation position and construction of a water fluorine heat exchanger are high.
- The hot air exhausted by the server exchanges heat with the backplane installed at the rear of the cabinet. The heat changes the coolant in the backplane from the liquid state to the gas state. The coolant carries heat exhausted by the server to the cooling distribution unit (CDU) at the top of the cabinet. After being cooled by the CDU, the coolant changes to the liquid state and flows back to the backplane by gravity. In this way, a heat exchange cycle is completed. The other side of the CDU is connected to the chilled water circulating system to continuously absorb the heat transferred by the coolant. The chilled water is provided by the outdoor cooling station. Free cooling technologies can also be used based on the site climate.

- A heat pipe backplane air conditioner has the following features:
  - Energy saving and high efficiency: Cooling efficiency is improved by directly cooling the cabinet. The coolant keeps cyclic using the phase change and gravity. No external energy is required for air supply and cooling, which reduces internal energy consumption of the equipment room and is more energy-saving compared with traditional precision air conditioners.
  - High-density heat dissipation: The heat dissipation issue of high-density servers is resolved. Currently, the cooling capacity of the heat pipe backplane air conditioner ranges from 8 kW to 16 kW.
  - No occupation of equipment room space: The indoor unit is integrated with the cabinet. The issues of insufficient cooling capacity and local overheating in the equipment room are resolved without occupying extra equipment room space.
  - Flexible configuration and easy installation: Indoor installation does not affect the normal operation of the server and the server does not need to be shut down. It is applicable to the equipment room reconstruction scenario.
  - Other features: Both the indoor unit and CDU are static devices. They are durable and reliable, generate no noise during operating, almost require no maintenance, and provide a comfortable environment for O&M personnel.
- The gravity-assisted backplane air conditioner solution has the following problems: 1. The water-cooled condenser is installed higher than the backplane air conditioner. Therefore, there are requirements on the installation clearance

and height. 2. Currently, all backplane air conditioners adjust the airflow passively, and have no active flow adjustment device. 3. The existing heat pipe backplane air conditioners mostly use multiple fans. However, if multiple fans are adjusted together, the supply air temperatures will be uneven.

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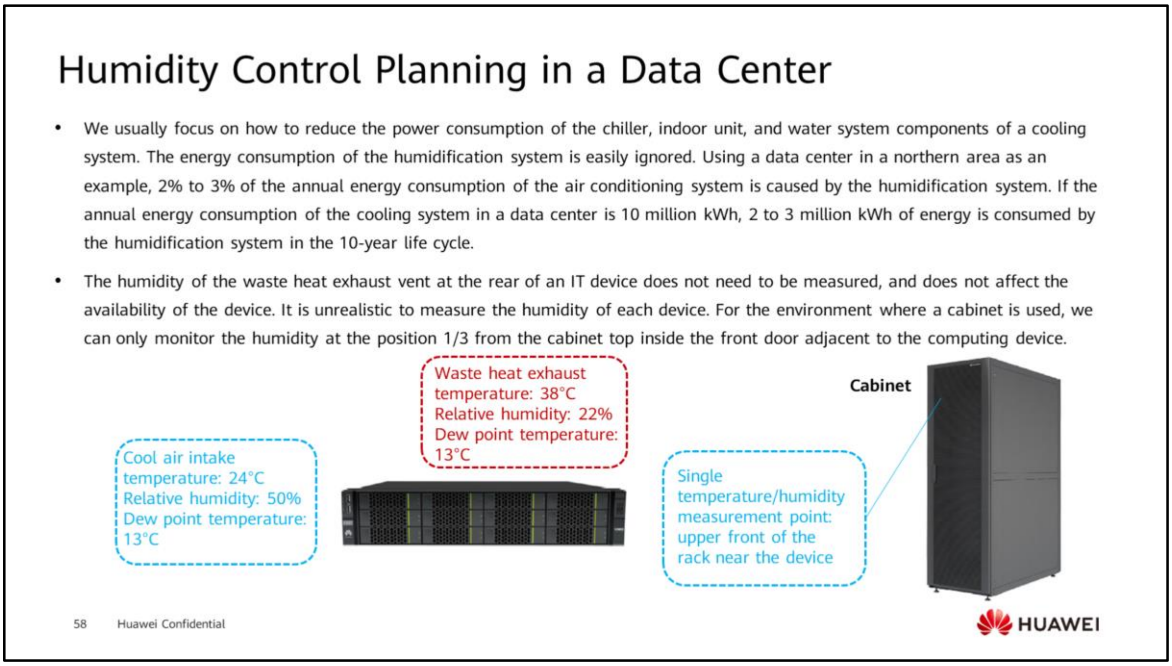
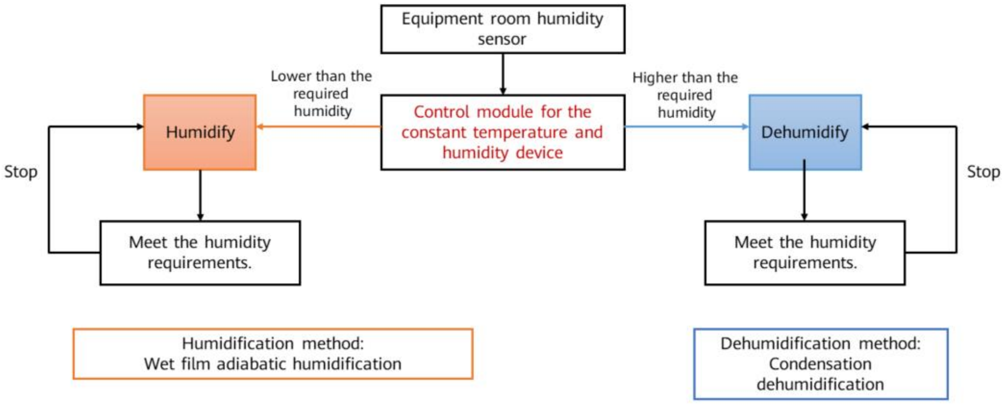


- Every three in-row air conditioners have one backup device to form N+1 redundancy. Generally, one humidifier is deployed for every 12 in-row air conditioners, and one humidifier is associated with one equipment room. The configuration can also be customized. Among every four air conditioners, one air conditioner with the humidification function is configured.

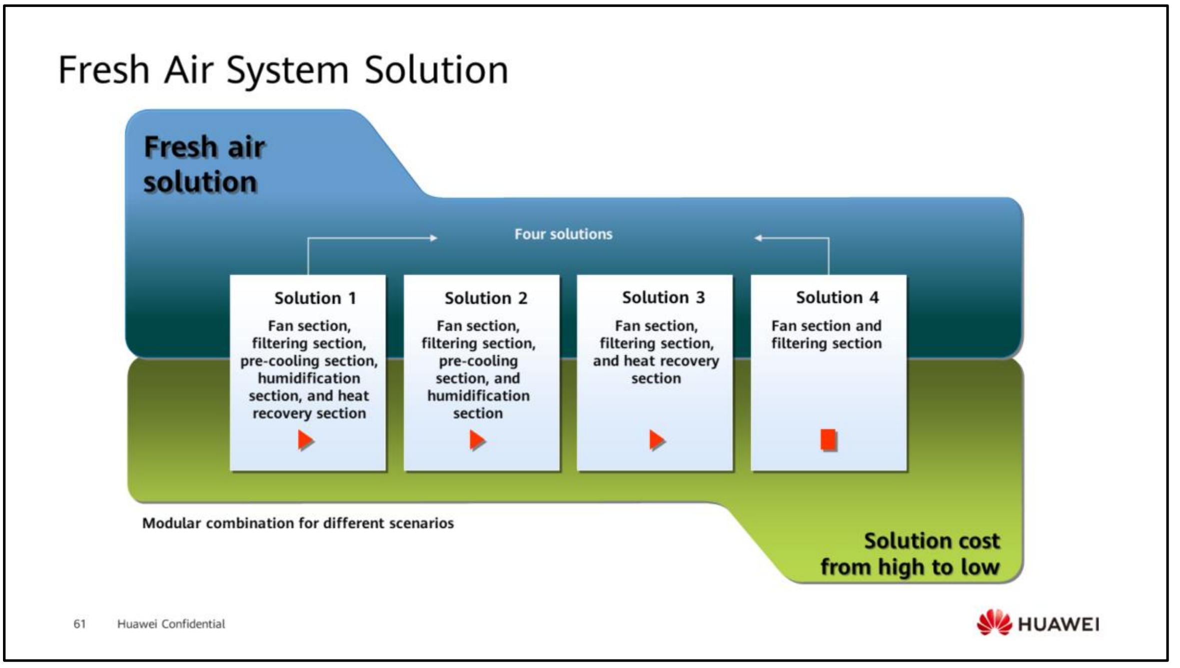
Humidity Control Policy



Humidification Mode Selection and Recommendation

Humidifier Type	Wet Film Humidifier	Electrode Humidifier	Infrared Humidifier
Humidification Principle	The water in the sprinkler on the top of the wet film permeates due to gravity and then is absorbed. When dry air passes through the wet film, water molecules absorb heat, evaporate, and turn into moist air.	After AC power is supplied to the electrodes of the storage and steam cylinder in the humidifier, the impurities in water start moving, and kinetic energy is turned into thermal energy. The generated steam is sprayed into the air flow through spray pipes and then evaporates.	Water evaporates when a highlighted infrared quartz lamp is hung above an open water pan. The generated steam spreads to the air flow that requires humidification.
Energy Consumption (Wh/kg)	15	780	700
Water Quality Requirement	Clean tap water	Clean tap water or softened water	Clean tap water
Replaced Component	Humidification module (replaced every 8 to 10 years based on the stain status)	Steam cylinder	Infrared lamp
Maintenance Interval	Once per year	Once per year	Once per year
Water Supply Utilization	30–70%	75–90%	75–90%
Advantages	No white powder, self-regulated and clean humidification, no noise, high strength, strong corrosion resistance, anti-microbial, long life cycle, small equipment size, less maintenance, and low OPEX	Key parts made of imported materials, low noise, adjustable humidification amount, high humidification purity, high cost, and often used for equipment room air conditioners	Rapid humidification, no drops and bacteria, excellent control performance, simple deployment, and self-cleaning
Disadvantages	Micro-organism pollution, and temperature decreasing during humidification	High energy consumption and OPEX, prone to scaling and difficult to clean	High energy consumption and OPEX, short life cycle, and high price

- The development trend of humidification systems is the same as that of data centers. Currently, green data centers that are energy-saving and environment-friendly are a major development trend. The development of humidification systems complies with this trend: From the built-in electrode humidifier and infrared humidifier with high energy consumption to the independent wet film humidifier with lower energy consumption, and to the integration of the wet film humidifier into the precision air conditioning system, the humidifier energy consumption has been reduced.
- It can be inferred that with the development of humidification technologies, more efficient and energy-saving humidification modes will emerge to meet the requirements of green data centers.



- When fresh air is not supplied to the return air vent of the indoor air conditioner (the indoor air conditioner bears the fresh air load), you need to configure a pre-cooling section to meet the supply air temperature requirements. When independent fresh air control is used in humidity control and the outdoor humidity is higher than the indoor control target, you need to configure a dehumidification section (cooling is used for dehumidification generally).
- When independent fresh air control is used in humidity control and the outdoor humidity is lower than the indoor control target, you need to configure a humidification section.
- To save energy, you can configure a heat recovery section to use exhaust air to preheat or pre-cool the fresh air. There are plate type and rotary-wheel type.
- The heating section needs to be configured only when the fresh air unit uses the constant temperature and humidity air supply solution. After cooling and dehumidification, air needs to be reheated and then transferred to the dry bulb working condition for air supply. This is a non-energy saving solution and is not recommended.
- In the data center air conditioning field, the fresh air solution is usually combined with free cooling to form an air conditioning system.
- Fresh air volume: number of personnel in the equipment room and equipment room space
- Outdoor air specifications: outdoor air temperature, humidity, and cleanliness
- Economy requirements: If two or more solutions are available, you need to

analyze the initial investment and OPEX.

Contents

Calculation of the Cooling Load of Air Conditioners – Determination of the Cooling Load of Air Conditioners

Load calculation

Air conditioner cooling load

- Understand the source of the cooling load of the air conditioner.
- Understand the factors that affect the cooling load.
- Understand temperature requirements for data centers.

Collecting statistics on air conditioning functional areas

- Understand the purpose of area division.
- Calculate the cooling load for each area.
- Distinguish the characteristics of air conditioning systems in different areas.

Estimating the air conditioner cooling load

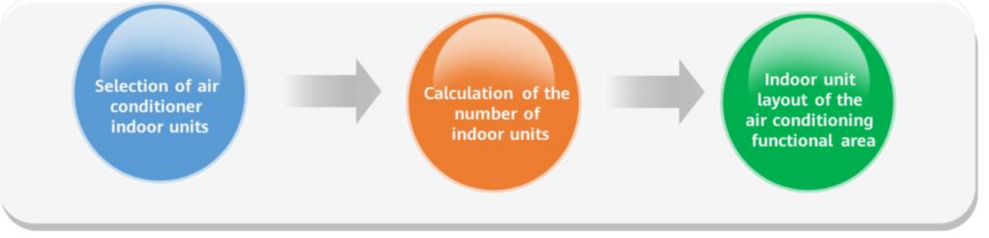
- Ways to obtain the cooling load when the conditions are not met
- Two estimation methods

Selecting IT power

- Select the optimal power density for a data center considering devices.
- Select quantity and power of devices in a single cabinet.

Determining the Air Conditioner Indoor Unit Configuration

- Determine whether to use in-cabinet, in-row, or in-room cooling based on the power density.
- Configure the air conditioner indoor unit capacity based on the estimated service growth rate.
- Check whether there are raised floors, whether cold or hot aisle containment exists, whether cold and hot air is mixed, and whether air supply is blocked in different equipment room areas.
- Determine PUE requirements, continuous cooling requirements, and reliability level requirements, and evaluate whether hot spots will occur.
- If two or more solutions are available, you need to analyze the initial investment and OPEX.



Summary

- Floor Plan
- Modular Layout Planning
- Key Points of System Planning

Quiz

True or False

1. For air-side free cooling data center, mountain fire, salt field, and hazardous chemical explosion may affect the running of the cooling system.
2. Only using direct air free cooling does not meet the Tier III standard.

- 1.T 2.T

Thank you.

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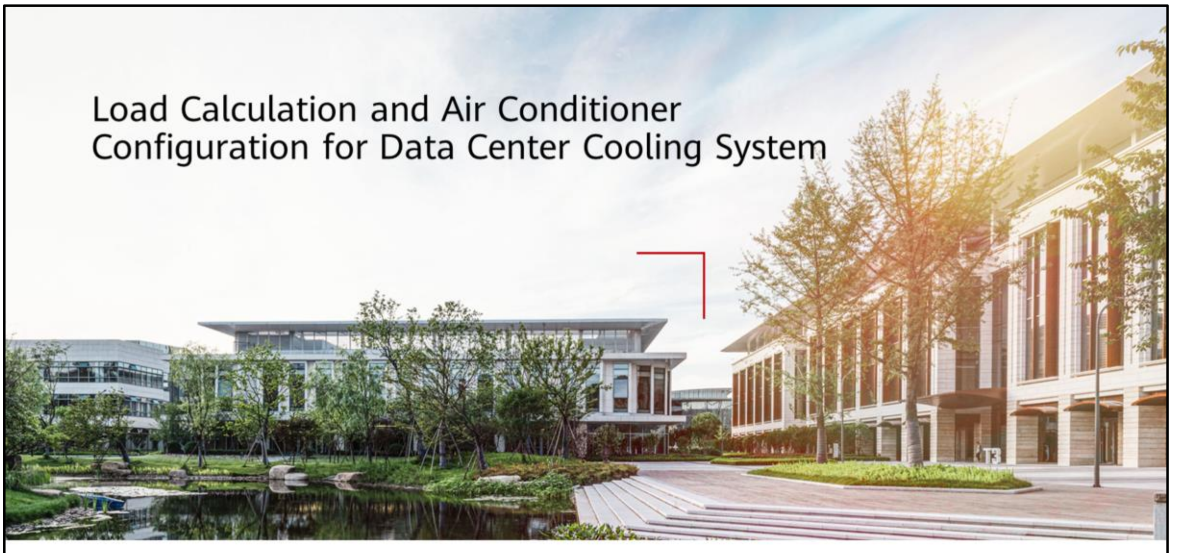
Load Calculation and Air Conditioner Configuration for Data Center Cooling System



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Foreword

- This course consists of two parts:
  - Part 1 describes the cooling load calculation principles, related standards, theoretical calculation, and load calculation examples of data center air conditioners.
  - Part 2 describes the air conditioners in a data center, in terms of configuration principles and features, recommended model selection, layout selection, and key planning points of the air supply mode.

Objectives

On completion of this course, you will be able to:

- Master the load types of data centers.
- Master how to calculate the cooling load of data centers.
- Understand the methods for estimating the cooling load.
- Be able to output simple configuration solutions.
- Get familiar with the types of data center air conditioners.
- Master the type selection of data center air conditioners.
- Master the air conditioner layout and selection in an equipment room.
- Understand the basic air supply modes and selection of data center air conditioners.

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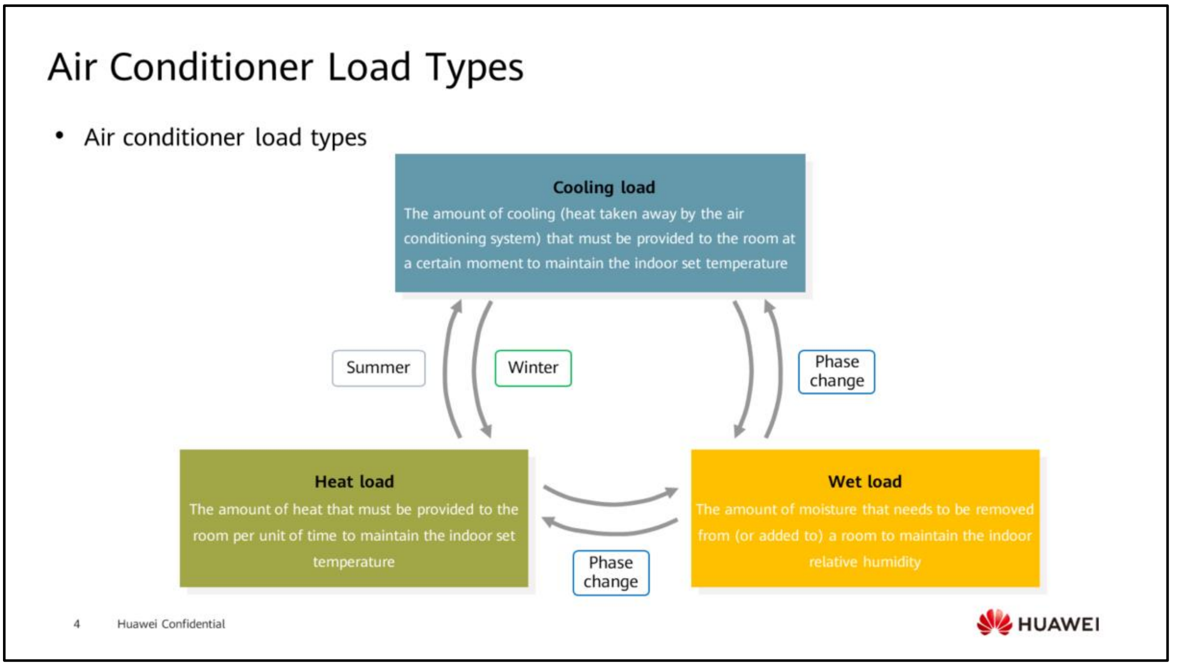
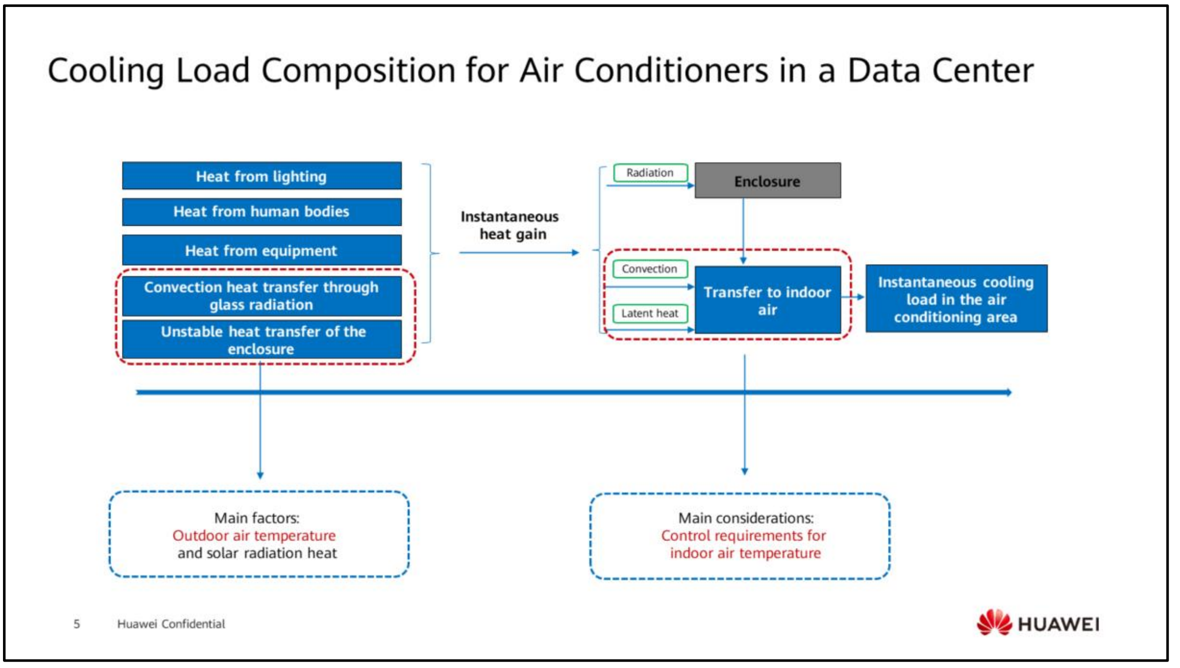
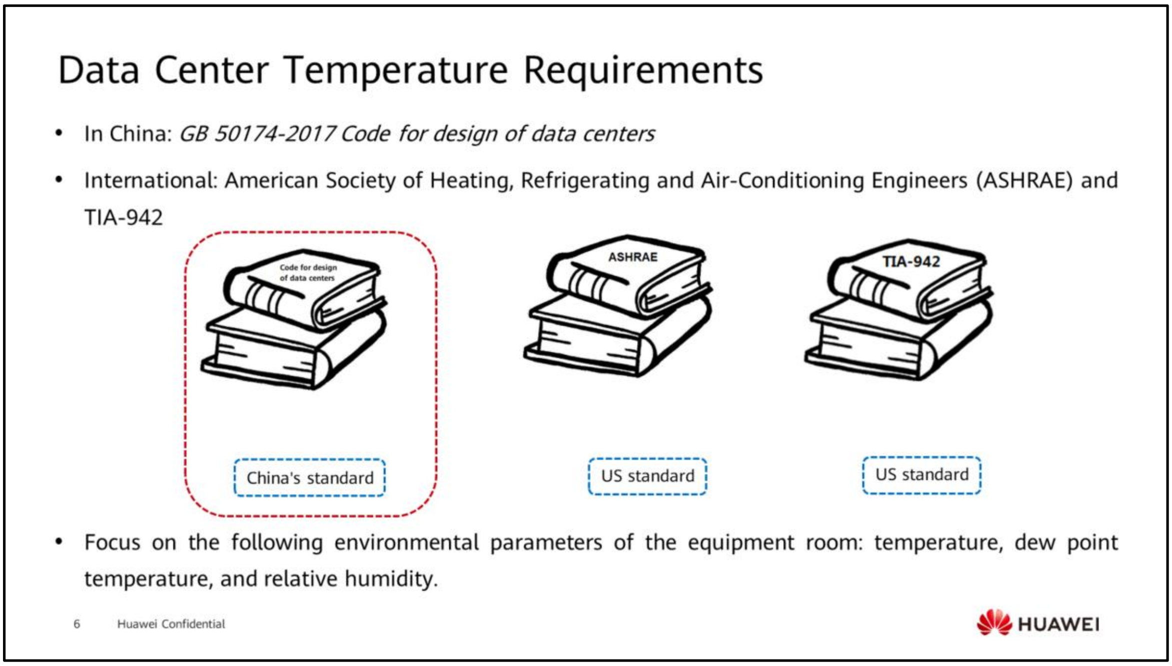


- The cooling load consists of sensible heat and latent heat.



- Instantaneous heat gain refers to the sum of all kinds of heat that enters the room through the enclosure and dissipates inside the room at a certain moment.



- The data center design consists of 12 professions, that is, process, planning, building, structure, air conditioning, power, water supply and drainage, power supply and distribution, lighting, communication information, automatic control, and technical economy. The process profession is of utmost priority, and other professions are designed to meet process requirements.
- From 2004 to 2011, ASHRAE released three editions of Thermal Guidelines for Data Processing Environments, in which the ambient temperature (intake air temperature) of servers is changed from 20° C–25° C to 18° C–27° C. This initiative has been recognized and supported by electronic information equipment manufacturers in most countries, including China.

ASHRAE - Suggestions on Temperature and Humidity Design for Data Centers (1)

- Recommended and allowable levels for Class 1, Class 2, and NEBS environments
  - The following table lists the recommended and allowable levels for Class 1, Class 2, and NEBS environments.

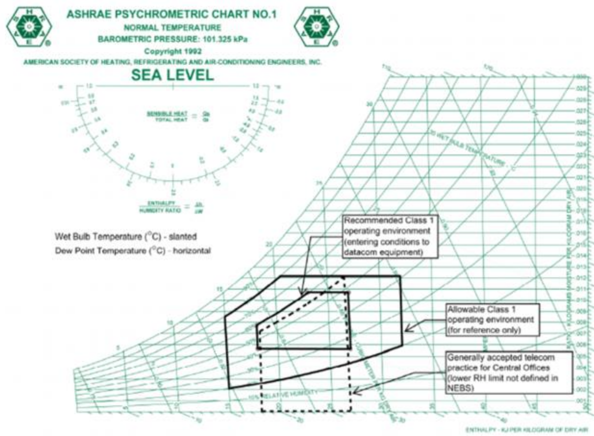
	Classes 1 and 2		NEBS	
Condition	Allowable Level	Recommended Level	Allowable Level	Recommended Level
Temperature control range[a]	15 to 32°C[f] (Class 1) 10 to 35°C[f] (Class 2)	18 to 27°C	5 to 40°C[c,f]	18 to 27°C[d]
Maximum temperature rate of change[a]	5 K/h		(cooling) 30 K/h[c] (warming) 96 K/h[c,d]	
Relative humidity control range[a]	20 to 80%, 17°C max. dew point (Class 1) 21°C max. dew point (Class 2)	Dew point 5.5 to 15°C, rh less than 60%	5 to 85%, 28°C max. dew point[c]	Max 55%[e]
Filtration quality	65%, min. 30% (MERV 11, min. MERV 8)[b]			Min. 85% (Min. MERV 13)[b]

ASHRAE's requirements for Class 1, Class 2, and NEBS environments

- If the equipment is exposed to a high temperature for a long time (the temperature fluctuation frequency or amplitude is large), the equipment fault rate increases, the equipment service life decreases, the hardware/software fault rate increases, and the heat transfer performance decreases. If the temperature exceeds the allowable range for a short time, the equipment is not affected. However, if the equipment runs close to the temperature range for several months, the occurrence probability of the preceding issues increases. Designers and managers should work hard to make the equipment work within the allowable temperature range. ASHRAE (2008) and Telcordia (2001) recommend a temperature range of 18° C to 27° C.
- Network Equipment-Building System

ASHRAE - Suggestions on Temperature and Humidity Design for Data Centers (2)

- Illustration of allowable Class 1 environmental requirements on the psychrometric chart
  - The psychrometric chart shows the recommended temperature and humidity ranges and the allowable maximum ranges for Class 1 environments.



Comparison of Environment Requirements Inside Data Centers

Item	GB 50174	ASHRAE
Temperature (°C)	18–27°C	18–27°C
Humidity	The relative humidity is less than or equal to 60%.	20–80%
Temperature change rate	< 5°C/h if a magnetic tape drive is used < 20°C/h if a magnetic tape drive is used	The recommended maximum inlet temperature change for Classes 1 and 2 is 5 K/h.
Dew point temperature (°C)	5.5–15°C	17–21°C recommended for Classes 1 and 2
Cleanliness	< 17,600,000 particles	Calculation based on the filtering level

- The operating conditions of electronic information equipment manufactured by some manufacturers in and outside China are as follows:
  - Dell: 10–35°C, 20–80%; HP: 10–35°C, 20–80%
  - Huawei: 10–35°C, 8–85%; Lenovo: 10–35°C, 8–80%

- Particle in GB 50174: number of suspended particles with a diameter greater than or equal to 0.5 µm in 1 m3 air
- The ASHRAE (2008) recommended maximum inlet temperature change is 5 K/h for Classes 1 and 2. The typical requirements for tapes are that the change rate is less than 2 K/h and the relative humidity change is less than 5%/h (ASHRAE, 2004).
- The dew point temperature is used instead of relative humidity to make the measurement more accurate. Both the dew point temperature and relative humidity can indicate the moisture content in air. When the moisture content in air remains unchanged, the dew point temperature is a fixed value, while the relative humidity varies with the temperature. Therefore, GB 50174-2017 uses dew point temperature to indicate the moisture content in air.

How to Determine the Temperature and Humidity of Data Centers

- The specific temperature and humidity range must comply with the customer's requirements. If there is no specific requirement, you are advised to select based on the following principles:
  - If there is an aisle containment, the recommended temperature for the cold aisle or server inlet is 23°C ± 2°C or 24°C ± 2°C.

Cold aisle containment

Hot aisle containment

  - If there is no aisle containment, the recommended server inlet temperature is 23°C ± 2°C or 24°C ± 2°C. Relative humidity: 50% ± 5%

- The preceding lists the temperature control recommendations for Huawei modular data centers, which are based on the China's standards. The content about dew point temperature in the China's standards is for reference only.

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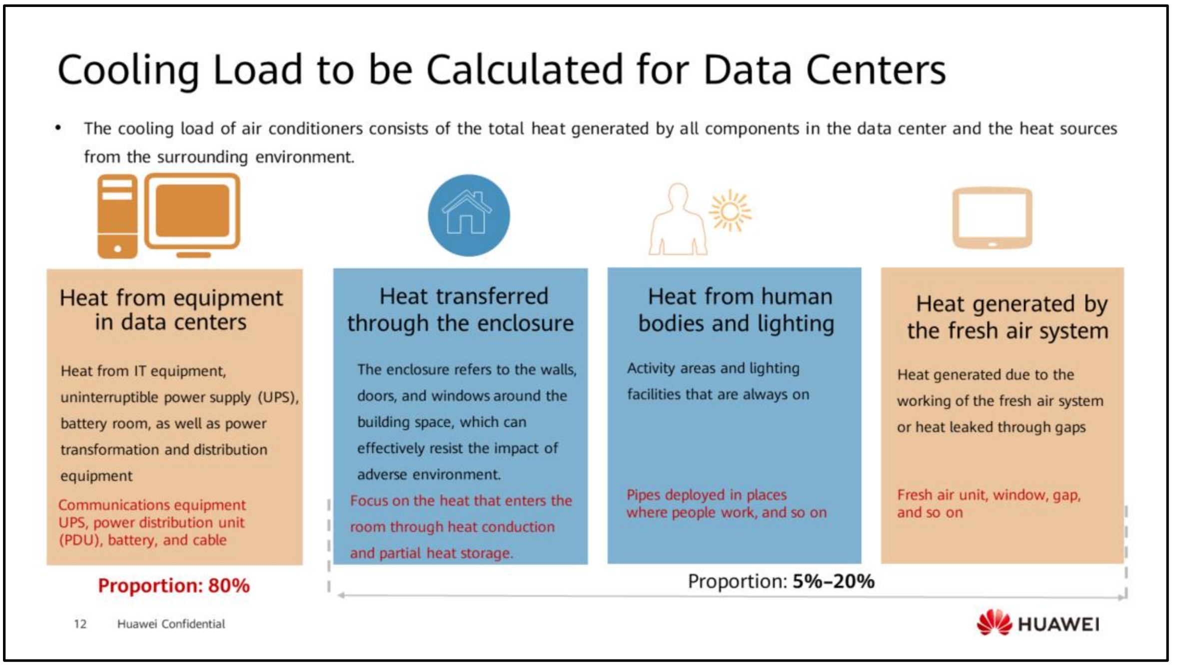
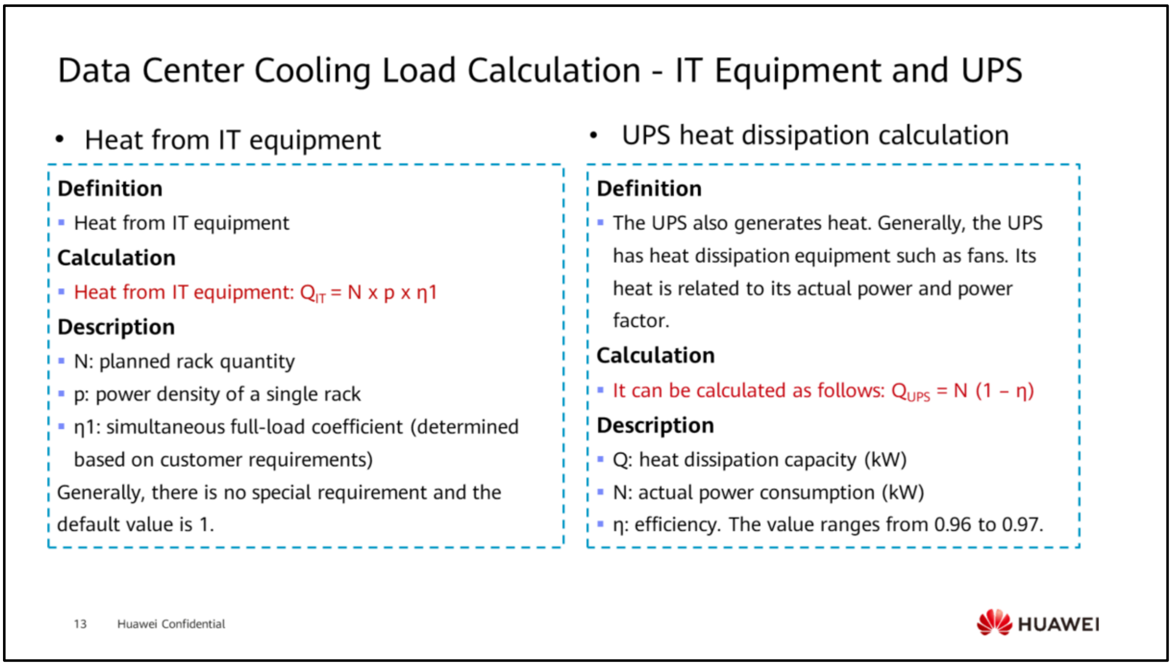


- For large data centers with outdoor walls and roofs, outdoor heat enters the data center through walls and roofs in the form of heat conduction and radiation. The air conditioning system must take away the heat. The cooling load of the air conditioning system must include this part of heat.



- The heat from IT equipment is generally a stable value.
- IT equipment includes communication equipment, servers, storage equipment, and switches.

Data Center Cooling Load Calculation - Heat from Power Transformation and Distribution Equipment

- Heat generated by power distribution equipment, such as PDUs, in Internet data centers (IDCs):

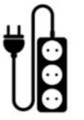
Definition

- Heat from PDUs and low-voltage (LV) power distribution equipment

Calculation

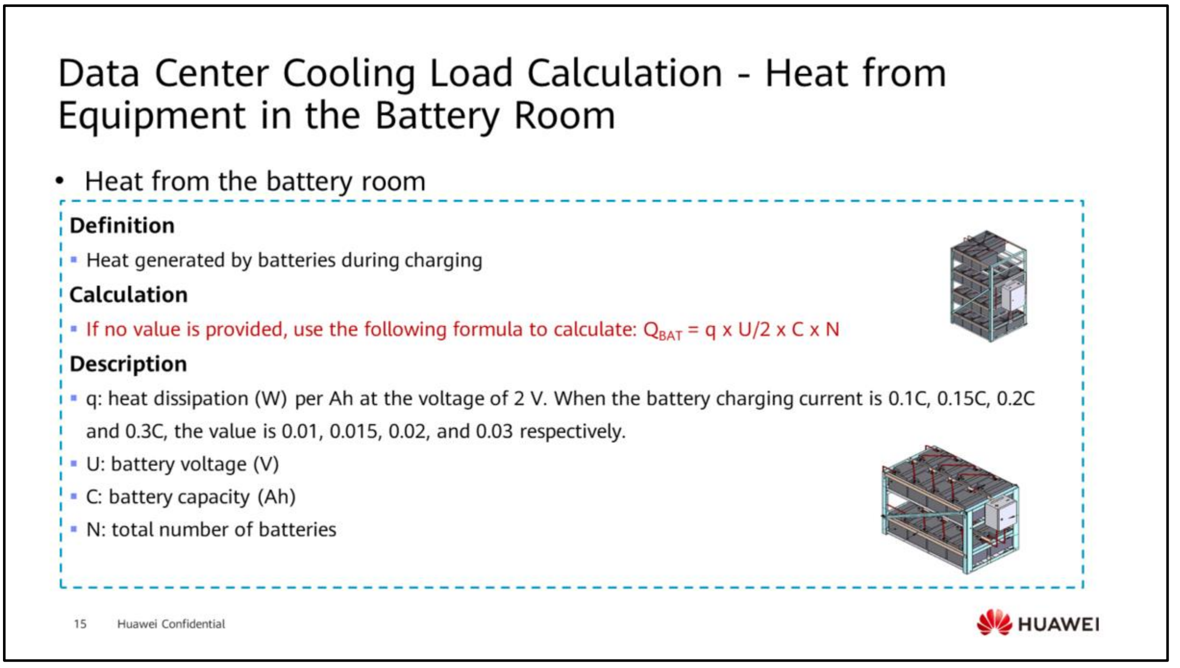
Heat from PDUs

- When the PDU is not equipped with an isolation transformer, the amount of heat generated is 0.5% x IT power consumption (kW).
- When the PDU is equipped with a built-in isolation transformer, the amount of heat generated is 2% x IT power consumption (kW).



Heat from LV power distribution equipment

- Heat from LV power distribution equipment = Total active power of the system (kW) x (1 – 99.5%)
- Heat from LV power distribution equipment = Total apparent power of the system (kVA) x Power factor x Load rate x (1 – 99.5%)



- Generally, a large-capacity UPS is deployed in an independent room. It has certain requirements for the temperature, humidity, and cleanliness of the indoor environment.

Data Center Cooling Load Calculation - Other Heat Sources

Item	Definition	Calculation	Remarks
Heat from the enclosure	Heat transferred to the data center through walls, doors, and windows due to temperature difference	Calculated based on stable heat transfer: Qw =K x F x (t1 – t2) K: heat transfer coefficient, which is calculated based on the building or ranges from 1.4 to 1.6. A value of **t1** minus **t2** may be determined based on 8°C to 10°C.	If there is no detailed calculation condition, estimate the heat dissipation by each unit: Q = A x n x 0.02 (kW/m²). In the formula, **A** indicates the area of the equipment room (m²), and **n** indicates the number of external walls, floors, and roofs that are adjacent to a non-air-conditioning room. (If the four walls of the equipment room, floor, and roof are adjacent to the non-air-conditioning room, the value of **n** is 6. If none of them is adjacent to the non-air-conditioning room, the value of **n** is 0.)
Heat from human bodies	Cooling load caused by human body heat dissipation	Human body sensible heat cooling load: Qr = p x N	p = 0.18 kW (sensible heat and latent heat generated by human bodies in the equipment room at a temperature of 24°C) N: maximum number of persons that may appear in the equipment room at the same time in normal cases.
Heat from lighting	Cooling load generated by the lighting system deployed in a room	Heat generated by lighting: Q = 1.2 x P x η1 x (Xt – T)	P: installation power of lighting equipment in the equipment room (kW) η1: simultaneous usage coefficient (provided by the electrical profession) Xt – T: cooling load coefficient of lights from the calculation time **t** to the light-on time **T** (obtained from the design manual). **1.2** is the heat dissipation coefficient additionally added for the fluorescent lamp rectifier. If there is no detailed calculation condition, estimate the heat dissipation by each unit: 15 W/m² for the IDC and UPS equipment room, and 10 W/m² for the battery room and LV power distribution room.
Heat from the fresh air system	Heat generated by the fresh air system	Qx = M x (h1 – h2)	M: fresh air volume in the equipment room (kg/s); h1: outdoor air enthalpy (kJ/kg); h2: indoor air enthalpy (kJ/kg) If the fresh air load is carried by the chilled water system of the data center, it should be included in the total cooling load. If the fresh air load is carried by an independent direct expansion (DX) air conditioner, it is not included in the total cooling load.

Load Calculation by Region (1)

- Table for air conditioner cooling load calculation by region

Region				Heat from Equipment in the Data Hall								Personnel Heat Dissipation		
Equipment Room	Floor	Area (m^2)	Net Height (m)	Number of Cabinets (N)	Average Cabinet Power (kW/Rack)	Load Coefficient η1	Simultaneous Full-Load Coefficient η2	Heat from IT Equipment (kW)	Heat Dissipation Load Coefficient of the PDU	Heat Dissipation Load of the PDU (kW)	Total Equipment Load (kW)	Heat Dissipation Per Unit (W/Person)	Number of Personnel	Total Personnel Heat Load (kW)
IDC 1														

Heat from Lighting		Heat from the Enclosure										Total Room Cooling Load	
Heat Dissipation Per Unit (W/m2)	Total Lighting Load (kW)	Heat Transfer Coefficient of the External Wall K1 W/(m2•° C)	Total External Wall Area (m2)	Rooftop Heat Transfer Coefficient K2 W/(m2•° C)	Total Rooftop Area (m2)	Indoor Design Temperature (° C)	Highest Outdoor Temperature	Heat Transfer Load of the External Wall (kW)	Heat Transfer Load of the Rooftop (kW)	Total Structure Load (kW)		Total Cooling Load (kW)	Area Load (kW/m2)

Load Calculation by Region (2)

- Load summary table

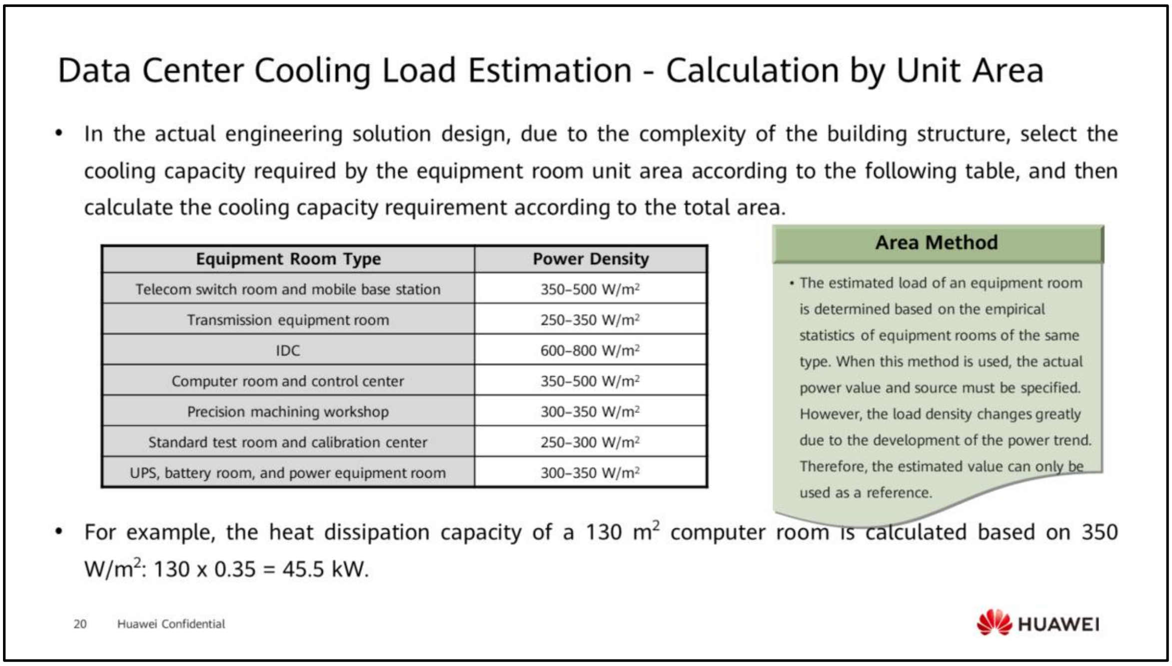
Equipment Room	Heat Dissipation Load of Equipment (kW)	Heat Dissipation Load of Personnel (kW)	Heat Dissipation Load of Lightings (kW)	Heat Dissipation Load of the Enclosure (kW)	Total Room Cooling Load (kW)	Redundancy Coefficient of Room Air Conditioners	Total Cooling Capacity of Room Air Conditioners (kW)
IDC 1							
IDC 2							
UPS room 1							
UPS room 2							
Battery room							
LV power distribution room 1							
LV power distribution room 2							
Operation room							
...							
Total Cooling Load (kW)							

- Note: If the load of the fresh air unit is carried by the chiller, the fresh air load should be included in the cooling capacity calculation of the chiller. Otherwise, it is not included.

Data Center Cooling Load Estimation Overview

- Two estimation methods:
  - Calculation by unit area
    - It is rough estimation based on the actual accumulated air conditioner load estimation counters. The air conditioner load counter refers to the cooling capacity required by the equipment in every 1 m^2 air conditioning area of the building.
  - Load statistics method (modular solution)
    - Modular solution: it is estimation based on the number of cabinets and power density of a single cabinet. Number of cabinets x Power density x Simultaneous coefficient (0.6–0.8 or 1) x Comprehensive coefficient (1.3–1.5 for open aisles and 1.1–1.2 for aisle containment)

- The total net cooling capacity of the air conditioners (after the heat generated by the air conditioners is reduced) should be greater than the cooling load of the air conditioners. The redundancy coefficient is usually multiplied by 1.05 to 1.1.



Data Center Cooling Load Estimation - Calculation by Unit Area

- In the actual engineering solution design, due to the complexity of the building structure, select the cooling capacity required by the equipment room unit area according to the following table, and then calculate the cooling capacity requirement according to the total area.

Equipment Room Type	Power Density
Telecom switch room and mobile base station	350–500 W/m^2
Transmission equipment room	250–350 W/m^2
IDC	600–800 W/m^2
Computer room and control center	350–500 W/m^2
Precision machining workshop	300–350 W/m^2
Standard test room and calibration center	250–300 W/m^2
UPS, battery room, and power equipment room	300–350 W/m^2

Area Method

- The estimated load of an equipment room is determined based on the empirical statistics of equipment rooms of the same type. When this method is used, the actual power value and source must be specified. However, the load density changes greatly due to the development of the power trend. Therefore, the estimated value can only be used as a reference.

- For example, the heat dissipation capacity of a 130 m^2 computer room is calculated based on 350 W/m^2: 130 x 0.35 = 45.5 kW.

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- This method is not used for modular data centers.

Data Center Cooling Load Estimation - Load Statistics Method (Modular Solution)

Equipment Room	Number of Racks	Power Density of a Single Rack (kW)	UPS Power (kW)	Battery Cabinet Power (Optional)	Simultaneity Coefficient (Recommended)	Comprehensive Coefficient (Aisle Containment or Open Aisle)	Total Cooling Capacity (kW)
IDC 1							
IDC 2							
...							
Total Cooling Load (kW)							

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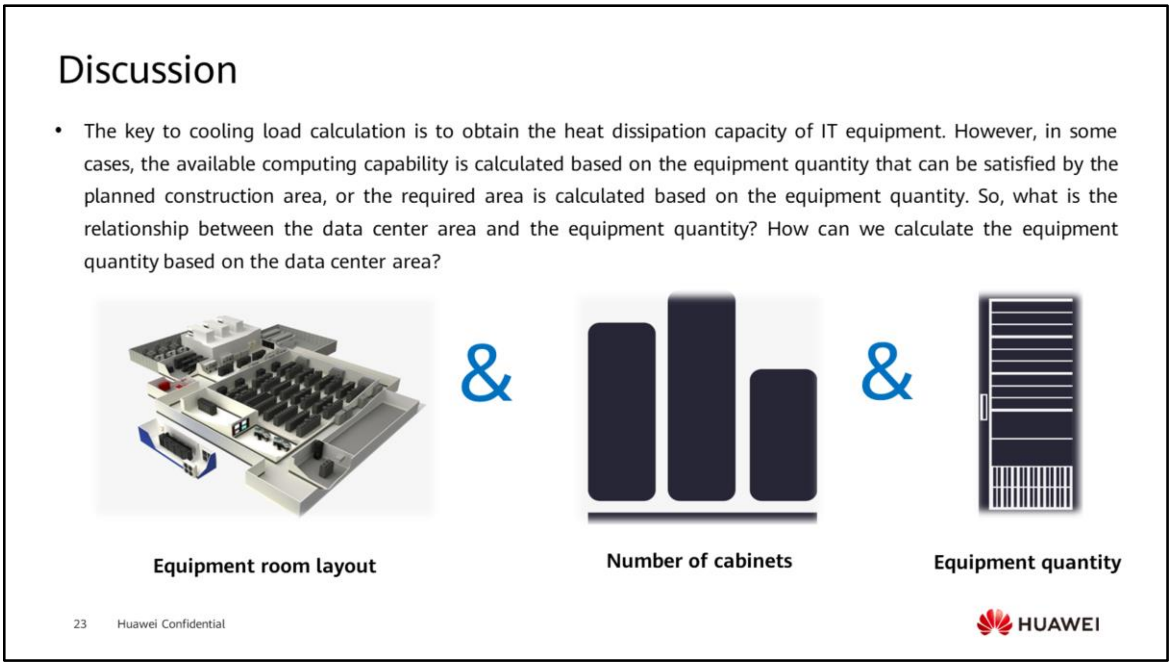
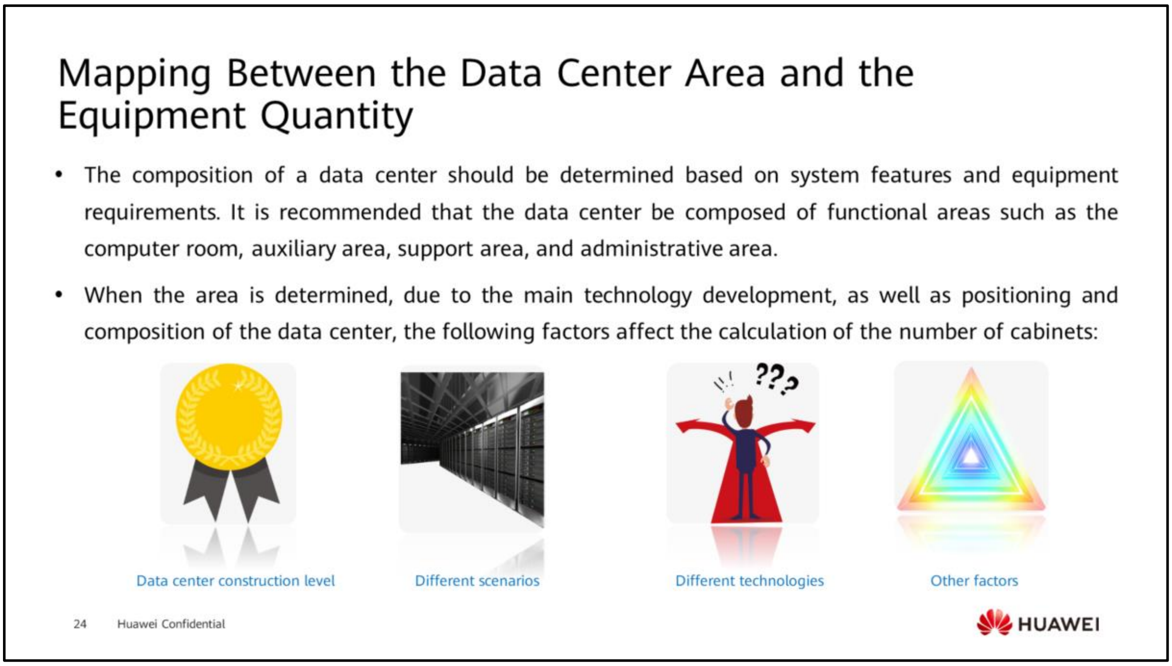


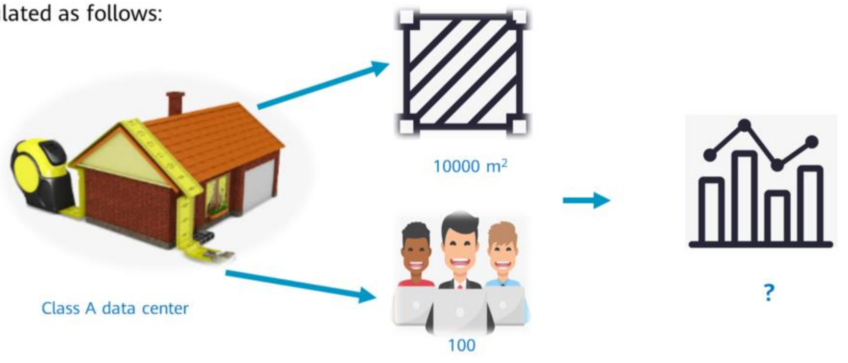
- It is common that the available computing capability is calculated based on the equipment quantity that can be satisfied by the planned construction area, or the required area is calculated based on the equipment quantity.

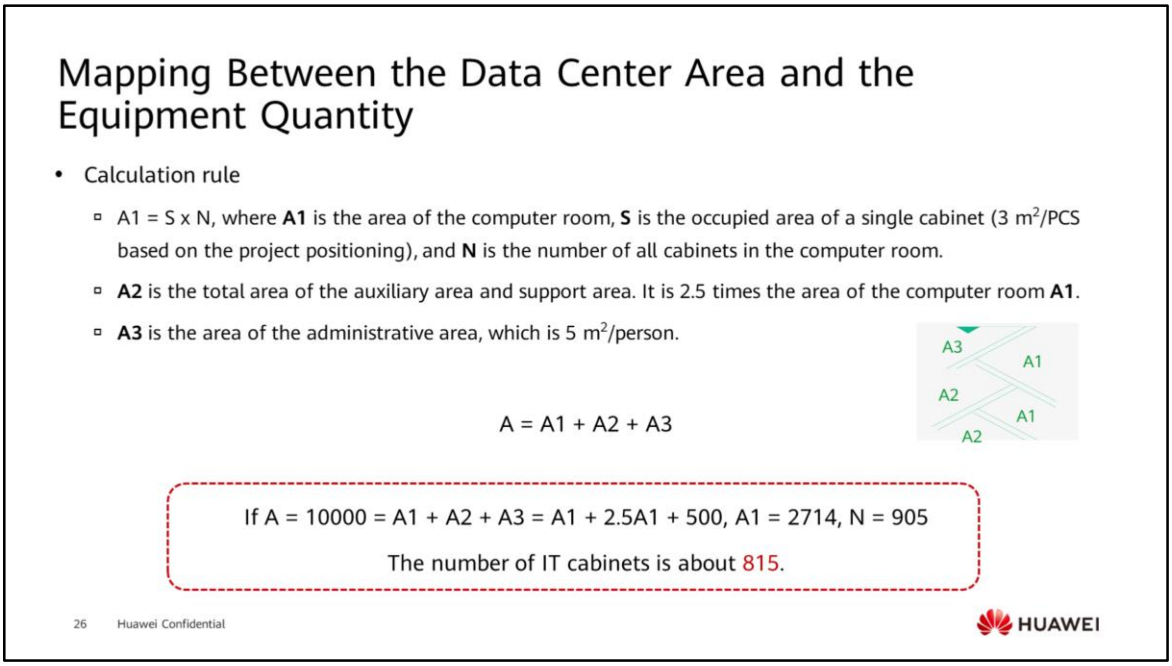


- (1) Data center construction level: According to different definitions of data center levels in and outside China, data centers of different levels have strict requirements on availability and annual shutdown time. Details are not described herein. However, data centers of different levels have different requirements on power supply and distribution and heating, ventilation and air conditioning (HVAC). As a result, the auxiliary construction area varies greatly.
- For example, Class A data centers require 2N power supply systems, and air conditioners dedicated for the equipment room work in N+X redundancy mode. Class B data centers require N+1 power supply systems, and air conditioners dedicated for the equipment room work in N+1 redundancy mode.
- (2) Impact of different scenarios on data center composition: Some data centers are constructed using idle factories and warehouses. From the perspective of reasonable space utilization, these data centers are different from new data centers. In addition, the building structure and shape of the building may have some individual differences on the effective usage of the data center area.
- (3) Impact of different technologies on data center composition: From the perspective of air conditioning, the selection of air-cooled and water-cooled technologies affects not only the air supply mode and airflow organization design of the data center, but also the space of the auxiliary area. For example, the water-cooled condensation tower is generally deployed on the top of the data center building, while the air-cooled air conditioners are distributed by floor.
- (4) Other factors: The importance of services involved in some data centers or the wide application of professions will increase the number of maintenance personnel. Whether the space occupied by the maintenance personnel is included in the overall area and whether the data center display area is included in the overall planning affect the calculation process of the two factors.

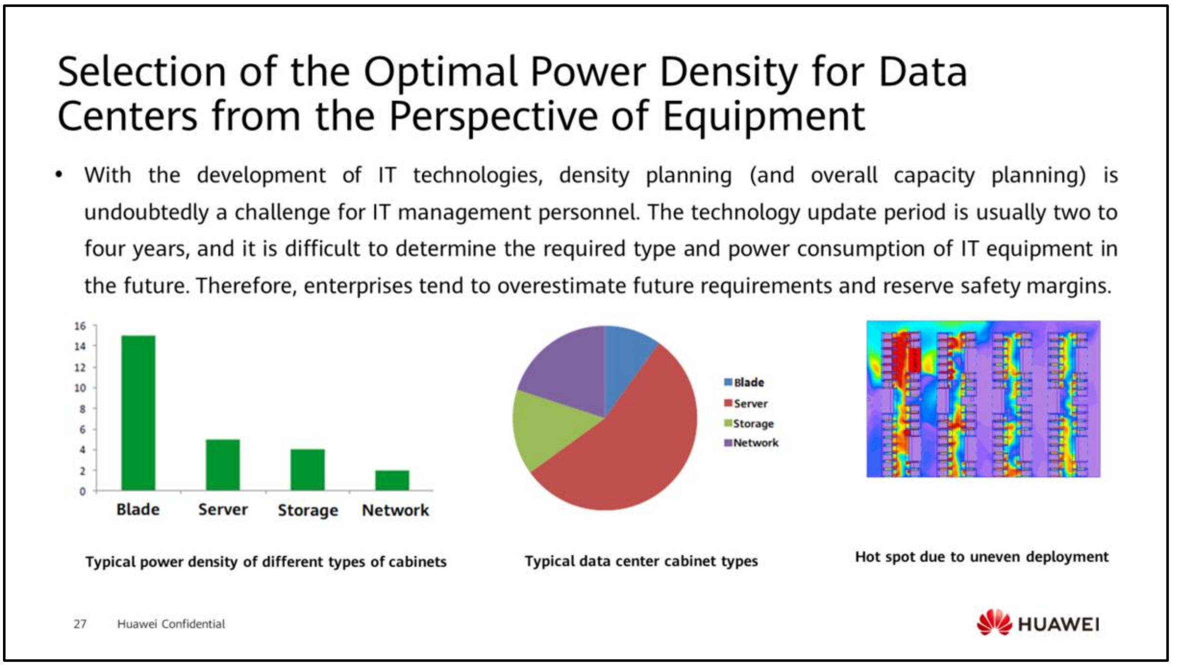
Mapping Between the Data Center Area and the Equipment Quantity

- Based on the preceding factors, assume that a new Class A data center covers an area of about 10,000 square meters and has about 100 maintenance personnel. In this scenario, the number of cabinets is calculated as follows:





- Based on the modular design of the data center, assume that every 20 cabinets form one module, including 18 IT cabinets and two power supply and distribution cabinets. The number of IT cabinets accounts for about 90% of the total number of cabinets in the computer room.



- With the development of IT technologies, density planning (and overall capacity planning) is undoubtedly a challenge for IT management personnel. The technology update period is usually two to four years, and it is difficult to determine the required type and power consumption of IT equipment in the future. Therefore, enterprises tend to overestimate future requirements and reserve safety margins. It is important to understand the following IT equipment attributes:
  - The nameplate does not reflect the actual power consumption.
  - The power consumption of IT equipment is not constant.
  - The performance (computing) per watt is improving.
- The equipment cannot reach the rated power on the nameplate. Generally, the power of IT equipment does not exceed 50% of the rated value on the nameplate. The actual power depends on the equipment configuration.

Quantity and Power of Equipment in a Single Cabinet

U space of a cabinet

U space arrangement

- In a data center, a 42 U cabinet, excluding the space occupied by switches and PDUs, provides a total of 36 U space. Considering that 1 U space is reserved between adjacent equipment in a cabinet for heat dissipation, each cabinet can house a maximum of eighteen PCS of 1 U equipment or twelve PCS of 2 U equipment.

Power adaptation analysis

- **5 kW+**: The power density of most single cabinets in a data center is lower than 5 kW. However, with the popularity of supercomputing and other services in recent years, high-density or ultra-high-density cabinets are gradually available in the market.
- According to the **statistics in 2019**, the average power consumption of a single cabinet is 5 kW, 8 kW, and 10 kW, and the service proportion is 50%, 30%, and 20%, respectively.
- **It is recommended that the average power consumption of a single cabinet be about 7 kW.**
- **5 kW cabinets are also widely used in data centers.**

Contents

Comparison of Air Conditioner Configuration Principles for Data Center Cooling System

- Comparison of Uptime, GB 50174, and TIA-942

Uptime	GB 50174	TIA-942	Functional Requirements	Equipment Configuration	System Configuration
Tier I	Class C	I	Basic requirement, no redundancy	N	The system meets basic requirements and has no redundancy.
Tier II	Class B	II	Redundant component	N+X (X = 1 to N)	N+1 redundancy provides an additional device, module, path, or system beyond the basic requirements. Failure or maintenance of any individual device, module, or path will not affect normal operation.
Tier III	Class A	III	Two systems are maintained concurrently.	2N or 2 (N+1)	Two systems are deployed in active/standby mode. 2N redundancy provides each of the basic systems with two completely same devices, modules, paths, or systems. Entire failure or maintenance of a system, including device, module, path, and system, will not affect normal operation.
Tier IV		IV	Fault tolerance	2N or 2 (N+1)	Two systems run concurrently.

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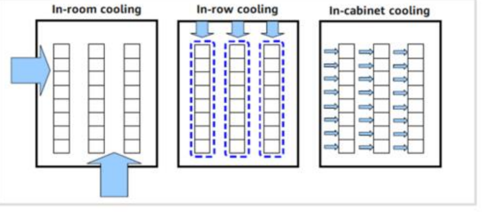
- Tier I: small- and medium-sized users whose services can be interrupted
- Tier II: ultra-high-speed, ultra-large-capacity engineering and supercomputing centers
- Tier III: data centers or equipment rooms that: mainly performs distributed data processing and sharing operations for massive storage and high-speed information query; and can tolerate occasional or transient service interruption and maximize profits. Typical application industries include BAT, telecom, and hosting enterprises.
- Tier IV: data centers or equipment rooms that perform secure, precise, short-delay, and continuous data processing and sharing. The tolerance of service interruption is zero. Typical application industries include finance, civil aviation, petrochemical, and military.

Air Conditioner Forms of In-Room, In-Row, and In-Cabinet Cooling

- The air conditioning system in a data center has two important functions: providing the total cooling capacity and distributing cold air to IT loads.
- For in-room, in-row, and in-cabinet cooling air conditioners, how to distribute cold air to loads is the key. The airflow organization is limited by the equipment room structure and layout. The actual airflow is invisible during the implementation and varies greatly with the deployment location.



Air conditioner forms of in-room, in-row, and in-cabinet cooling

Comparison Among In-Room, In-Row, and In-Cabinet Solutions in Flexibility

- Flexibility

Type		In-Room	In-Row	In-Cabinet
Flexibility	Advantages	When the power density is less than 4 kW/rack, the cooling mode can be quickly changed.	Easy to plan for any power density Easy to share cooling capacity	Easy to regulate any power density; separated from the existing cooling system √
	Disadvantages	The efficiency is low when the airflow is not contained in the entire environment.	The cold and hot aisle layout is required.	The cooling capacity cannot be shared with other cabinets.

Conclusion: In-cabinet cooling is the most flexible mode, can be deployed in shortest time, and supports the highest power density. However, extra expenditure is required.

Comparison Among In-Room, In-Row, and In-Cabinet Solutions in System Availability

- System availability

Type		In-Room	In-Row	In-Cabinet
System availability	Advantages	Redundant devices can be shared among all cabinets in a data center. √	Redundant devices can be shared among multiple cabinets in an area. Cooling close to heat sources eliminates the vertical temperature gradient. √	Cooling close to heat sources eliminates hot spots and vertical temperature gradient. High fault tolerance
	Disadvantages	Airflow containment is required to isolate cold air from hot air.	Redundancy must be deployed in each cabinet area.	Redundancy must be considered for each cabinet.

Conclusion: Both the in-row and in-room cooling has high system availability and good sharing.

Comparison Among In-Room, In-Row, and In-Cabinet Solutions in Life Cycle Cost

- Initial investment cost

Type		In-Room	In-Row	In-Cabinet
Initial investment cost	Advantages	The floor can be configured, and the airflow organization mode can be changed easily. √	The cooling requirements can be met, and the planning and engineering workload is eliminated or reduced.	Prefabricated systems and standardized components eliminate or reduce the planning and engineering workload.
	Disadvantages	The air supply is too heavy. The pressure in the underfloor downflow area depends on the equipment room size and floor depth.	The initial cost increases as the data center scale increases.	Due to the change of power, the cooling system is over-planned, which wastes the cooling capacity and increases the initial cost.

Conclusion: In in-room underfloor downflow cooling solutions, the cooling distribution mode can be quickly changed by reconfiguring the perforated floor. In a low-density data center, all cabinets share cooling redundancy. This mode is cost-effective and simple.

Comparison Among In-Room, In-Row, and In-Cabinet Solutions in Maintainability

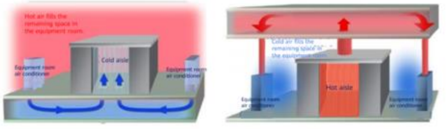
- Maintainability

Type		In-Room	In-Row	In-Cabinet
Maintainability	Advantages	The cooling equipment is located around or outdoors to keep technical personnel away from IT equipment.	Modular components shorten the shutdown time. Standardized components reduce the need for technical personnel. √	Standardized components reduce the need for technical personnel. Internal personnel can complete routine maintenance. √
	Disadvantages	The system is large and needs to be maintained by trained technical personnel or experts.	The cooling equipment is located in the cabinet row. Therefore, technical personnel need to be close to IT equipment to maintain the cooling equipment, which increases risks.	2N redundancy is required for concurrent maintenance.

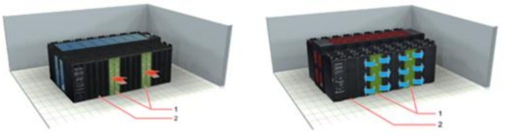
Conclusion: The in-cabinet and in-row cooling have higher maintainability. Modular components greatly reduce the maintenance difficulty.

Summary

- Conclusion: The in-room and in-row airflow containment design provides excellent flexibility, predictability, and scalability, reduces energy consumption and TCO, and improves availability, meeting the requirements of data centers. In-cabinet cooling applies to high-density and high-precision deployment or unstructured layout. In-room cooling without airflow containment will still be an effective solution for low-density data centers.



In-room air conditioner + aisle containment solution



In-row air conditioner + aisle containment solution

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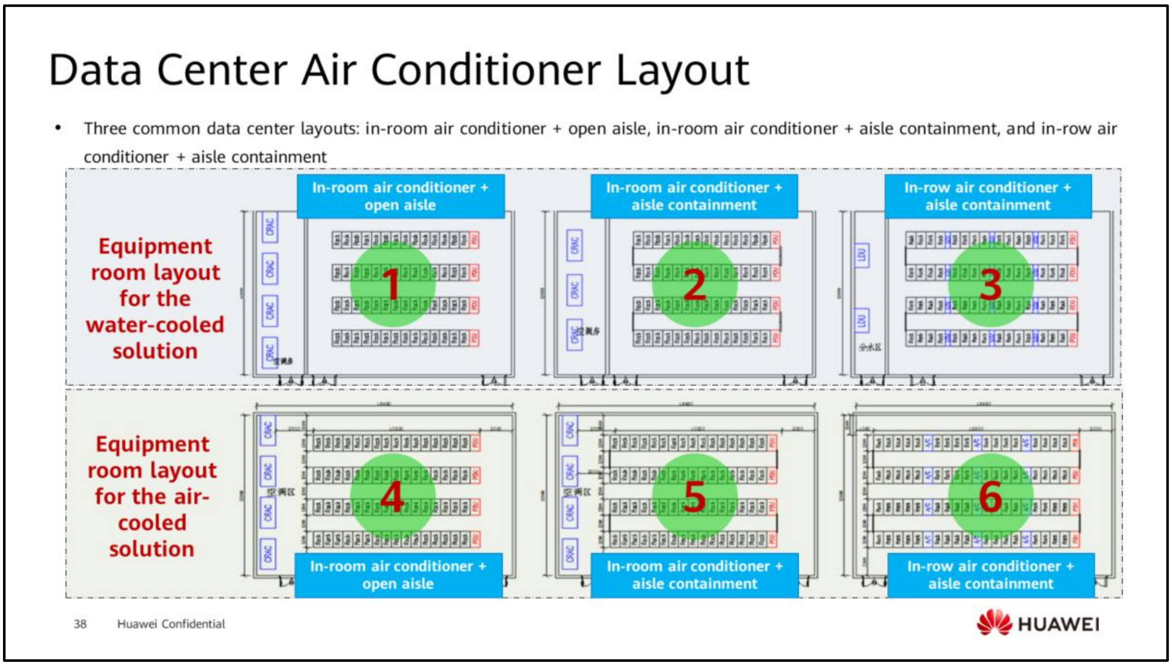
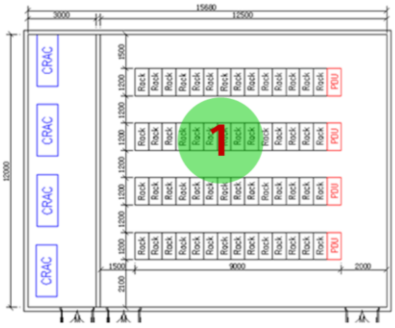


- Describe three common data center layout solutions (in-room air conditioner + open aisle, in-room air conditioner + aisle containment, and in-row air conditioner + aisle containment), and compare them in terms of equipment room utilization, supported power density, energy saving, and safety.

Water-Cooled Solution: In-Room Air Conditioner + Open Aisle

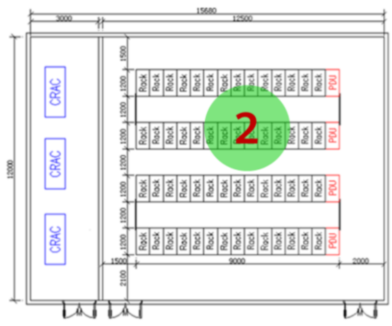
- Equipment room area: 188 m^2
- Number of racks: 56
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 56 x 4 x 0.8 x 1.4 = 250 kW
- Air conditioner configuration: four 100 kW air conditioners (three active and one standby)
- Typical PUE: 2.0–3.5
- Summary: It is a traditional solution, adopting air supply mode using air caps, and in-room air conditioner + open aisle. The cooling effect is poor due to mixing of cold and hot air. Long-distance air supply is prone to hot spots. Generally, the density of single cabinet does not exceed 4 kW/rack. It has high PUE and energy consumption. The equipment room utilization rate and safety is average. One standby air conditioner is available.



In-room air conditioner + open aisle PUE: 2.0–3.5

Water-Cooled Solution: In-Room Air Conditioner + Aisle Containment

- Equipment room area: 188 m2
- Number of racks: 56
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 56 x 4 x 0.8 x 1.15 = 206 kW
- Air conditioner configuration: three 100 kW air conditioners (two active and one standby)
- Typical PUE: 1.75–1.9
- Summary: It is an optimized traditional solution, adopting underfloor downflow, and in-room air conditioner + aisle containment. The cooling effect is good because the cold and hot air is separated. Long-distance air supply is prone to hot spots. Generally, the density of single cabinet does not exceed 5 kW/rack. Moderate PUE and energy consumption. The equipment room utilization rate and safety is average. One standby air conditioner is available.

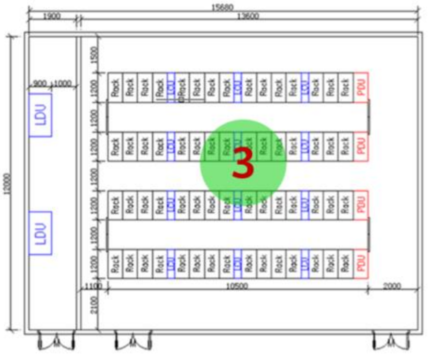


In-room air conditioner + aisle containment
PUE: 1.75–1.9

- The estimated cooling load of the equipment room is 206 kW. During configuration, a 200 kW load is configured. The error of this part has been considered in the comprehensive coefficient of 1.15.

Water-Cooled Solution: In-Row Air Conditioner + Aisle Containment

- Equipment room area: 188 m^2
- Number of racks: 60
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 60 x 4 x 0.8 x 1.15 = 220 kW. The estimated cooling load of each module is 110 kW.
- Air conditioner configuration: six 30 kW air conditioners in each module (four active and two standby)
- Typical PUE: 1.45–1.65
- Summary: It is a modular solution. The cooling effect is good because the cold and hot air is separated. Short-distance precise air supply eliminates hot spots. High-density deployment is adopted. Generally, the density of single cabinet does not exceed 13 kW/rack. Low PUE and energy consumption. The equipment room utilization rate is high, and more cabinets can be deployed compared with the traditional solution. Higher safety. Two standby air conditioners are available.



In-row air conditioner + aisle containment PUE: 1.45–1.65

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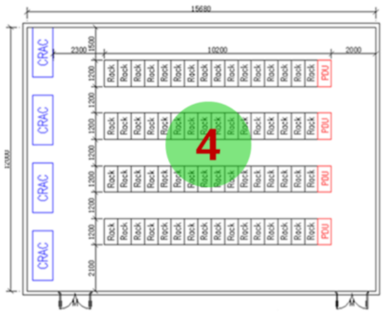
- The number of racks varies according to the installation distance of the air conditioners and the air supply distance. The in-room solution and in-row solution have their own requirements on the number of racks.

Air-Cooled Solution: In-Room Air Conditioner + Open Aisle

- Equipment room area: 188 m^2
- Number of racks: 64
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 64 x 4 x 0.8 x 1.4 = 286 kW
- Air conditioner configuration: four 100 kW air conditioners (three active and one standby)
- Typical PUE: 2.5–3.5
- Summary: It is a traditional solution, adopting air supply mode using air caps, and in-room air conditioner + open aisle. The cooling effect is poor due to mixing of cold and hot air. Long-distance air supply is prone to hot spots. Generally, the density of single cabinet does not exceed 4 kW/rack. It has high PUE and energy consumption. The equipment room utilization rate is average. Moderate safety. One standby air conditioner is available.

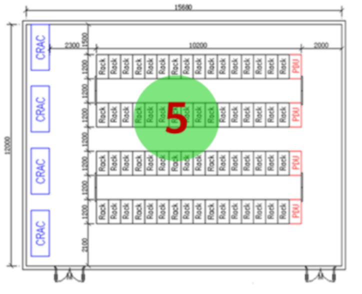


In-room air conditioner + open aisle PUE: 2.5–3.5

- Due to different installation distance requirements, the air-cooled solution has multiple cabinets compared with the water-cooled solution.

Air-Cooled Solution: In-Room Air Conditioner + Aisle Containment

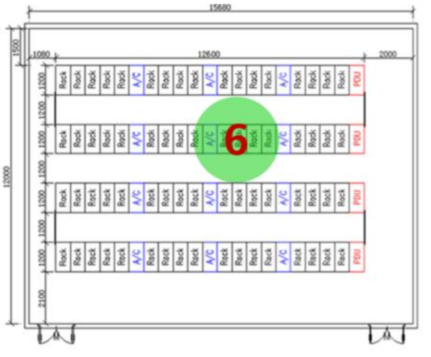
- Equipment room area: 188 m^2
- Number of racks: 64
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 64 x 4 x 0.8 x 1.15 = 236 kW
- Air conditioner configuration: four 100 kW air conditioners (three active and one standby)
- Typical PUE: 1.9–2.0
- Summary: It is an optimized traditional solution, adopting underfloor downflow, and in-room air conditioner + aisle containment. The cooling effect is good because the cold and hot air is separated. Long-distance air supply is prone to hot spots. Generally, the density of single cabinet does not exceed 5 kW/rack. Moderate PUE and energy consumption. The equipment room utilization rate is average. Moderate safety. One standby air conditioner is available.



In-room air conditioner + aisle containment
PUE: 1.9–2.0

Air-Cooled Solution: In-Row Air Conditioner + Aisle Containment

- Equipment room area: 188 m^2
- Number of racks: 68
- Power density: 4 kW/rack
- Estimated cooling load of the equipment room: Number of racks x Power density x Simultaneous coefficient (0.6 to 0.8) x Comprehensive coefficient (open aisle: 1.3 to 1.5; aisle containment: 1.1 to 1.2) = 68 x 4 x 0.8 x 1.15 = 250 kW. The estimated cooling load of each module is 125 kW.
- Air conditioner configuration: six 35 kW air conditioners in each module (four active and two standby)
- Typical PUE: 1.5–1.7
- Summary: It is a modular solution. The cooling effect is good because the cold and hot air is separated. Short-distance precise air supply eliminates hot spots. High-density deployment is supported. Generally, the density of single cabinet does not exceed 13 kW/rack. Low PUE and energy consumption. The equipment room utilization rate is high, and more cabinets can be deployed compared with the traditional solution. Higher safety. Two standby air conditioners are available.



In-row air conditioner + aisle containment PUE: 1.5–1.7

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Comparison Between Three Solutions

Item		Solution 1: In-Room + Open Aisle	Solution 2: In-Room + Aisle Containment	Solution 3: In-Row + Aisle Containment	Conclusion
Equipment room area		188 m^2	188 m^2	188 m^2	-
Water-cooled solution	Equipment room utilization rate	56 racks	56 racks	60 racks	Solution 3 has higher equipment room utilization rate.
	Maximum power density	4 kW/rack	5 kW/rack	13 kW/rack	Solution 3 supports higher power density.
	PUE	2.0–3.5	1.75–1.9	1.45–1.65	Solution 3 has lowest PUE and is most energy-saving.
	Safety	Three active air conditioners and one standby air conditioner in the equipment room	Two active air conditioners and one standby air conditioner in the equipment room	Four active air conditioners and two standby air conditioners in the module	Solution 3 has more standby air conditioners and features higher safety.
Air-cooled solution	Equipment room utilization rate	64 racks	64 racks	68 racks	Solution 3 has higher equipment room utilization rate.
	Maximum power density	4 kW/rack	5 kW/rack	13 kW/rack	Solution 3 supports higher power density.
	PUE	2.5–3.5	1.9–2.0	1.5–1.7	Solution 3 has lowest PUE and is most energy-saving.
	Safety	Three active air conditioners and one standby air conditioner in the equipment room	Three active air conditioners and one standby air conditioner in the equipment room	Four active air conditioners and two standby air conditioners in the module	Solution 3 has more standby air conditioners and features higher safety.

Conclusion: The in-row air conditioner + aisle containment solution is the optimal among the three solutions in terms of **equipment room utilization rate**, maximum **power density** of a single cabinet, **PUE**, and **safety**. The in-room + aisle containment solution is the second choice. The least recommended solution is the in-room air conditioner + open aisle solution.

Advantages of the In-Row Cooling Mode

- When designing a new data center, consider in-row cooling as the main cooling mode. Compared with the hybrid cooling architecture solution, the in-row cooling solution alone has more advantages.
  - The raised floor is not required.
  - The cabinet rows do not conflict with the cooling devices deployed around the room.
  - The redundancy is simplified.
  - Energy consumption costs are reduced.
  - Maintenance expenses are reduced.
  - Incompatibility between equipment from different vendors is reduced.

- The raised floor is not required: Generally, the cooling devices around the room need to rely on the raised floor space for the air distribution of IT equipment. However, if in-row cooling devices are used to provide cooling for the entire room, the costs for installing and maintaining the raised floor can be avoided.
- The in-row cooling devices do not conflict with those deployed around the room: When two cooling architectures are deployed in the same room, they may conflict with each other in terms of heating, cooling, humidification, and dehumidification. This will lead to lower operational efficiency and higher electricity bills. However, if only in-row cooling devices are used, and equipment can coordinate with each other, thereby avoiding such a conflict.
- The initial investment is reduced: The combination of in-row cooling and cooling deployed around the room is too conservative, resulting in a huge waste of money. Using only in-row cooling devices to cool loads in the data center can reduce the cost by 50%.
- The redundancy is simplified: If a data center needs to use the N+1, N+2, or 2N redundancy design, the cooling devices around the room do not require redundancy, saving more costs.
- Energy consumption costs are reduced: Excessive additions to cooling devices often lead to higher energy consumption costs, which are more pronounced if the excess cooling devices are powered by constant-speed fans (commonly used in ceiling-mounted cooling devices around rooms).
- Maintenance expenses are reduced: Using only in-row cooling devices eliminates the need of maintaining cooling devices around the room and reduces the OPEX of a data center.
- Incompatibility between equipment from different vendors is reduced: When the hybrid design is used, the systems used are usually from different vendors. The more devices

from different vendors are used, the more complex the data center O&M becomes.

Contents

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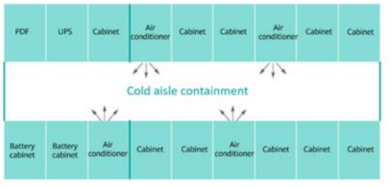
In-Row Cooling Solution

- Key planning points for in-row air supply (commonly used in data centers): Determine the air conditioner type, whether cold aisle containment is used, and the unit positioning.
- Air conditioner type
  - DX in-row air conditioner (Consider the piping and drainage modes. If necessary, consider the raised floor mode.)
  - Chilled water (CW) in-row air conditioner (Consider chilled water piping mode)

Top piping	Bottom piping
1. No raised floor is required, and the layout is simple. 2. Water pipes are routed from the top, which threatens equipment safety in case of water leakage.	1. The raised floor is required. 2. Water leakage does not threaten equipment safety.

- Precautions for unit positioning
  - ➢ Ensure that there is no gap between cabinets.
  - ➢ Avoid mixing of cold and hot air.
  - ➢ Place the air conditioner in a proper position.
  - ➢ Keep equipment load balance



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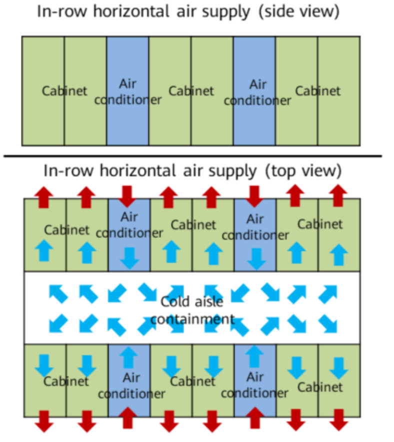
- In-row air conditioners can be used if the power density is greater than 5 kW/rack.

Characteristics of In-Row Air Supply

- Characteristics of in-row air supply
  - Close-coupled cooling and cold aisle form a cold-pool plenum to ensure even air supply.
  - Better cooling distribution to ensure more even cooling and airflow
  - Higher cost, lower PUE, and easy to deploy in phases
  - Low requirements on the floor height. The raised floor is not mandatory.
  - Applicable to medium- and high-density data centers with a power density greater than or equal to 5 kW/cabinet



In-Room Cooling Solution

- Key planning points for in-room air supply: Determine the type and air supply mode of in-room air conditioners, whether to use cold aisle containment, air return mode, and unit positioning.
- Air conditioner type
  - DX in-row air conditioner
  - CW in-row air conditioner
- Air supply mode
  - Upflow: Consider air cap and air duct configurations.
  - Downflow: Estimate and determine the height of the raised floor, whether aisle containment is used, and the air return mode.

In-Room Cooling Solution - Upflow

- Key planning points of upflow: Air cap vs. Air duct (rarely used in new data centers)

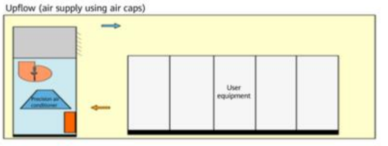
Upflow using air caps

Advantages: simple construction, low cost, and short air supply distance. Generally, the air supply distance of the air conditioners is less than or equal to 25 m.

Disadvantage: poor uniformity of the temperature field

The noise is loud.

Applicable to: small- and medium-sized data centers where the air supply distance of a single air conditioner is less than 25 m

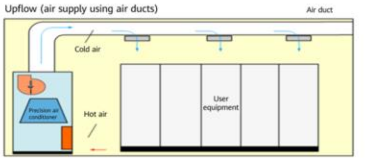


Upflow using air ducts

Advantages: long air supply distance and even air supply

Disadvantages: high construction cost and complex engineering. Enough floor height of a data center is required (the air duct is 500 mm thick).

Applicable to medium- and large-sized data centers that have high requirements for air conditioners or use air caps to supply air unconditionally. Select a proper external residual pressure based on the distance between air ducts.



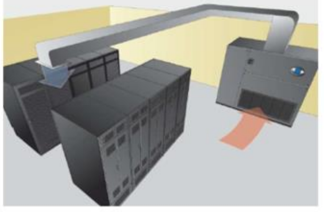
In-Room Cooling Solution - Downflow

- Key planning points for underfloor downflow (commonly used in data centers): Estimate and determine the height of the raised floor, whether aisle containment is used, and the air return mode.
- Aisle containment
  - Generally, it is recommended that the cold and hot aisles be used if the power density of a data center is 1–4 kW/rack to meet equipment requirements.
  - If the power density is greater than 4 kW/rack, cold or hot aisle containment is recommended. Currently, cold aisle containment is more widely used than hot aisle containment.
- Return air type

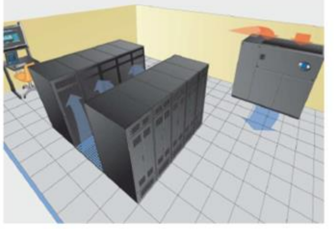
Return Air Type	Characteristic
Free air return	If the return air efficiency of the data center is low, the overall temperature of the data center will be high. Therefore, when power cables are routed from the top, the air return vent of the air conditioners must be located under the power cables to prevent the power cables from blocking the hot air return.
Air return from the ceiling	The return air vent is set on the suspended ceiling of the hot aisle. In this way, the hot air is guided, and the cold and hot air cannot be mixed easily. As a return air plenum, the suspended ceiling ensures a stable and efficient return air process.

Comparison Between Upflow and Downflow Applications

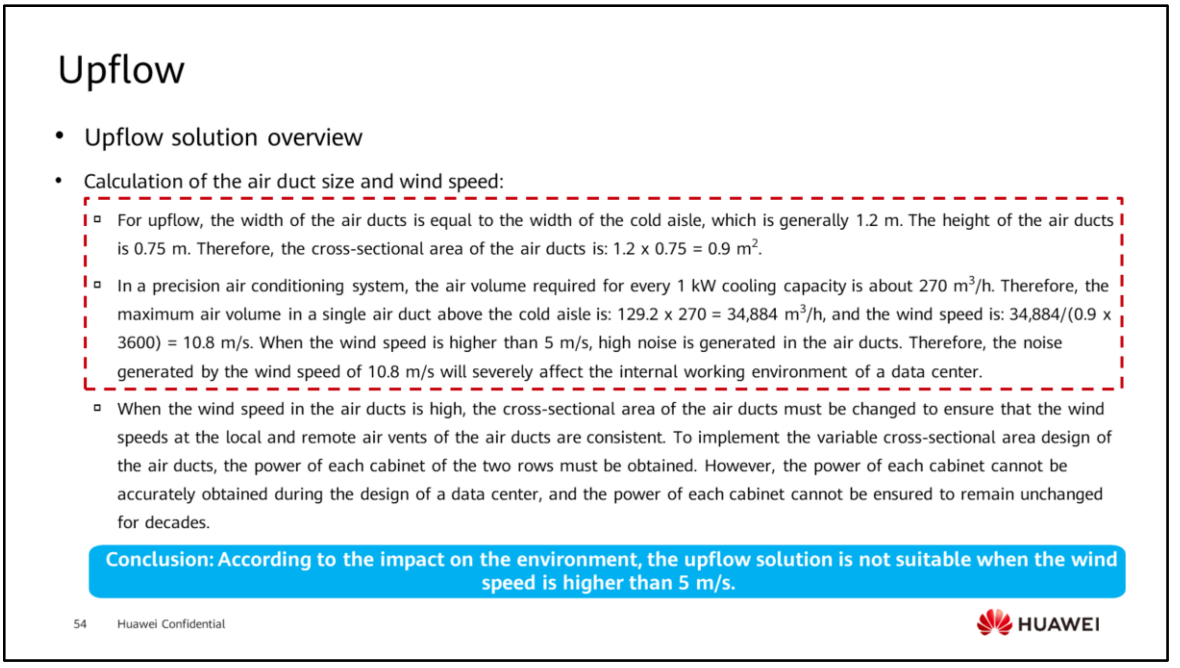
- Which of the two air supply modes is more reasonable? The analysis is as follows.
- Assume that there are 17 cabinets in each row of the cold aisle and hot aisle in a data center. The cooling load of each cabinet is 3.8 kW. The total cooling load of the two rows of cabinets on both sides of the cold aisle is: 17 x 2 x 3.8 = 129.2 kW.



Air supply diagram 1



Air supply diagram 2



- When the upflow mode is used, cabinets are installed in rows on the hard floor. Air supply ducts are deployed above the cold aisles, and cable trays are deployed above the cabinets.

Downflow

- Downflow solution overview
- Calculation of the air duct size and wind speed:
  - When the downflow mode is used, the space under the raised floor can house a large plenum. Cold air enters the plenum from the air conditioners, and then is sent to the cold aisle in the front of the cabinet through the air supply vent on the floor. The size of the plenum can be selected as required.
  - The width of the two rows of cabinets is 3.6 m. If the net height of the floor is 0.75 m, the maximum wind speed under the floor is: 34,884/(3.6 x 0.75 x 3600) = 3.58 m/s when the downflow mode is used. Therefore, compared with the upflow mode, the wind speed is significantly reduced.
  - In the downflow mode, the air vent floor with adjustable ventilation rate is used. The ventilation area and wind speed of the front air vent floor of each cabinet are adjusted to provide proper air volume based on the cabinet requirements.

Conclusion: The downflow mode has low wind speed and is easy to achieve on-demand air supply.

- If the indoor net height of the building where the data center is located meets the requirements, adopt the air return mode using space above the suspended ceiling. In this way, the ineffective mixing of cold air and hot air is reduced as much as possible, and the efficiency of the air conditioning system is improved.

Conclusion

- Assume that there are 17 cabinets in each row of the cold aisle and hot aisle in a data center. The cooling load of each cabinet is 3.8 kW. The total cooling load of the two rows of cabinets on both sides of the cold aisle is: 17 x 2 x 3.8 = 129.2 kW.

Item	Air Duct Size	Wind Speed	Air Supply Evenness	Noise Level	Aesthetics
Upflow	Large	High	Poor	High	Poor
Downflow	Standard	Low	Adjustable	Low	Good

Underfloor Downflow vs. In-Row Air Supply

- There are two modes of airflow organization in data centers: underfloor downflow and in-row air supply. The following table lists the comparison between the two modes.

Item	Downward Air Supply and Upward Air Return (Data Center)	In-Row Air Supply (Data Center)
Hot spot probability	Changes in the cabinet power density may cause hot spots.	Changes in the cabinet power density can be adjusted by means of cooling capacity sharing to reduce the possibility of hot spots.
Airflow mixing	If the aisle is not sealed, cold and hot airflows may be mixed, reducing the cooling effect.	Close to the heat source, short air supply distance, and good cold and hot partition prevent the possibility of airflow mixing.
Cooling capacity allocation	The pressure of underfloor downflow depends on the equipment room dimensions and floor depth. During design and selection, ultra-large models are used to ensure reliability.	The cooling requirement and cooling capacity can be accurately matched without over-planning.
Application scenarios	Applicable to the scenario where the cabinet power density is low	Applies to scenarios where the power density is greater than 5 kW/rack, especially greater than 8 kW/rack.

- In the process of selecting the indoor airflow organization for a data center, in-row air supply as well as downward air supply and upward air return are the most commonly used air supply modes.
- Generally, the underfloor downflow mode is used in scenarios with low power density (lower than 8 kW/rack), and the in-row air supply mode is used in scenarios with high power density.

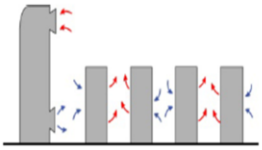
Recommended Air Supply Solution

- The underfloor downflow mode is not flexible, and the cooling effect is poor when the power density is high. Therefore, this mode applies to low-density scenarios. The in-row air supply mode applies to modular layouts and high-density scenarios.
- Before selecting an air supply solution, determine the air supply mode first: underfloor downflow or in-row air supply. Then select an appropriate air supply solution based on the cabinet power density. For details about how to select a proper air supply solution, see the following table.

Scale	Power Density (kW/Rack)	Air Supply Solution
Small-sized data center	$1 \leq P \leq 5$	Underfloor downflow + Cold and hot aisle (unsealed)
Medium-sized data center	$5 < P \leq 8$	Underfloor downflow + Cold aisle containment
		Underfloor downflow + Cold aisle containment
Large-sized data center	$5 < P \leq 15$	In-row air supply + Cold/Hot aisle containment

Return Air Solution in Free Air Supply Mode

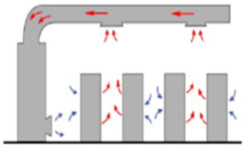
- In-room cooling



Free air return

Small-sized network equipment room (power consumption less than 40 kW):

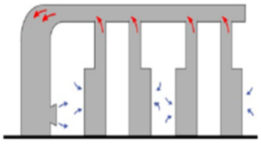
- ✓ Not recommended for most data centers
- ✓ Low cost
- ✓ The energy efficiency is the lowest in all airflow distribution architectures because all cold airflows will be mixed with hot return air. The supply air temperature is difficult to predict.
- ✓ Racks with a maximum cooling power consumption of 4 kW can be cooled.



Precise air return

General-purpose equipment room (power consumption less than 40 kW):

- ✓ Not recommended for most data centers
- ✓ Low cost and easy installation
- ✓ It is more energy efficient than free air return, because 40–70% of the IT hot return air will be captured and transferred back to the cooling equipment. The air supply temperature is more predictable than free air supply due to less mixing of hot air and cold air.
- ✓ Racks with a maximum cooling power consumption of 8 kW can be cooled.



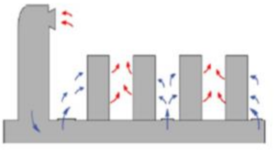
Air return with airflow containment

Large-sized or hosting data center:

- ✓ The energy efficiency is the highest in all airflow distribution architectures because the architecture allows high supply air temperature of cooling equipment, which increases the duration of free cooling.
- ✓ 70–100% of the IT exhaust hot air will be captured and transferred back to the cooling equipment. The air supply temperature is the most predictable because hot air is not mixed with cold air.

Return Air Solution in Precise Air Supply Mode

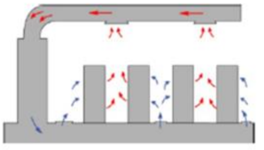
- In-room cooling



Free air return

Data center with constant power density:

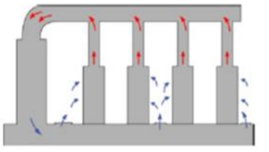
- ✓ Not recommended for new data centers because the predictable power density cannot be met.
- ✓ It is more energy efficient than free air supply because more hot air is transferred back to the cooling equipment.
- ✓ Racks with a maximum cooling power consumption of 6 kW can be cooled.



Precise air return

Small and medium-sized data center:

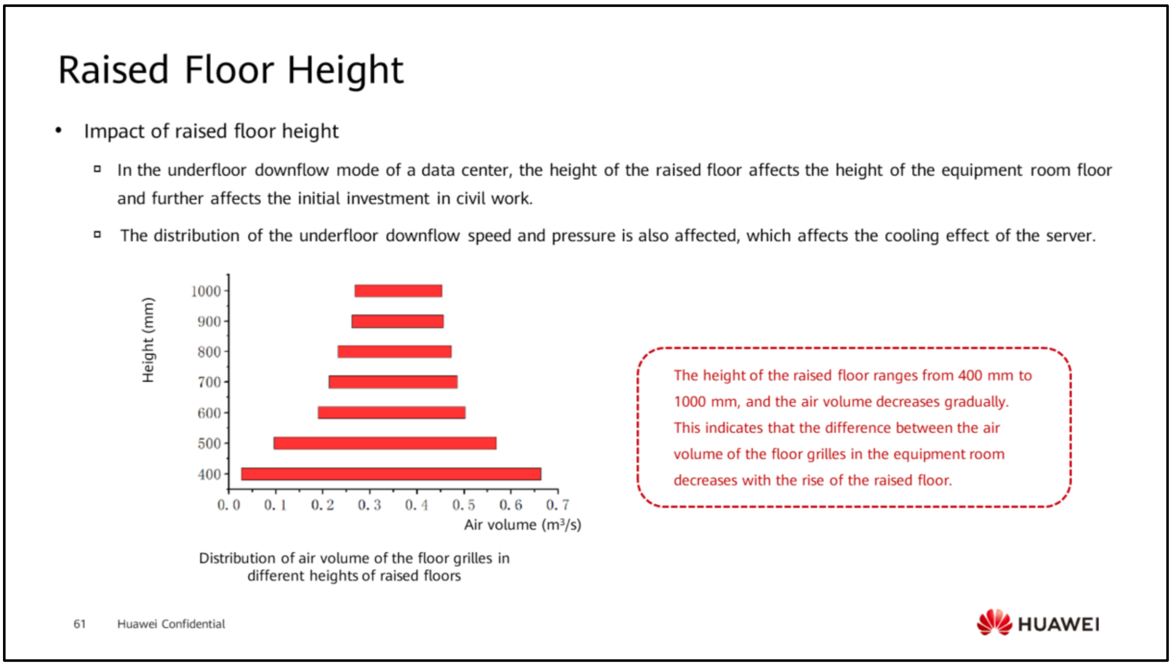
- ✓ It is more energy efficient than free air return, because 60–80% of the IT hot return air will be captured and transferred back to the cooling equipment. The air supply temperature is more predictable than free air supply due to less mixing of hot air and cold air.
- ✓ Racks with a maximum cooling power consumption of 8 kW can be cooled.



Air return with airflow containment

High-temperature rack:

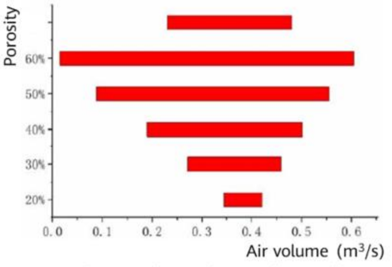
- ✓ It has higher energy efficiency than precision air supply and return because 70–100% of the IT hot return air will be captured and transferred back to the cooling equipment. The air supply temperature is the most predictable because hot air is not mixed with cold air.
- ✓ Higher supply air temperature for cooling equipment is supported, thereby increasing the duration of free cooling.
- ✓ Racks with a maximum cooling power consumption of 30 kW can be cooled.



- In a proper scale, try to select a higher floor.
- In the preceding figure, the height of the raised floor is the only variable. Seven groups of raised floor heights (400 mm, 500 mm, 600 mm, 700 mm, 800 mm, 900 mm and 1000 mm) are selected for comparison and analysis. Five typical cross-sectional areas and the temperature of the entire equipment room are selected for comparison and analysis.

Air Supply Grille Porosity

- Impact of underfloor downflow grille porosity
  - The objective of data center cooling is to ensure that the server inlet temperature does not exceed the maximum allowable inlet temperature. The main cause of the high inlet temperature of the cabinet server is that the cooling airflow through the floor grilles is insufficient. As a result, the server sucks in the hot air from the hot aisle and forms hot spots.



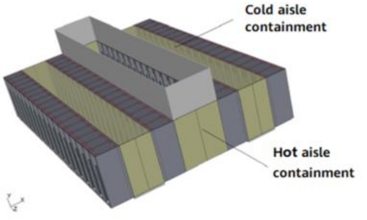
Distribution of air volume in floor grilles

As the porosity of the floor grilles decreases, the unevenness of the air volume of the floor grille in the equipment room decreases.

- The preceding figure shows the distribution of the air volume in floor grilles. The longer the red bar, the worse the evenness of air exhaust.

Underfloor Downflow - Cold/Hot Aisle Containment

- Cold aisle containment indicates that the two ends and top of the cold aisle are sealed. The cold air passes through the cabinet server and then returns to the air conditioners through the air return vent for cooling. Hot aisle containment refers to installing pipes on the hot aisle to lead the hot air discharged by the cabinet server to the suspended ceiling and then to the air conditioners for cooling.

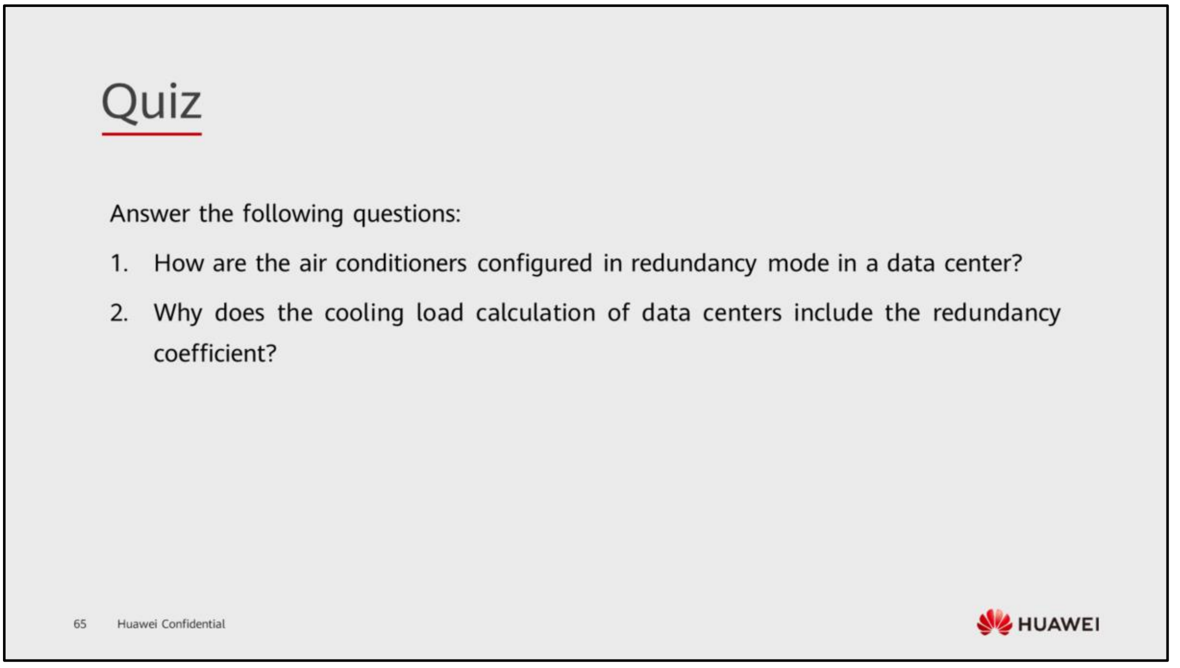


Underfloor downflow – cold and hot aisle containment

- When the hot aisle is sealed, cold air can be transferred from any position in the equipment room to the cabinet server. Therefore, there is no requirement on the raised floor. For the airflow distribution mode of raised floor air supply, the cold aisle containment is more economical, efficient, simple, and easy to implement. The cold/hot aisle containment can prevent mixing of cold and hot air, reduce the intake air temperature of cold air, and reduce partial overheating. As the mixing of cold air and hot air is reduced, the temperature difference between the supply air and return air is increased, and the cooling efficiency of the air conditioning system is improved. For data centers with a power density of 4–8 kW/rack, aisle containments must be considered.

Summary

- Selection of the air conditioner type of the data center air conditioner
- Equipment room layout and selection of air conditioners
- Air supply mode and selection of data center air conditioners
- Data center load type
- Cooling load calculation of data centers
- Cooling load estimation method



- 1. The N+1 or N+X mode varies depending on customer requirements and data center levels.
- 2. The cooling loss and other impacts are considered.

Thank you.

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Data Center Chilled Water Air Conditioning System Configuration

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Foreword

- This course introduces components, configuration principles and methods, and energy saving configuration methods of the chilled water air conditioning system in a data center.

Objectives

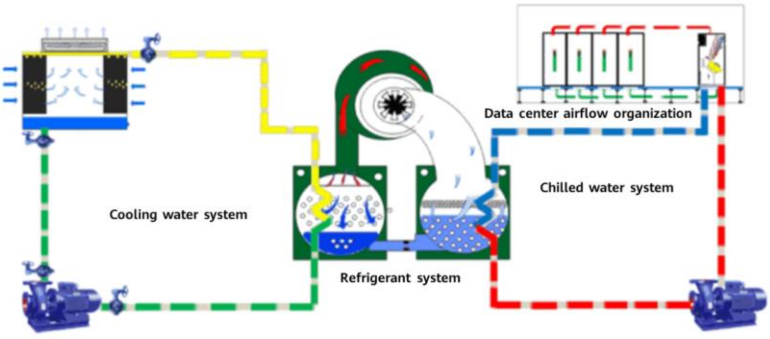
On completion of this course, you will be able to:

- Get familiar with the configuration methods of chilled water air conditioners in a data center.
- Understand the air conditioner water system types and their application scenarios.
- Calculate the air conditioner configuration based on actual projects.
- Study the feasibility of the chilled water air conditioning system.

Contents

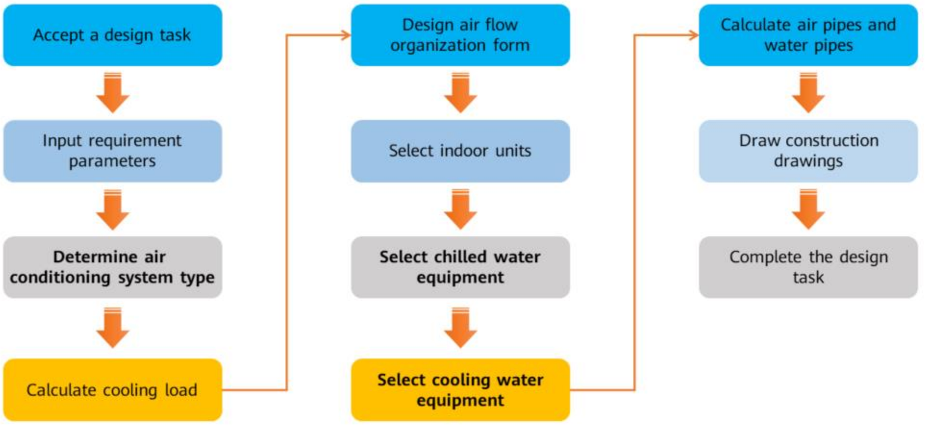
Chilled Water Air Conditioning System Components

- Chilled water system: consists of chillers, transmission pipes, chilled water pumps, indoor units, valves, and other accessories.
- Cooling water system: consists of cooling towers, transmission pipes, cooling water pumps, valves, and other accessories.
- Condensate water system: consists of transmission pipes, drainage pumps, etc.



- Cold (hot) water system: provides cold (hot) water for air handling units.
- Cooling water system: provides cooling water for the condenser of a water-cooled chiller.
- Condensate water system: discharges air condensate water.

Configuration Design Process for the Chilled Water Air Conditioning System



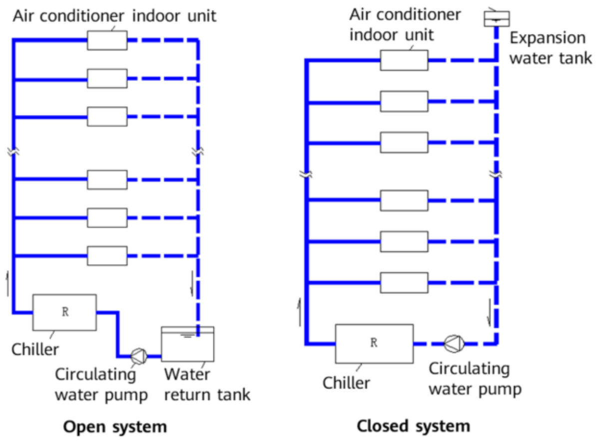
Contents

Chilled Water System Classification

- The chilled water system is a bridge between the cooling source and the indoor units. It is better to consume less energy in transmission. Therefore, the proper design and configuration of the chilled water system ensure the safe and economical operation of the air conditioning system in a data center.
- The chilled water system needs to be determined based on the project scale, data center function requirements, climatic conditions, cooling sources, pumps, and indoor units. After technical and economic comparison, the chilled water system can be designed as an air conditioning system with different pipe types and adjustment modes.
- In the air conditioning engineering, air conditioning systems can be classified from different perspectives. There are five classification bases: circulation mode, water supply and return mode, pipe distribution mode, operation adjustment mode, and circulating pump configuration mode. In the actual design of the air conditioning system, these different bases need to be considered to select the air conditioning system suitable for the actual project.

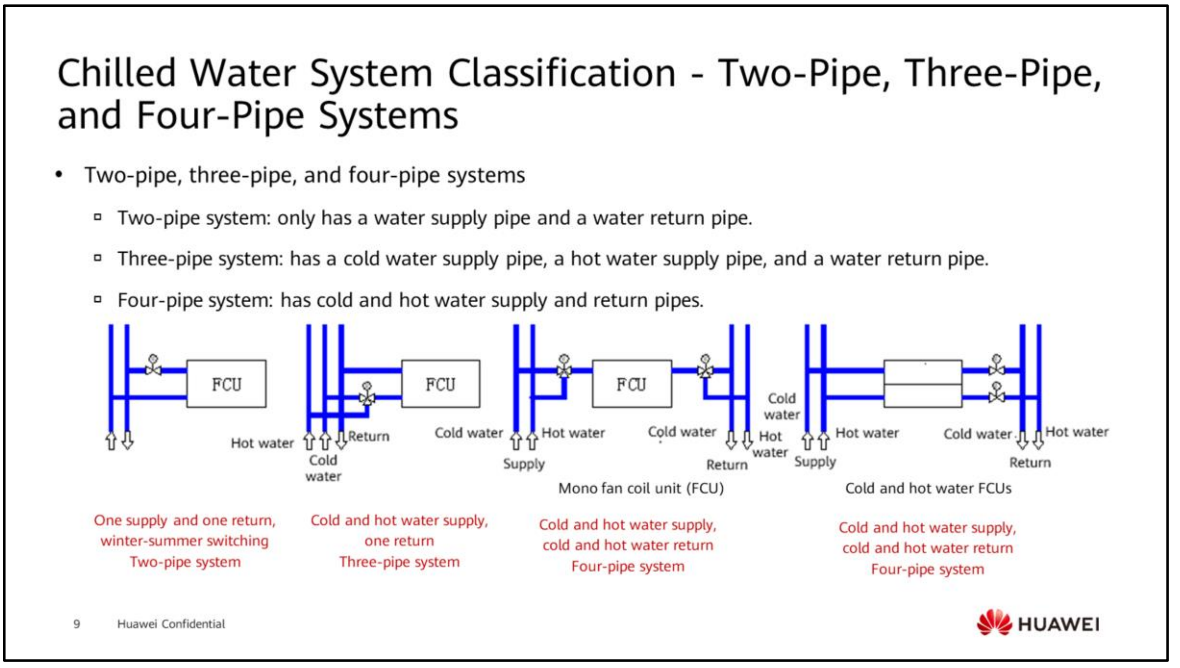
Chilled Water System Classification - Open and Closed Systems

- Open and closed systems
  - Open system
    - The pump has a high lift and energy consumption.
    - Circulating water is easily polluted.
    - The water return tank has the cold storage capacity.
  - Closed system
    - The pump has a low lift and energy consumption.
    - Circulating water is not easily polluted.



- Open system: There is a water tank or pool between pipes to ventilate. When water flows back, the pipes ventilate.
  - Advantages: The chilled water tank has the cold storage capability, which can reduce the turn-on time of a chiller and increase the energy adjustment capability. The chilled water temperature fluctuates slightly.
  - Disadvantages: When chilled water contacts with the air, high oxygen content in circulating water is easy to corrode pipes. In addition to overcoming the pipe resistance, the head of the water pump should be able to lift water to a certain height. Therefore, the lift and energy consumption of the water pump are relatively high. If self-flowing return water is used, the diameter of the return water pipe is large, which will increase the investment.
  - Application scenarios: The air conditioning system sprays water to cool the air. The temperature fluctuation of chilled water is small or the energy adjustment of a chiller cannot adapt to the change of the air conditioning system. The open tank is used to store chilled water to reduce the peak load. The cooling water system with a spray cooling tower is used.
- Closed system: Water in pipes does not contact with the air. An expansion water tank is installed only at the highest point of the system.
  - Advantages: Pipes do not contact with the air, and pipes and equipment are not easily corroded. The lift required by a pump is determined only by the pipe resistance and does not need to overcome the hydrostatic pressure. The lift and power of the pump are low. The system is simple.
  - Disadvantages: Its cold storage capacity is weak. When the load is low, the chiller needs to be started frequently. Sometimes, a pressurized water pump is required to refill water to the expansion water tank.
  - Application scenarios: The air conditioning system uses fan coil units, inducers, and water-cooled surface coolers. An air-conditioning cold water

system for high-rise buildings is used. A hot water system is used.

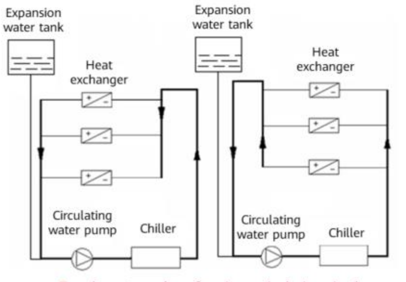


- Two-pipe system
  - The system has only a water supply pipe and a water return pipe. It circulates cold water in summer and hot water in winter, and uses valves to switch between them.
  - The two-pipe system is simple and easy to construct. The initial investment is low, but it cannot be used in places that require both cold and hot water supply.
  - According to GB 50736-2012, when all areas in a building require simultaneous cold and hot water supply switching only by season, the two-pipe system should be used.
- Three-pipe system
  - The system has a cold water supply pipe, a hot water supply pipe, and a water return pipe. The cold water and hot water share one water return pipe.
  - The system can supply cold and hot water simultaneously. Compared with the four-pipe system, it is simpler. However, the system is more complex than the two-pipe system and requires higher investment. In addition, the three-pipe system has the loss of mixing the cold and hot water return.

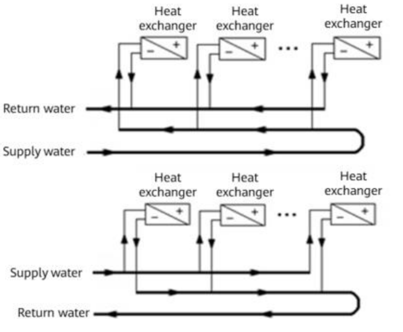
- Four-pipe system
  - In the system, separate water supply pipes and water return pipes are set for cold water and hot water to form two sets of independent water supply and return pipes for cooling and heating respectively.
  - The system can supply cold and hot water simultaneously, which meets the requirements of high-quality air conditioning environment. However, the system is complex, requiring high initial investment and more building space.
  - According to GB 50736-2012, when the cold and hot water supply needs to be frequently switched or used simultaneously, the four-pipe system is recommended.
- Zone-based two-pipe system
  - Based on the load characteristics of air conditioning areas in buildings, air conditioning water pipes are classified into the two-pipe cold water system and two-pipe cold-hot water system. For areas that require cooling throughout the year, the two-pipe cold water system is used. For other areas, the two-pipe cold-hot water system is used.

Chilled Water System Classification - Reversed and Direct Return Systems (1)

- Reversed and direct return systems
  - In the reversed return system, the pipe distance of the water flow passing through each parallel loop is basically the same, so the resistance loss of each pipe is nearly the same.

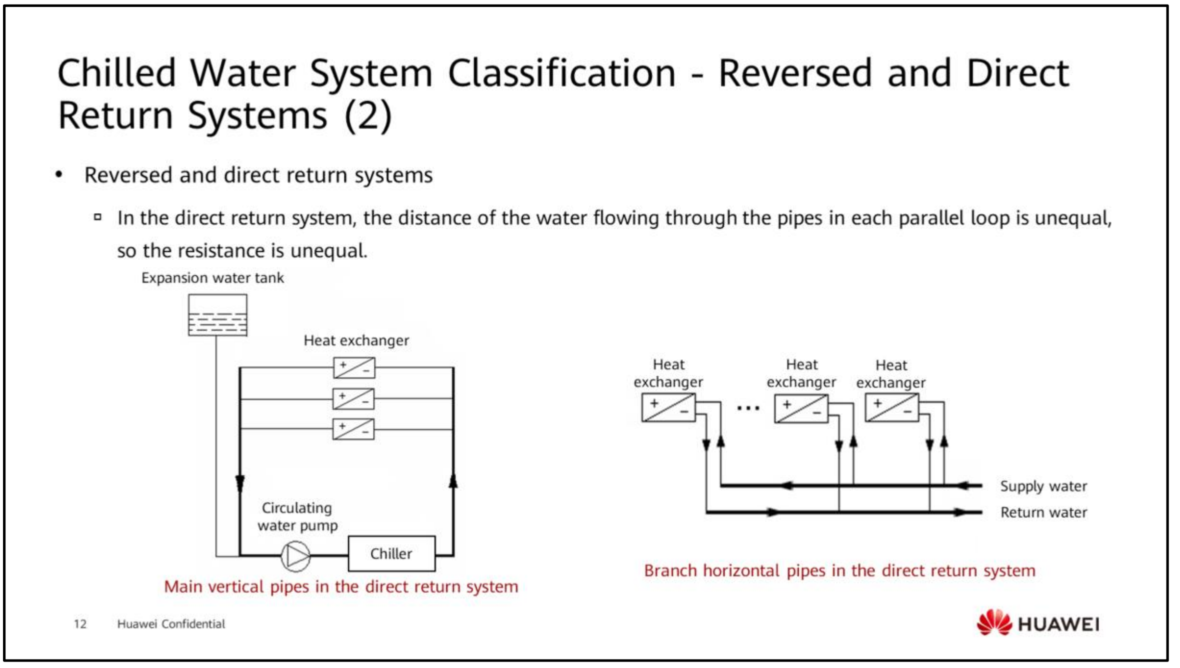


Two layout modes of main vertical pipes in the reversed return system



Two layout modes of branch horizontal pipes in the reversed return system

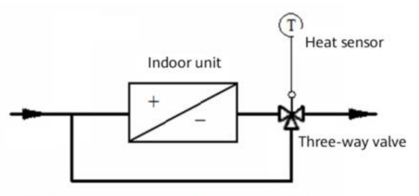
- Advantages of the reversed return system: When the water resistance of each terminal heat exchanger is approximately the same, the total pipe length of each parallel loop is basically the same. Therefore, the reversed return system has good hydraulic stability and balanced water distribution among loops, and is convenient to be adjusted.



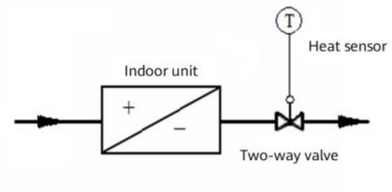
- Advantages of the direct return system: Simple pipe configuration, less pipe material consumption, less construction difficulty, and lower investment.
- Disadvantages of the direct return system: The total pipe length of the parallel loops is unequal, and the resistance between the loops is not balanced, which leads to uneven flow distribution.

Chilled Water System Classification - Constant and Variable Flow Systems

- Constant and variable flow systems
  - Constant flow system: The water flow is constant. The temperature difference between the supply and return water is changed to adapt to the change of the load.
  - Variable flow system: The temperature difference between the supply and return water remains unchanged. The water flow is changed to adapt to the change of the load of the air conditioner. The water flow varies with the load.



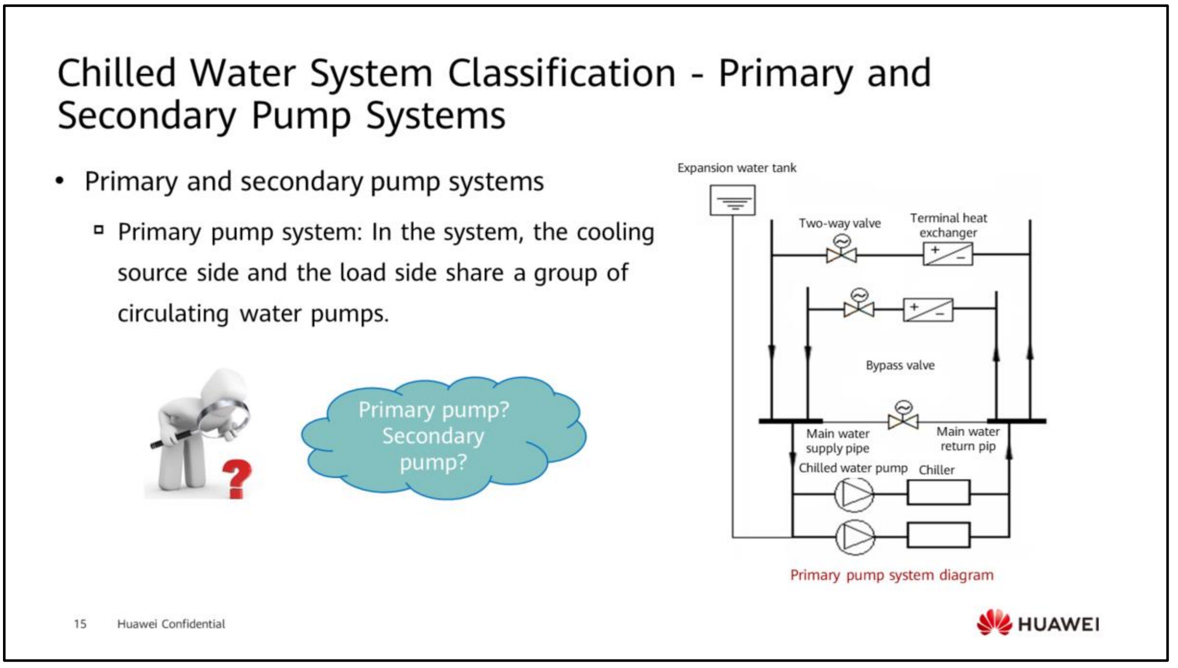
Three-way valve adjustment diagram



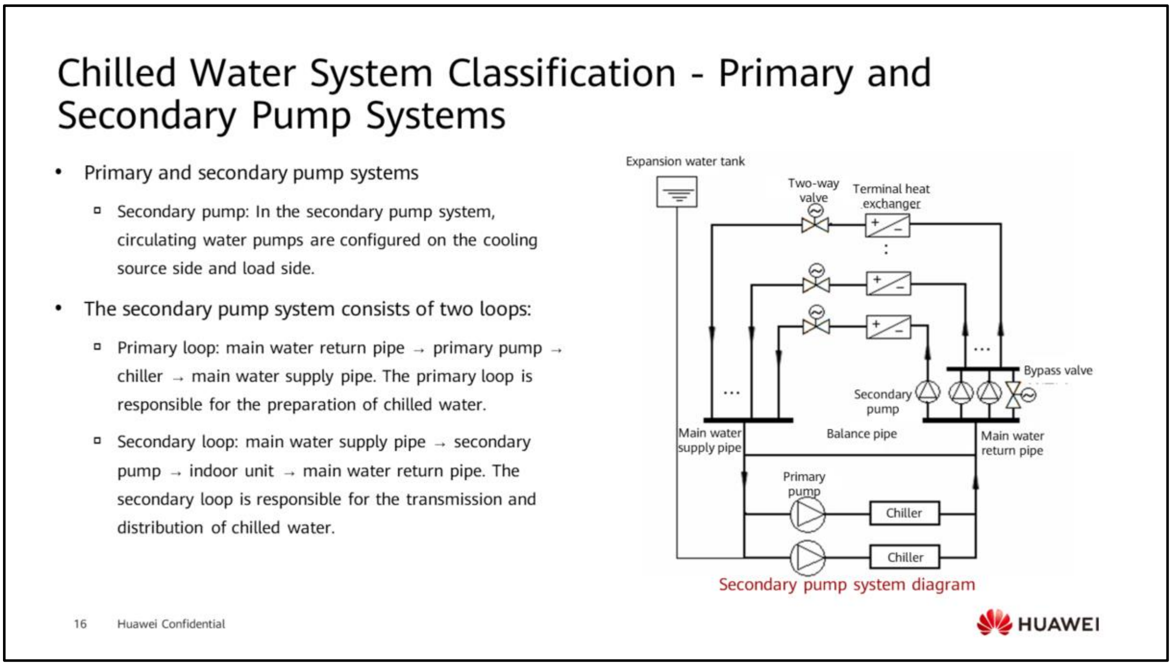
Two-way valve adjustment diagram

- Constant flow system: When the load decreases, the temperature difference between the supply water and return water of the water system decreases. As a result, the energy transmitted to the load by the system decreases to meet the load reduction requirements. However, the transmission energy consumption of the water system does not decrease. Therefore, the water transmission efficiency decreases.
  - The constant flow system works as follows: An electric three-way valve is used to adjust each air conditioner indoor unit of the system. When the room temperature does not reach the set value, the straight-through pipe of the three-way valve is opened, the bypass pipe is closed, and the supply water passes through the indoor units. When the room temperature reaches or exceeds the preset value, the straight-through pipe is closed and the bypass pipe is opened. All water flows into the water return pipe through the bypass pipe. Therefore, the water flow on the load side is constant.
  - Advantages of the constant flow system: It is simple and convenient and does not need more complex automatic control equipment. The three-way valve is used to adjust the water flow at the user end. Users do not interfere with each other, and the system runs stably.
  - Disadvantages of the constant flow system: The water flow of the system is determined by the maximum load. The water supply volume is greater than the required water volume in most time. The energy consumption of the transmission is always in the maximum value, and the ineffective energy consumption of a pump is high.

- Variable flow system: When the load decreases, the system water flow decreases accordingly, so that the system delivers less energy to the load to meet the load reduction requirement. Because the reduction of water flow can reduce the energy consumption of water transportation, energy can be saved greatly.
  - The variable flow system works as follows: Each air conditioner indoor unit of the variable flow system is regulated by an electric two-way valve. When the room temperature does not reach the set value, the two-way valve is opened fully or greatly, and the water flow through the indoor units increases. When the room temperature reaches or exceeds the set value, the two-way valve is closed fully or greatly, and the water flow through the indoor units decreases. Therefore, the water flow rate on the load side is variable.
  - Advantage of the variable flow system: The energy consumption of pumps decreases with the decrease of load (energy saving). In piping system design, the simultaneous-use coefficient can be considered. The pipe diameter is smaller, and the initial investment of the pumps and pipes decreases.
  - Disadvantage of the variable flow system: The control device of the variable flow system has high requirements and is complex.



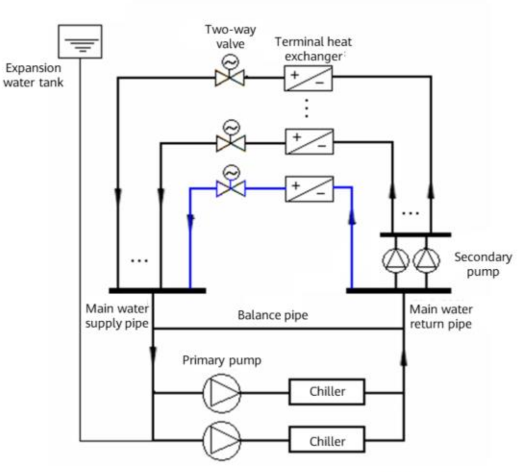
- The primary pump system works as follows: The system uses a bypass pipe to maintain the constant flow of the cooling source side and let the load side in variable flow operation. A differential pressure bypass device is set between the main chilled water supply and return pipes. When the air conditioner load decreases, the resistance of the pipe on the load side increases, and the differential pressure control device automatically increases the opening of the bypass valve. The reduced water flow on the load side returns to the main water return pipe from the bypass pipe and flows back to the chiller. Therefore, the water flow of the chiller evaporator is always constant.
  - Advantages and disadvantages of the primary pump system
    - Advantages: The system is simple with few control components, so it is easy to operate and manage
    - Disadvantages: The water flow adjustment is restricted by the minimum water flow rate of the chiller. The system is unsuitable when there is a great gap between the water supply radius and lift of each zone. Therefore, it can only be used in small and medium air conditioning systems.



- Advantages and disadvantages of the secondary pump system
    - Advantages: The system can adapt to the situation that the load change regularity of each zone is different and the loop lift or water supply radius of each zone is greatly different. It can realize variable flow of the secondary pump and save energy consumption of transportation.
    - Disadvantages: The system is complex and has high requirements on control devices. It also requires a large floor area of a data center and high initial investment.

Chilled Water System Classification - Primary and Secondary Pump Systems

- Hybrid system of primary and secondary pumps
  - In the transmission and distribution loop of the chilled water, the loop with short pipes and small pressure loss is directly supplied by the primary pump, and the loop with large pressure loss is supplied by the secondary pump. In this way, a hybrid system of the primary and secondary pumps is formed.



Chilled Water System Classification Basis and Key Design Points

Classification Basis	Water System Types	Key Design Points
Circulation mode	Open circulation system	1. The pump lift of the open system is high. 2. An open system must be configured with a chilled water storage tank. 3. A closed system must be configured with an expansion water tank.
	Closed circulation system	
Water supply and return mode	Two-pipe system	1. The number of water system equipment suites to be configured varies with the water supply and return modes. 2. The more the number of pipes, the more complex the layout of the pipes in design.
	Three-pipe system	
	Four-pipe system	
	Zone-based two-pipe system	

Chilled Water System Classification Basis and Key Design Points

Classification Basis	Water System Types	Key Design Points Comparison
Water supply and return pipe layout	Reversed return system Direct return system	1. The pipes of the reversed return system are long and the layout is complex. 2. The reversed return system needs to be configured with a higher water pump lift. 3. The resistance balance of the parallel pipes should be taken into account during the design of the direct return system.
Operation adjustment mode	Constant flow system Variable flow system	1. The constant flow system can be configured with constant frequency pumps. 2. The variable flow system must be configured with variable frequency pumps. 3. Chillers with strong adaptability to flow change should be selected for the variable flow system. 4. The variable flow system needs to be equipped with a complex control system.
Circulating pump configuration mode	Primary pump system Secondary pump system	1. The primary pump system needs to be equipped with water pumps only on the cooling source side. 2. The secondary pump system needs to be equipped with pumps on both the cooling source side and the user side.

- The primary pump system is divided into the primary pump constant flow system and variable flow system.
- The secondary pump system is usually a variable flow system with a variable frequency pump on the load side and a constant frequency pump on the cooling source side.

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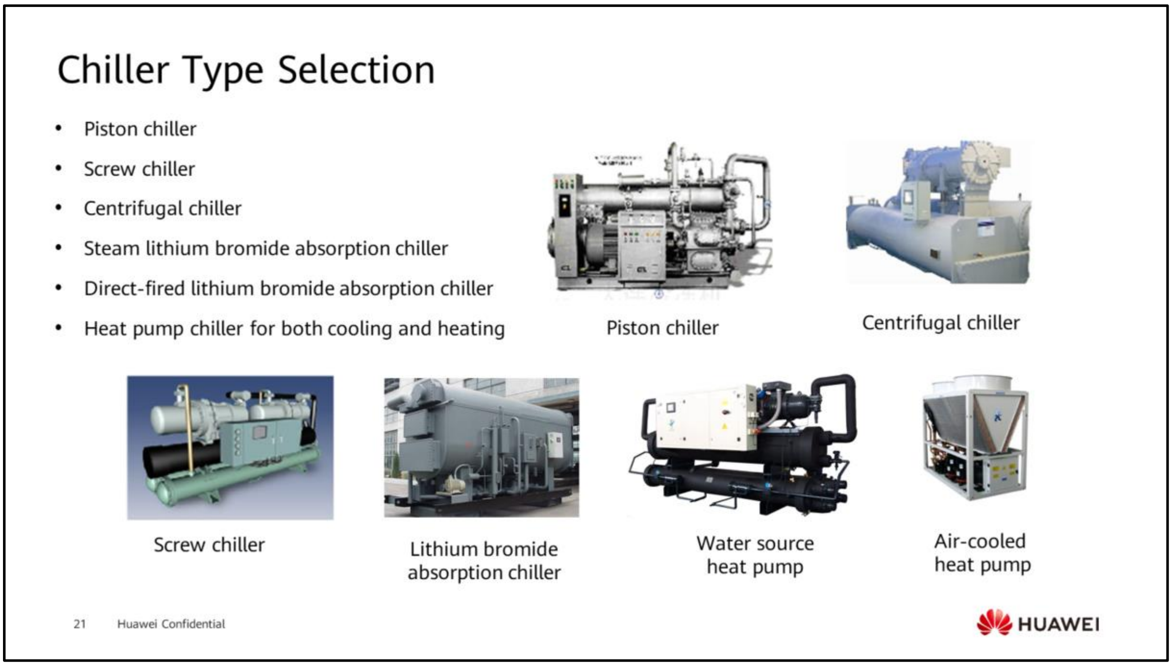

- Comparison should be made before chiller selection. Electric compression chillers and lithium bromide absorption chillers should be compared.
- If the power supply is tight or the electricity price is high but there is gas supply, the direct-fired lithium bromide absorption chiller is recommended.
- The air-cooled or buried pipe ground source chiller is recommended to supply chilled water to small and medium buildings in hot summer and cold winter areas and arid areas.
- Air-cooled chiller: It is applicable to office buildings having flexible construction and scattered small rooms but without basements or dedicated refrigeration rooms.
- Heat pump chiller (water source, air source): It is applicable to buildings that require both cooling and heating air conditioners.

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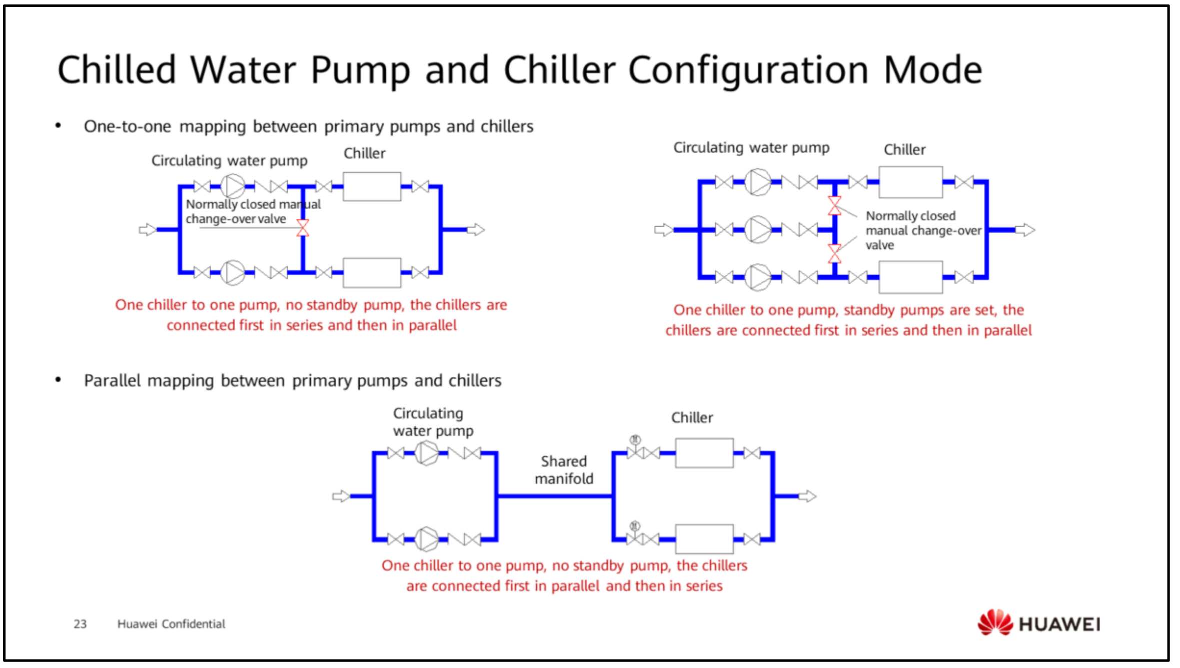

- One-to-one mapping between primary pumps and chillers
  - Advantages: Chillers with different flow can be connected in parallel for working. The flow between the pump and the chiller (evaporator) is easy to match. When the load changes, the chiller with the corresponding flow can be started to avoid the waste of energy caused by the large chiller with small loads.
  - Disadvantage: Pumps cannot be used as backups for each other.
- Parallel mapping between primary pumps and chillers
  - According to GB 50736-2012 Design Code for Heating Ventilation and Air Conditioning of Civil Buildings, when it is difficult to configure one pump for each chiller, a shared manifold can be used. In this case, an electric two-way valve needs to be installed between the chiller and the circulating water pump for separation.
  - Advantage: If the pumps connected in parallel are the same, any one of the pumps in the parallel pump group can be used as a standby pump.
  - Disadvantage: When the chillers or pumps have different sizes, it is difficult to match the flow between the pumps and the chillers (evaporators). Starting or stopping chillers will have a negative impact on the running chillers.

Chilled Water Circulating Pump Flow Calculation

- Calculate the flow of the circulating water pump as follows:
  - Types: Horizontal double suction pump or horizontal end suction pump
  - System type: Primary or secondary chilled water pump system
  - The formula for calculating the flow of a circulating water pump is as follows:

    $G = K * Q / (1.163\Delta t) = 0.86 * K * Q/\Delta t$
  - G: pump flow (m^3/h)
  - Q: cooling (heating) load (kW) of the pump
  - K: additional flow coefficient of the pump. The value ranges from 1.05 to 1.1.
  - Δt: temperature difference between supply and return water (°C)

Horizontal centrifugal pump

Vertical centrifugal pump

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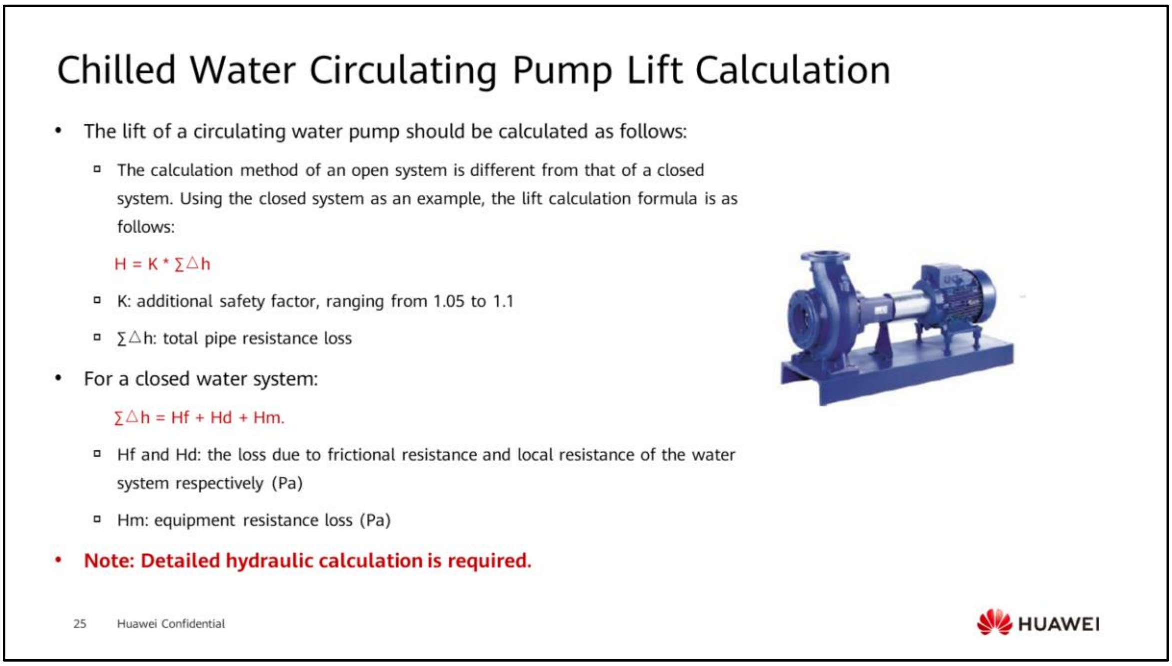
- Generally, the single suction pump is used. If the flow is greater than 500 m3/h, the double suction pump is recommended.
- In addition to small units such as modular units and the primary pump variable flow system, the number of circulating water pumps in the primary pump system and the number of primary pumps in the secondary pump system should be consistent with the number and flow of chillers.
- The secondary cold water pump in the secondary pump system should be determined based on system zoning, the flow and the operation adjustment mode of each zone. At least two secondary cold water pumps should be deployed in each zone, and the variable frequency speed regulating pump should be used.

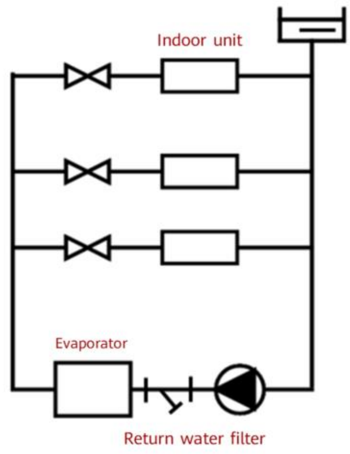


- Primary pump system:
  - For the closed circulation system, the pump lift should be calculated based on the sum of the resistance of pipes and pipe fittings, the resistance of the self-control valve and filter, the resistance of the chiller evaporator (or heat exchanger), and the resistance of the indoor unit heat exchanger.
  - In addition to the preceding resistance, the pump lift of the open system should also include the height difference between the lowest water level of the water storage tank or chilled water storage tank and the indoor unit. If a spray chamber is deployed, the resistance of the indoor unit heat exchanger should be replaced by the necessary pressure head in front of the nozzle.

- Secondary pump system:
  - The lift of the primary pump in the closed circulation system should be calculated based on the sum of the resistance of the pipe and pipe fittings on the cooling source side, the resistance of the self-control valve and filter, and the resistance of the chiller evaporator.
  - In addition to the resistance described in item 1, the lift of the primary pump of the open system should include the height difference between the lowest water level of the water storage tank or chilled water storage tank and the chiller evaporator.
  - The lift of the secondary pump in the closed circulation system should be calculated based on the sum of the resistance of the pipe and pipe fittings on the load side, the resistance of the self-control valve and filter, and the resistance of the indoor unit heat exchanger.
  - In addition to the resistance described in item 3, the lift of the secondary pump in the open system should also include the height difference between the lowest water level of the water storage tank or chilled water storage tank and the indoor unit. If there is a spray chamber, the resistance of the indoor unit heat exchanger should be replaced by the necessary pressure head in front of the nozzle.

Chilled Water Circulating Pump Lift Estimation

- Chilled water pump lift components (can be used for drawing or equipment reviewing)
  - Water resistance of the chiller evaporator: generally 5 to 7 mH_2O (For details, see the product sample.)
  - Water resistance of the surface cooler or evaporator of the indoor unit (such as precision air conditioner or FCU): generally 5 to 7 mH_2O (For details, see the product sample.)
  - Resistance of the return water filter: generally 3 to 5 mH_2O
  - Water resistance of water distributors and collectors: generally 3 mH_2O
  - Loss due to water pipe friction resistance and local resistance loss of the cooling system: generally 7 to 10 mH_2O
- To sum up, the lift of the chilled water pump ranges from 26 to 35 mH_2O. Generally, the lift ranges from 32 to 36 mH_2O.
- Note: In the specific design phase, the lift must be calculated based on the actual situation of the cooling system. Do not copy the empirical value.



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- Generally, distribution manifolds are designed at the water supply and return outlets of the chilled water unit to connect pipes to each area.

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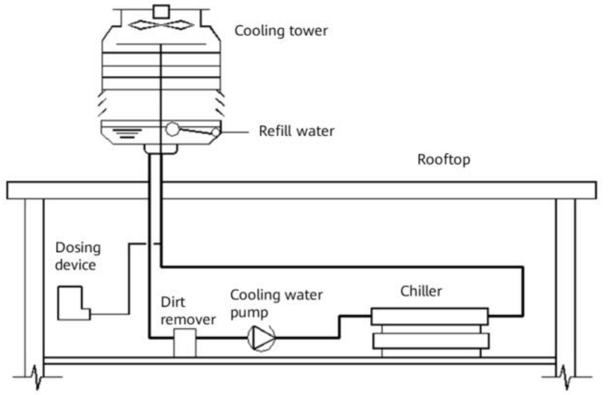
Cooling Water System Concept

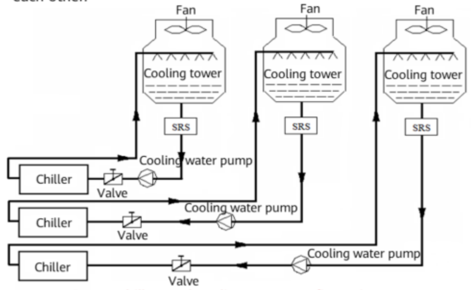
- The cooling water system uses a cooling tower to supply circulating cooling water to the condenser of a chiller. The system consists of the cooling tower, cooling water tank, cooling water pump, condenser, and connection pipes.



- If the air-cooled chilled water air conditioning system is used, the cooling water system is not required.

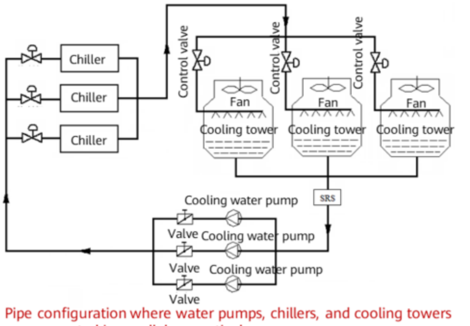
Cooling Water System Types

- One-to-one configuration of pumps, chillers, and cooling towers
  - Advantages: The cooling water system of each chiller is independent of each other. The systems are subject to coordinated control for flow matching. Balance pipes are not required between cooling towers.
  - Disadvantages: The pipeline layout is complex, the number of pipes and the space they occupy are large. Therefore, pipes cannot back up each other.



Pump, chiller, and cooling tower configurations

- Cooling water pipe configuration where pumps, chillers, and cooling towers are connected in parallel respectively
  - Advantages: No standby device is required. Few pipes are used and the investment is small.
  - Disadvantages: When the sizes of chillers (condensers) are different, it is difficult to match the cooling water flow between equipment.



Pipe configuration where water pumps, chillers, and cooling towers are connected in parallel respectively

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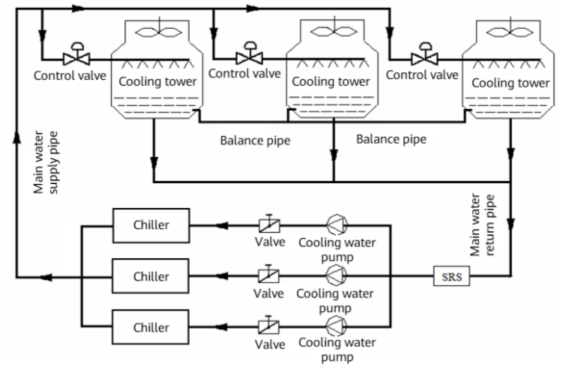
- Balance pipe
- SRS: Automatic scale removal system for cooling water

Cooling Water System Types

- Cooling water pipeline with a main water supply pipe and a main water return pipe
  - A balance pipe is installed between the water pans of each cooling tower so that the cooling towers run at the same water level. This prevents water level inconsistency between water pans of each cooling tower and avoids water overflow of some cooling towers and water refilling of other cooling towers.



Cooling water pipeline with a main water supply pipe and a main water return pipe

- The following methods are recommended to solve uneven flow distribution:
  - Electric two-way valves are installed on the branch water return and supply pipes of cooling towers. The two sets of valves operate as a pair and are electrically interlocked with the startup and shutdown of the cooling towers.
  - Balance pipes are used to interconnect water pans of cooling towers.
  - The main water supply pipe is a collecting pipe that is two gauges larger than the water return pipe.

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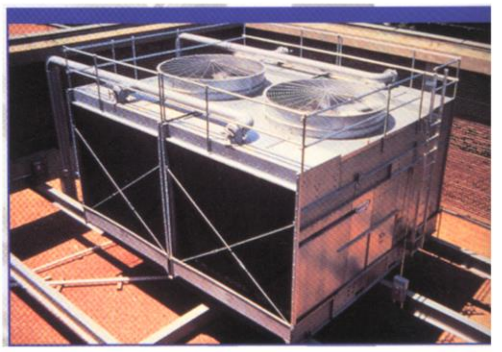
Cooling Tower Heat Exchange Principle

- Heat exchanging principle of a mechanical draft cooling tower
  - The mechanical draft cooling tower is the main equipment for evaporative cooling of circulating water. Its working principle is that the hot circulating water is sprayed from the cooling tower and then flows to a collecting basin. At the same time, the fan blows air from bottom to top in a reverse direction. Therefore, the water film and cold air on the packing are in wide contact, and mass transfer and heat transfer occur, taking away the heat of the circulating water.
  - Mainstream cooling tower brands: Marley, Evapco, BAC.

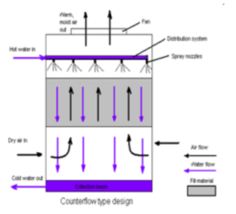


- Heat dissipation modes of cooling water in the cooling tower: contact heat dissipation and evaporative heat dissipation.
- Contact heat dissipation
  - When the cooling water meets the air, there are three types of heat transfer depending on the difference between the return water temperature Tw1 and the air temperature Tq1 of the cooling tower:
    - When Tw1 > Tq1, the cooling water transfers heat to the air and gets cooled.
    - When Tw1 = Tq1, there is no heat transfer between the cooling water and the air, and the cooling water temperature remains unchanged.
    - When Tw1 < Tq1, the air transfers heat to the cooling water, and the cooling water temperature increases.
  - Therefore, when the ambient temperature is equal to or higher than the cooling water temperature, the contact heat dissipation of the cooling tower fails. At this time, its cooling effect will depend entirely on the evaporative heat dissipation of cooling water. Therefore, the cooling effect will be significantly reduced.

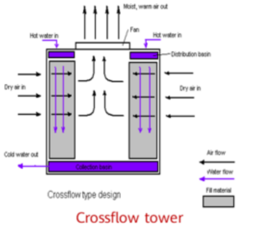
- Evaporative heat dissipation
  - Influence of meteorological factors on evaporative heat dissipation of cooling water: Influence of air temperature: The higher the air temperature (dry bulb temperature), the stronger the evaporative heat dissipation. Influence of air humidity: The lower the relative humidity, the faster the evaporative heat dissipation. On the contrary, high ambient humidity results in poor evaporative heat dissipation. When water vapor in the air saturates, evaporation cannot be performed, and the evaporative heat dissipation is equal to zero.
  - Influence of air pressure: the lower the air pressure, the easier the water evaporates. Increasing the ventilation of the cooling tower can effectively reduce the static pressure on the surface of the cooling water and facilitate the evaporative heat dissipation of the cooling water.
  - Influence of wind speed: The greater the wind speed, the greater the convection heat transfer coefficient. In addition to closed cooling towers, various open cooling towers require natural or mechanical ventilation.
  - To sum up, the cooling process of cooling water in a cooling tower is a process of exchanging heat with the air, and its cooling effect is greatly affected by atmospheric weather conditions.

Cooling Tower Classification

Classification Basis	Category	Characteristics
Shape	Round tower	Small projects with a flow of less than 100 m^3/h and no requirements for water drift and noise, occupying a large area **(rarely used)**
	Square tower	Can be assembled, 30% more expensive than the round tower.
Airflow direction	Crossflow tower	Low noise, high cost-effectiveness, and high market share **(commonly used)**
	Counterflow tower	Effective and noisy
Material	Stainless steel tower	-
	Fiberglass tower	Cost-effective **(commonly used)**
Contact with air?	Open tower	The upfront investment is low, but water refilling is required **(commonly used)**
	Closed tower	The cooling capacity is small, and the capital expenditure (CAPEX) is 10 times that of the open tower. However, the subsequent operation cost is low.



Counterflow tower



Crossflow tower

- The water-cooled chilled water unit must use a cooling tower. The air-cooled chiller water unit does not require the cooling tower.

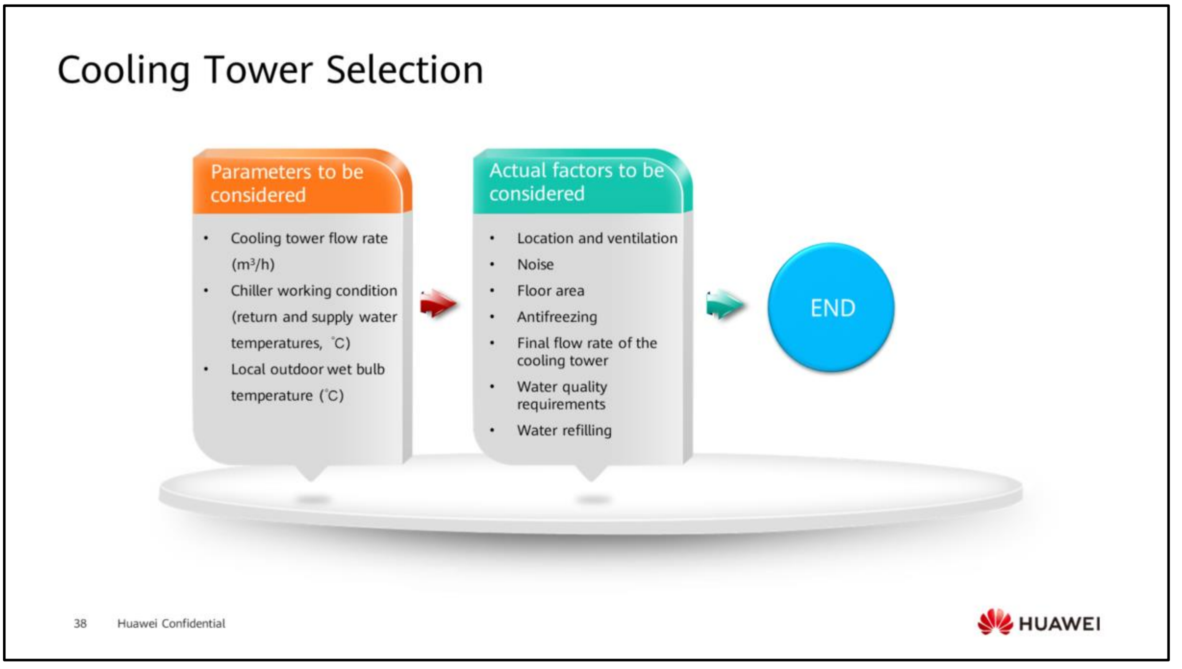
Cooling Tower Installation Position

- The three common positions for installing cooling towers are as follows:
  - When the chiller plant is installed in the basement of a building, and the cooling tower is installed on the well-ventilated outdoor green belt or outdoor ground.
  - If the chiller plant is a single-storey building, the cooling tower can be installed on the roof of the chiller plant or on the outdoor ground.
  - When the chiller plant is installed in the ground floor or basement of a multi-storey building or a high-rise building, the cooling tower is installed on the roof of the podium of the building. If the chiller plant is not installed in the mentioned locations, the cooling tower can only be installed on the roof of the main building of a high-rise building.

Scenario 1

Scenario 2

Scenario 3



- An open cooling tower is recommended for the cooling system of a data center. If water needs to be protected against pollution, a closed cooling tower can also be used. The combustion performance level of cooling tower materials cannot be lower than Class B1.
- The cooling tower should not be deployed near heat sources, exhaust gas, smoke generation point, chemical stack, or coal stack.
- The distance between cooling towers or between a cooling tower and other buildings should be set based on the ventilation requirements of the tower and the interaction between the tower and the buildings. In addition, the safety distance for fire prevention and explosion prevention of the building and the construction and maintenance requirements of the cooling tower should also be considered
- The cooling tower must be far away from high temperature or harmful gas, such as air exhaust from the kitchen. In addition, the cooling tower must be free from water drifting that may affect the surrounding environment.

- The impact of the cooling tower noise on the environment should comply with the standard values of various urban areas or environmental noise specified in the GB 3096 Environmental Quality Standard for Noise. The space attenuation of the cooling tower can be calculated based on the assumption that the attenuation is 5 dB when the distance increases by one time of the noise value. The synthetic sound pressure level of sound sources of multiple cooling towers should be calculated by logarithm.
- After the position of the cooling tower is determined, if the designed and selected low-noise cooling tower cannot meet the requirements, noise reduction and insulation measures should be taken.
- Areas with the risk of freezing. The following antifreezing and thermal insulation measures should be taken for a cooling tower running in winter:
    - It is recommended that the cooling tower be separately deployed and the antifreeze cooling tower be used.
    - The water refill pipes, cooling water supply and return pipes installed on the roof and in the rooms without heating should be insulated and heated. The chassis of the cooling tower for storing water should also be equipped with trace heating facilities.
    - For the cooling water pipe installed on the outdoor sunny side, the length of the pipe that is exposed to the sunlight and generates temperature rise can be considered for heat insulation.

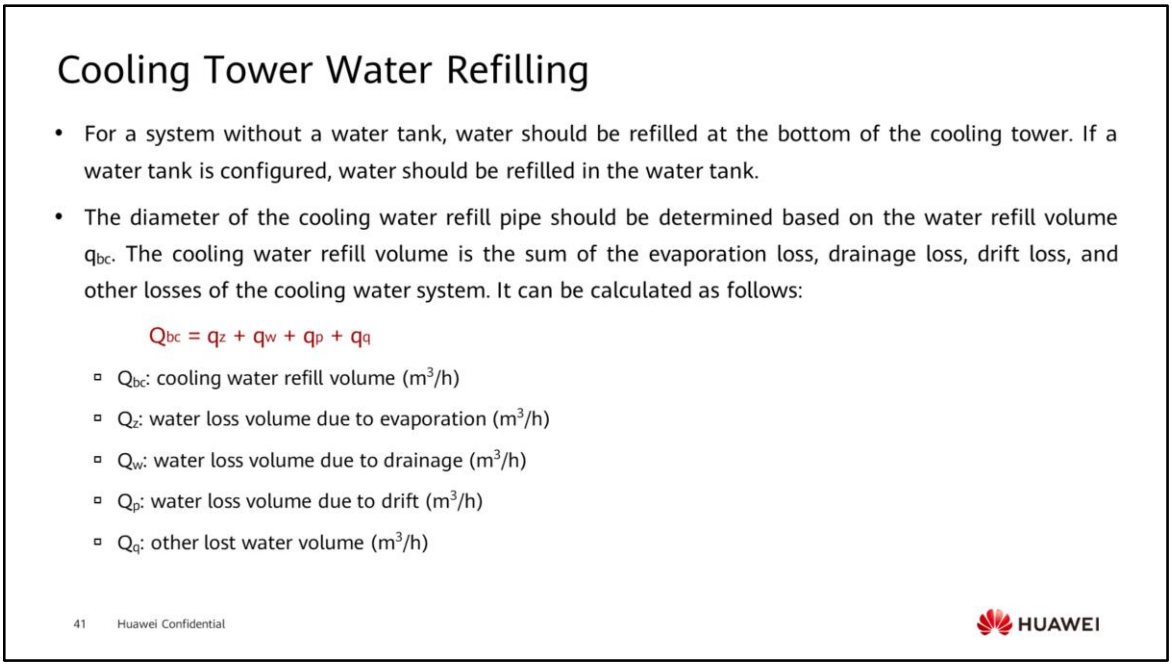
Cooling Tower Water Flow Calculation

- Calculate the water flow processed by a cooling tower as follows:

  $G = 1.2 * 3600\ Q / (\rho * C * \Delta t) = 0.86 * 1.2 * Q/\Delta t$

  - G: the designed water volume of the cooling tower
  - 1.2: allowance coefficient
  - Q: chiller condensing heat (kW). Q = Chiller cooling capacity + Compressor input power
  - ρ: water density at 35°C (993.96 kg/m^3)
  - C: specific heat capacity of water at constant pressure (4.1784kJ/kg * K)
  - Δt: the temperature difference of the cooling water system (°C)

- When selecting a cooling tower, you can preliminarily select the cooling tower specifications based on the return and supply water temperature, local wet bulb temperature, and cooling tower water flow. Then, you can check whether the selected cooling tower meets the parameter requirements of cooling water based on the curve or table of non-standard working conditions for the sample. If the requirements are not met, the specifications should be modified.



- The cooling water refill system must meet the performance requirements of the air conditioning system in a data center. The flow and pressure of the cooling water refill system must meet the requirements of the equipment in use.
- If the cooling water refill is interrupted, the cooling system will be interrupted. In this case, a water refill storage device should be deployed. The storage time should not be shorter than the time for a local emergency water truck to arrive at the site. If the storage time cannot be determined, it should be at least 12 hours. A water refill port should be reserved on the water refill storage device.
- It is recommended that municipal tap water be used to refill cooling water. Epigenetic water, well water, lake water, and river water that meet the water quality requirements can also be used.
- Measures should be taken for the storage of cooling water to prevent the water quality from deteriorating.
- Evaporation loss: The evaporation loss of cooling water is related to the cooling water temperature drop. Generally, when the temperature decreases to 5° C, the evaporation loss is 0.93% of the circulating water volume. When the temperature drops to 8° C, it is 1.48% of the circulating water.
- Drift loss: water loss due to the strong wind of the cooling tower. The drift loss of China-made equipment is 0.3% to 0.35% of the circulating water volume, and that of international equipment is 0.15% to 0.3% of the circulating water volume.
- Drainage loss: The concentration times of cooling water should not exceed 3 to 3.5 times through drainage. Generally, the drainage loss should be 0.3%–1% of the circulating water volume.
- Other losses: cooling water losses caused by water leakage.
- In conclusion, the general water refill rate can be estimated to be 2% to 3%.

Contents

Flow Lift Calculation for a Cooling Water Circulating Pump

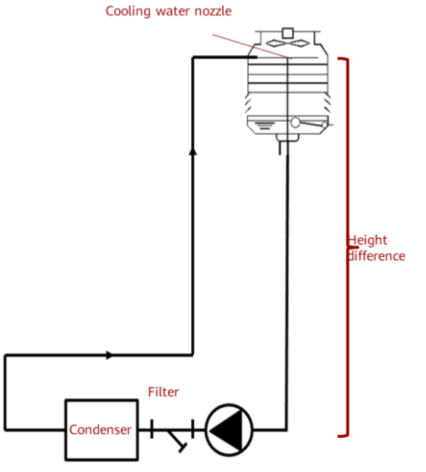
- The flow calculation method of a cooling water pump is the same as that of a chilled water pump.
- The lift of a circulating water pump should be calculated as follows:
  - Take an open cooling tower as an example. The lift calculation formula is as follows:

    H = K * (H1 + H2 + H3 + H4)
  - H1: the height difference (m) between the lowest water level of the water pan of the cooling tower and the water distributor or water return (When there is a cooling water tank, H1 indicates the height difference between the lowest water level of the water tank and the water distributor or water return.)
  - H2: the hydraulic head (m) required for the water distributor of the cooling tower
  - H3: the resistance (m) of the chiller condenser.
  - H4: total resistance of the pipe system (m) (including the local resistance of the control valve and dirt remover)
- Note: Detailed hydraulic calculation is required.

- The lift of a cooling water pump should be the sum of the following items:
  - Height difference between the water pan of the cooling tower and the water distributor.
  - Free hydraulic head required by the distributor pipe of the cooling tower: provided by the manufacturer. For details, see the product brochure. Generally, the free hydraulic head of a typical crossflow tower is 0.05 MPa.
  - Chiller condenser resistance: provided by the manufacturer. For details, see the product brochure.
  - Resistance of suction pipes, discharge pipes, fittings, automatic control valves, filters, and dirt removers.
  - Add 5% to 10% of the sum of the preceding items.

Lift Estimation for a Cooling Water Circulating Pump

- The lift design of a cooling water pump is similar to that of a chilled water pump. The main difference is that the height difference between the water pan of the cooling tower and the nozzle needs to be calculated for an open system.
- Cooling water pump lift components (can be used for drawing or equipment reviewing)
  - Water resistance of the chiller condenser: generally 5 to 7 mH_2O (For details, see the product sample.)
  - Water spray pressure of the cooling tower nozzle: generally 2 to 3 mH_2O
  - Height difference between the water pan and the nozzle of the cooling tower (open cooling tower): generally 2 to 3 mH_2O
  - Return water filter resistance: generally 3 to 5 mH_2O
  - Loss due to water pipe friction resistance and local resistance loss of the cooling system: generally 5 to 8 mH_2O
- To sum up, the lift of the cooling water pump ranges from 17 mH_2O to 26 mH_2O. Generally, the lift ranges from 21 mH_2O to 25 mH_2O.
- Note: The lift must be calculated based on the actual situation of the cooling system. Do not copy the empirical value.



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Summary

- Chilled Water Air Conditioner Design Overview
- Chilled Water System Configuration
- Cooling Water System Configuration

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Energy-Saving Solution Configuration for Data Center Cooling Systems

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Foreword

- This course describes how to configure energy-saving solutions for air conditioning systems in data centers and how to improve the reliability of air conditioning systems in data centers by means of continuous cooling.

Objectives

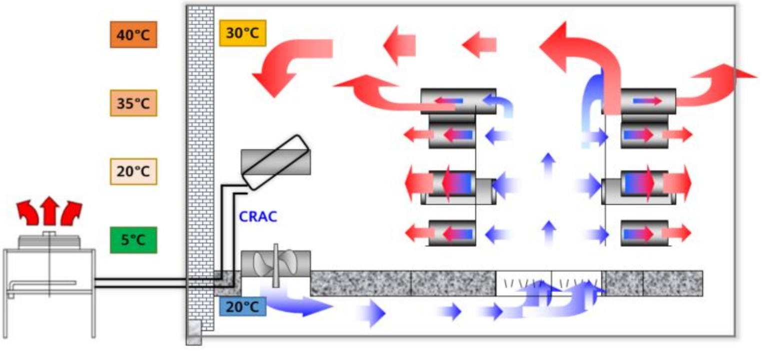
On completion of this course, you will be able to:

- Master the method of configuring air conditioning systems for free cooling in data centers.
- Master the method of configuring continuous cooling for air conditioning systems in data centers.

Contents

Concept of Direct Ventilation Free Cooling

- In the season when the ambient temperature is low, outdoor air is directly introduced to a data center as a cooling source after being filtered and humidified, which saves a large amount of energy. This cooling mode is called air-cooled free cooling or direct ventilation free cooling. This solution features simple working principles and low costs, and can reduce energy consumption of data centers.



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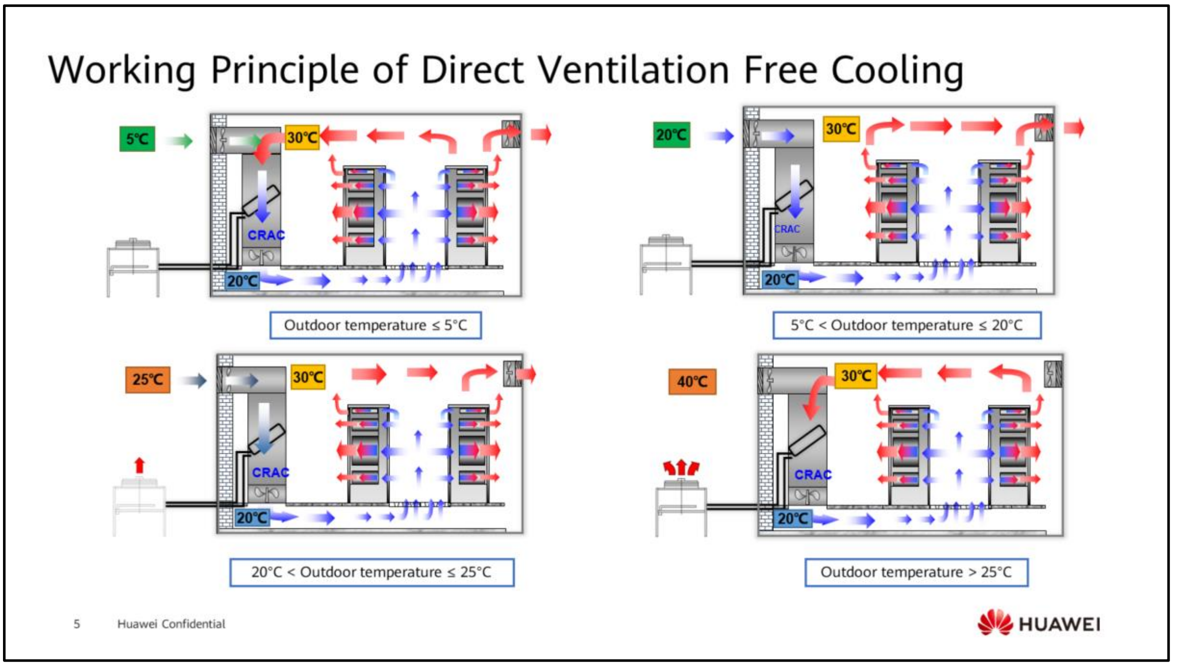
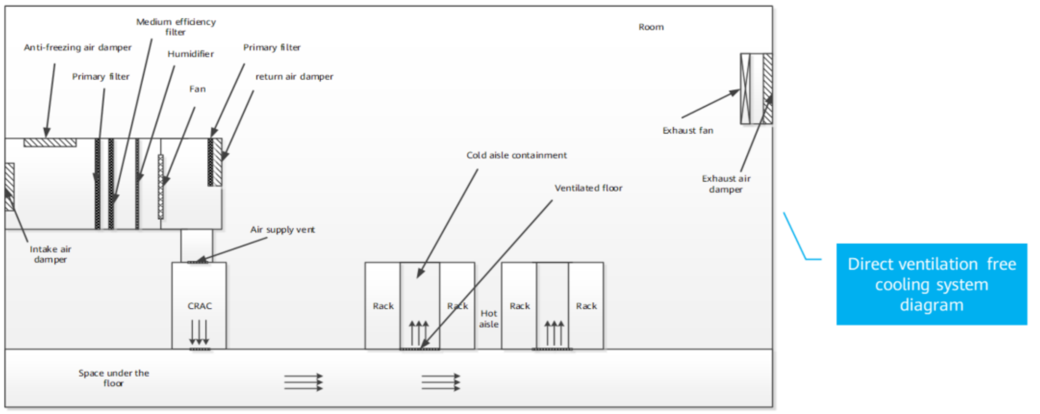


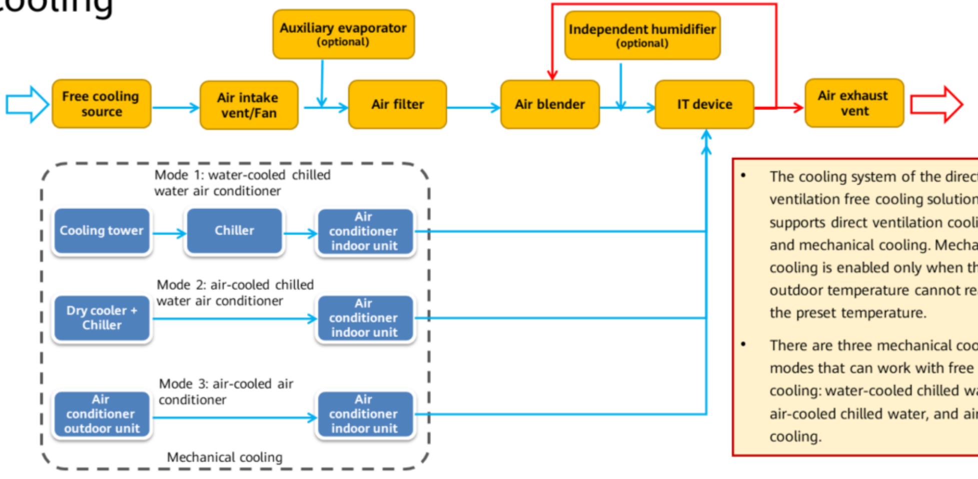
- When the outdoor air condition is within the specified range (generally lower than 20° C), outdoor cool air is filtered by the filter using fans and louvers, and then is directly sent to a data center. In direct ventilation mode, the compressor of the air conditioner stops working. The fans exchange the outdoor cold air with the indoor hot air. Therefore, the energy consumption of the air conditioner is extremely low. In theory, the energy efficiency ratio (EER) of the air conditioner can reach 25, and the dynamic power usage effectiveness (PUE) can be as low as 1.10.
- When the outdoor temperature is higher than the air intake temperature of the device, the direct ventilation device automatically shuts down and the air conditioner starts for cooling. In electric cooling mode (non-direct ventilation), the EER of the air conditioner depends on the efficiency of the air conditioner. Generally, the EER ranges from 3 to 6, and the dynamic PUE is 1.39. The annual average PUE depends on the energy efficiency in electric cooling mode and the running time in direct ventilation mode (that is, the local climate).

Composition of a Direct Ventilation Free Cooling System



- A filter is to filter the outdoor fresh air to meet the cleanliness requirements of the indoor environment. Filters can be classified into roughing filters and medium efficiency filters.
- Humidifiers used in data centers include dry steam humidifiers, infrared humidifiers, spray humidifiers, high-pressure atomizing humidifiers, air water mixed humidifiers, ultrasonic humidifiers, and wet film humidifiers. The most common humidifiers used in data centers are electrode humidifiers, infrared humidifiers, wet film humidifiers, and ultrasonic humidifiers. Electrode humidifiers and infrared humidifiers are widely used in the humidification systems of precision air conditioners. Wet film humidifiers are the most widely used independent humidifiers in data centers and are referred to as "data center humidifiers".

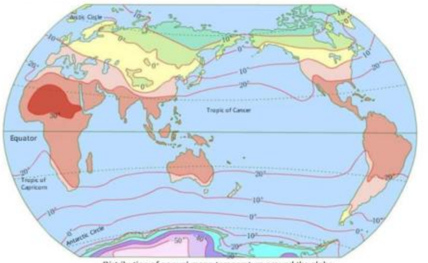
Three Configuration Solutions for Direct Ventilation Free Cooling



- The cooling system of the direct ventilation free cooling solution supports direct ventilation cooling and mechanical cooling. Mechanical cooling is enabled only when the outdoor temperature cannot reach the preset temperature.
- There are three mechanical cooling modes that can work with free cooling: water-cooled chilled water, air-cooled chilled water, and air cooling.

Application Scenarios of Direct Ventilation Free Cooling

- Direct ventilation is susceptible to the external environment. Therefore, site selection is critical to a data center using direct ventilation. A site must be selected from the following two aspects:
  - Climate. More energy is saved in a region with a higher latitude or lower temperature.
  - Air quality. The solution feasibility depends on the air pollution degree. A site should be located in a region with low pollution to prevent the indoor equipment from being corroded.



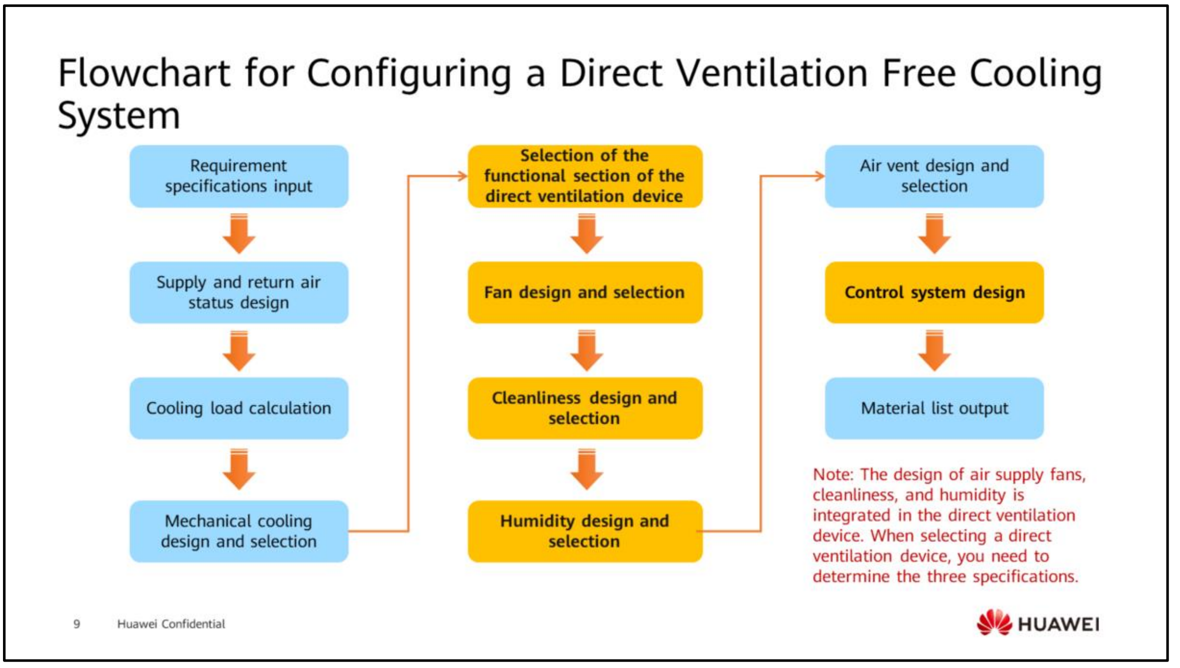
Distribution of annual mean temperature around the globe

According to the preceding analysis and suggestions of direct ventilation vendors, the direct ventilation solution is not recommended if the annual average temperature outside a data center is above **20°C**.

- If the outdoor air quality is poor, the direct ventilation solution is not recommended. Chemical filters are not recommended for data centers due to their large air resistance, heavy maintenance workload, and high cost. Therefore, during outdoor environment evaluation, the direct ventilation solution is not recommended for areas with poor air quality. For details about the standards for outdoor harmful gas concentration, see ASHRAE 66.1. The following table lists the requirements.

Contaminant	Major Standards	Average Time
Carbon monoxide	9 ppm (10 mg/m³)	8-hour
	35 ppm (40 mg/m³)	1-hour
Lead	1.5 μg/m³	Quarterly average
Nitrogen dioxide	100 μg/m³	Annual arithmetic average
PM10	150 μg/m³	24-hour
PM2.5	35 μg/m³	24-hour
Ozone	0.08 ppm	8-hour
Sulfur oxides	0.14 ppm	24-hour

- Take STULZ as an example. In the design process, the direct ventilation solution is determined by querying the annual ambient temperature of the place where the data center is located and calculating the number of days/hours when the annual ambient temperature is lower than the preset supply air temperature. Set the supply air temperature to 24° C for 8760 hours in a year. If the ambient temperature is lower than 24° C for more than half of the time, direct ventilation can be used for cooling.



- The yellow parts are the key parts described in this slide. Other parts are described in other sections.
- Requirement specifications input: cabinet power density, cabinet quantity, data center area, and data center environment specifications (dry-bulb temperature, relative humidity, pParticulate matter concentration, and harmful gas concentration)
- Supply and return air status design: Determine the supply and return air status (supply and return air temperature and humidity) of the data center. If the preset supply and return air temperatures are higher, the free cooling time using the outdoor air is longer, and the time for starting the compressor is shorter, which reduces the power load of the compressor.
- Cooling load calculation: Calculate the cooling load of the data center.

- Mechanical cooling design and selection: Select a cooling solution, design and select the chiller based on the load, and calculate the air volume of the unit. The design of mechanical cooling is to determine the auxiliary cooling mode. A high-efficiency mechanical cooling mode can reduce the cooling loss and the cooling power load.
- Fan design and selection: exhaust fan design (air volume and motor power)
- Selection of the functional section of the direct ventilation device: Select a functional section (cooling, humidification, filtering, or preheating). Design air blender dimensions.
- Cleanliness design and selection: Determine the filtering mode, level, and cross-sectional area.
- Humidity design and selection: Output the humidification mode and humidification capacity. If the preset humidity range is wider, the time required for humidifying a data center is shorter, and the humidification capacity is less, which reduces the energy consumption caused by humidification.
- Air vent design and selection: 1. Determine the types of required air vents (anti-freezing air vent, return air vent, exhaust air vent, and
- Control system design: Complete the control logic design.
- Material list output: Output the general material list based on the preceding material selection solution.

Specifications Input and Supply and Return Air Status Design

- Specifications input

Input specifications 1: customer requirement specifications	
Cabinet power density	
Number of cabinets	
Data center area	
Input specifications 2: outdoor specifications	
Annual environmental specifications of the data center	Temperature (dry-bulb temperature)
	Humidity (relative humidity or humidity ratio)
	Particulate matter concentration
	Harmful gas concentration
	Local wind direction

- Supply and return air status design
  - Preset anti-freezing temperature (T_f)
  - Supply air temperature ($T_s \pm \Delta t$) (considering the air conditioner control precision)
  - Designed return air temperature (T_r)
  - Supply air humidity range (RHl, RHh)

Based on indoor specifications requirements

Ambient temperature requirements for data center devices

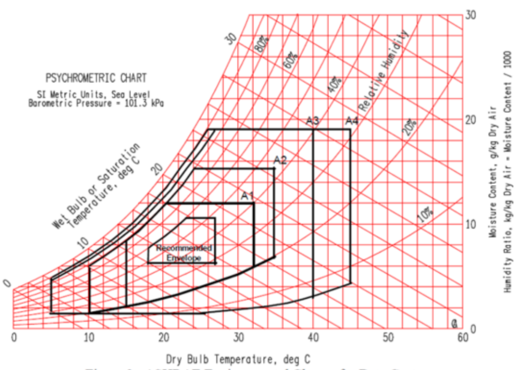
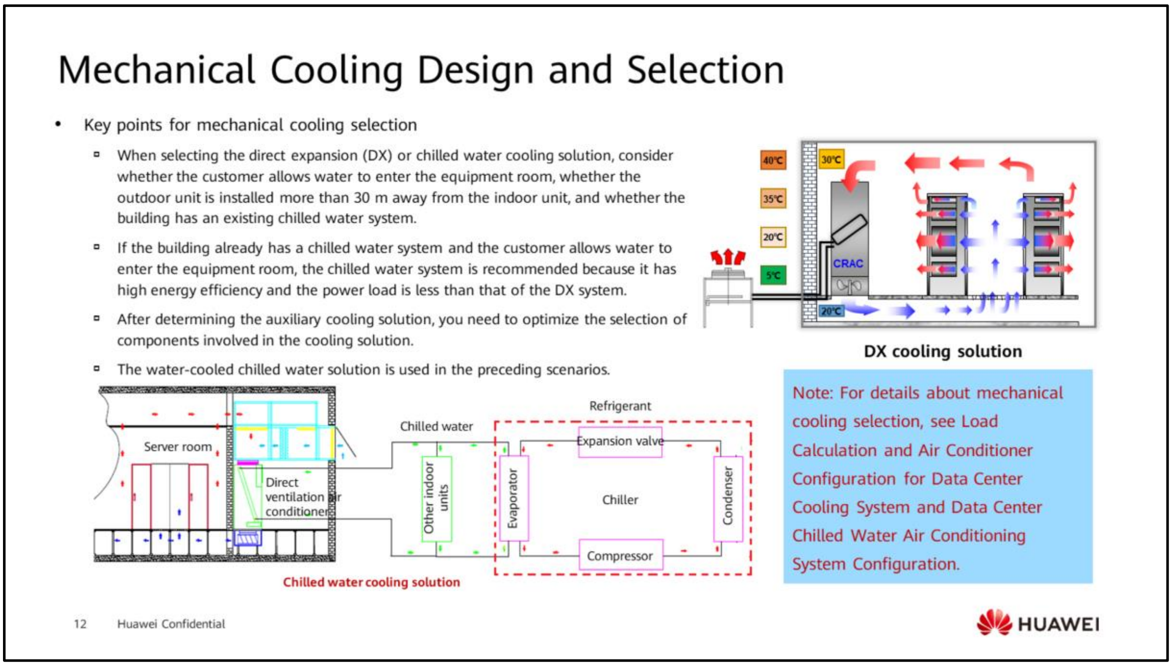


Figure 2. ASHRAE Environmental Classes for Data Centers

- Anti-freezing temperature: If the outdoor temperature is below 3° C, open the anti-freezing air damper to preheat the outdoor air.
- If the preset supply and return air temperatures are higher, the free cooling time using the outdoor air is longer, and the time for starting the compressor is shorter, which reduces the power load of the compressor.
- If the preset humidity range is wider, the time required for humidifying a data center is shorter, and the humidification capacity is less, which reduces the energy consumption caused by humidification.
- Particulate matter concentration involves filter selection. Generally, the information about the concentration of outdoor particulate matter and the filtering level that the data center needs to meet are submitted to the filter vendor.
- The harmful gas concentration determines whether a chemical filter should be configured. Chemical filters do not meet the requirements for low PUE due to large air resistance, heavy maintenance workload, and high cost.
- Data center air supply and return status design is based on the ambient temperature requirements of the data center equipment and the customer's requirements. In principle, if the preset supply and return air temperatures are higher, the free cooling time using the outdoor air is longer, and the time of auxiliary mechanical cooling is shorter, which reduces the cooling load of the data center.



- According to TIA 942 requirements, it is recommended that different redundancy modes be used for components in mechanical cooling for data centers of different tiers, as shown by the following:
  - (1) Tier 1 data centers: Components are not redundant.
  - (2) Tier 2 and Tier 3 data centers: Components (such as indoor air conditioners, outdoor cooling water pumps, chilled water pumps, and chillers) work in N+1 redundancy mode.
  - (3) Tier 4 data centers: Components (such as indoor air conditioners, outdoor cooling water pumps, chilled water pumps, and chillers) work in N+X redundancy mode.

Humidity Control of Direct Ventilation Equipment and Selection of Air Blenders

- Humidity control
  - In the direct ventilation solution, electrode humidifiers and high-pressure micro-mist humidifiers are recommended.
- Selection of air blenders
  - **Selection of functional sections**

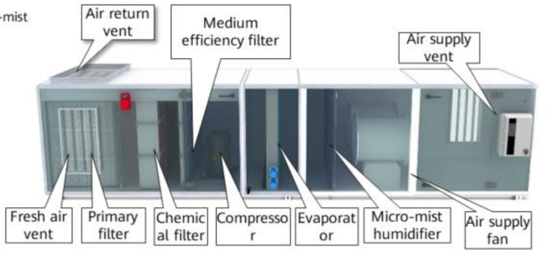
  Cold air processing involves filtering, humidification, preheating, cooling, and dehumidification. Corresponding functional sections need to be designed for these processes.

  - **Dimensions design**

  An air blender is used to filter and humidify the introduced outdoor fresh air. When designing air blender dimensions, consider the following two situations:

  1. Only the intake air damper and return air damper are available. The anti-freezing air damper is not considered.
  2. The intake air damper, return air damper, and anti-freezing air damper are available.

  In addition to different types of air dampers, the specifications of the filtering section and humidification section need to be considered based on the actual project requirements.



Functional sections of a direct ventilation air conditioning system

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Selection of Direct Ventilation Air Supply Fans and Exhaust Fans

- The air supply fan is inside the direct ventilation device, and the exhaust fan is outside the direct ventilation device.
- Selection of air supply fans
  - Air supply volume calculation

$$L_s = \frac{3600 \times K_1 \times Q}{\rho c_p (t_1 - t_2)}$$

  - Q: heat load (kW) of the data center
  - ρ: air density. The recommended value is 1.2 kg/m^3.
  - c_p: specific heat of the air at constant pressure. The recommended value is 1.01 kJ/kg·°C.
  - t1 and t2: preset room temperature and outdoor supply air temperature (°C)
  - K1: margin coefficient for calculating the supply air volume. Generally, the value ranges from 1.1 to 1.2.
- Calculation of supply air pressure
  - $P_{fan} > \Delta P_m + \Delta P_j + P_{filtering} + P_{humidification}$
- Design and selection of exhaust fans
  - The number of exhaust fans is equal to the number of precision air conditioners determined during the mechanical cooling design.
  - The air volume of the exhaust fan is approximately the same as that of the selected air supply fan.

Name	Specifications
Axial fan (exhaust fan)	Dimensions (R x W): 720 mm x 460 mm; rotation speed: 1450 rpm; blade angle: 25 deg; air volume: 15,297 m^3/h; air pressure: 224 Pa; power = 1.5 kW

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- The total pressure of the fan is mainly used to overcome the resistance encountered in the air supply process. Take the air supply fan as an example. The resistance of the fan includes the friction drag, local resistance, and resistance of functional sections (filtering and humidification sections).
- The friction drag (ΔPm) is related to the pipe material and pipe length: ΔPm = Δpm x l.
- Local resistance is mainly caused by the change of air flow direction. When a vortex occurs in the air that flows through a cross section, local resistance is generated. Formula for calculating the local resistance: $\Delta Pj = \zeta \times \rho \times v^2/2$. In the formula, ζ indicates the local resistance coefficient, and V indicates the air flow rate at the place where the local pressure loss occurs in the air duct.

Filter Selection for Direct Ventilation Devices

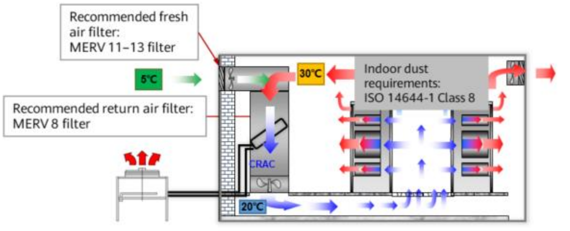
- Filter selection
- Filter class
  - In the actual engineering design, according to the data center air cleanliness requirements specified in the ASHRAE, primary filters and medium efficiency filters are generally used for air ducts. G4 primary filters and F7 medium efficiency filters are usually selected in the industry to ensure good filtering effects. G4 primary filters are recommended for the return air section.
- Calculation of filter cross-sectional area

$$F = Q / 3600U$$

  - Q: air supply volume (m^3/h) through the filter
  - U: windward speed (m/s) of the cross section of the filter. In the industry, the value of 1.87 m/s to 3.73 m/s is usually used.
  - F: cross-sectional area (m^2) of the filter

Requirements for particulate matter concentration in data centers

Particulate matter contamination	The cleanliness of a data center must meet the ISO 14644-1 (ISO 1999) class 8 requirements. A proper filter is required to meet the cleanliness requirements of this class. 1. MERV 8 filters recommended by ASHRAE Standard 127 (2007a) should be used to filter room air. 2. MERV 11 or MERV 13 filters recommended by ASHRAE 2009b should be used to filter the outdoor air entering a data center.



Filter standards for data centers recommended by ASHRAE

Direct Ventilation Control Logic Design

- Control logic design
  - Cooling mode design principle: The cooling mode is automatically selected by the air conditioner controller based on the outdoor ambient temperature and the actual load of the indoor equipment room. The switching logic of the cooling mode is controlled by three key temperatures: preset anti-freezing temperature (T_f), supply air temperature (T_s), and designed return air temperature (T_r).
  - Considering the control precision of the air conditioner, the supply air temperature range of the air conditioner is set to $T_s \pm \Delta t$. The following table describes cooling mode switching based on the outdoor ambient temperature.

Cooling mode

No.	Environment Requirement	Cooling Mode
1	$T_f \le t < T_s - \Delta t$°C	Direct ventilation cooling (fresh air + return air mixture)
2	$t < T_f$°C	Direct ventilation cooling (fresh air + anti-freezing air mixture)
3	$T_s - \Delta t < t \le T_s + \Delta t$°C	Direct ventilation cooling (all fresh air)
4	$T_s + \Delta t \le t < T_r$°C	Direct ventilation + mechanical cooling (hybrid operating mode)
5	$t \ge T_r$°C	Complete mechanical cooling (chilled water or DX cooling)

Operating mode and indoor air damper linkage control status

Operating Mode	Intake Air Damper	Return Air Damper	Anti-freezing Air Damper	Exhaust Air Damper
Chilled water/DX mechanical cooling	0%	100%	0%	0%
Hybrid cooling	100%	0%	0%	100%
Direct ventilation cooling	100%	0%	0%	100%
Direct ventilation cooling[1]	0–100%	0–100%	0%	0–100%
Direct ventilation cooling[2]	0–100%	0–100%	100%	0–100%

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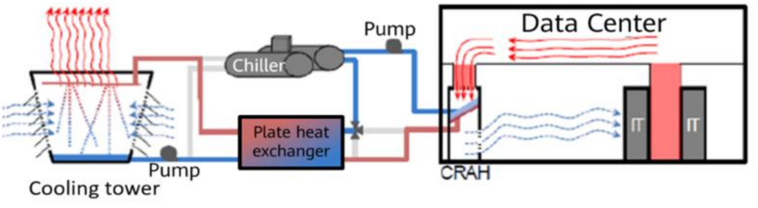
- Tf ≤ t < Ts – Δt°C: Direct ventilation is used for cooling. To ensure the supply air temperature, the return air damper is open to increase the air temperature by mixing air. In this mode, the fresh air damper, return air damper, and exhaust air damper are open, the anti-freezing air damper is completely closed, and the compressor stops running.
- t < Tf°C: Direct ventilation is used for cooling. To prevent the introduced outdoor air from being too cold, open the anti-freezing air damper to preheat the outdoor air and increase the supply air temperature. In this mode, the anti-freezing air damper is 100% open, the opening angles of the supply air damper, exhaust air damper, and return air damper are controlled, and the compressor stops running.
- Ts – Δt < t ≤ Ts + Δt: Direct ventilation is used for cooling, and the compressor stops running. In this mode, the fresh air damper and exhaust air damper are open, and the anti-freezing air damper and return air damper are completely closed.
- Ts + Δt ≤ t < Tr: Direct ventilation and mechanical cooling are used for hybrid cooling. In this case, the outdoor air temperature is lower than the return air temperature of the equipment room. If the compressor is used for hybrid cooling, the energy consumption is lower than that when only the compressor is used for cooling. In this mode, the supply air damper and exhaust air damper are open, and the return air damper and anti-freezing air damper are completely closed.
- t ≥ Tr: The compressor is used for cooling. In this case, energy consumption of the compressor is the highest. In this mode, the supply air damper, return air damper, and anti-freezing air damper are completely closed, and the exhaust air damper is open.

Contents

Water-based Free Cooling Solution Overview

- The heat exchanger acts as the bypass mode of the water chiller. When the outdoor air condition is within the configured range, the chilled water in the data center is cooled by using the cooling water. The pump sends the cooling water through the plate heat exchanger to cool the chilled water in the CRAH without mixing the cooling water and chilled water. The bypass valve of the chiller can be closed based on the condensate water temperature. This type of energy-saving cooling mode supports free cooling for some loads when the heat exchanger and the chiller are connected in series.



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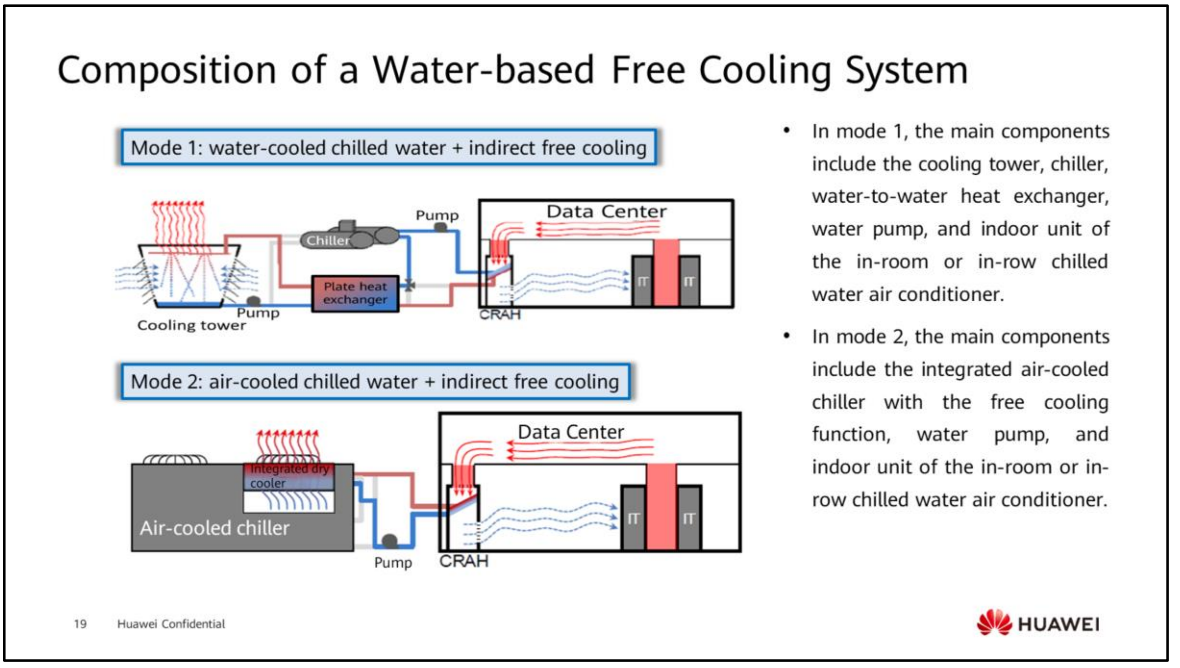
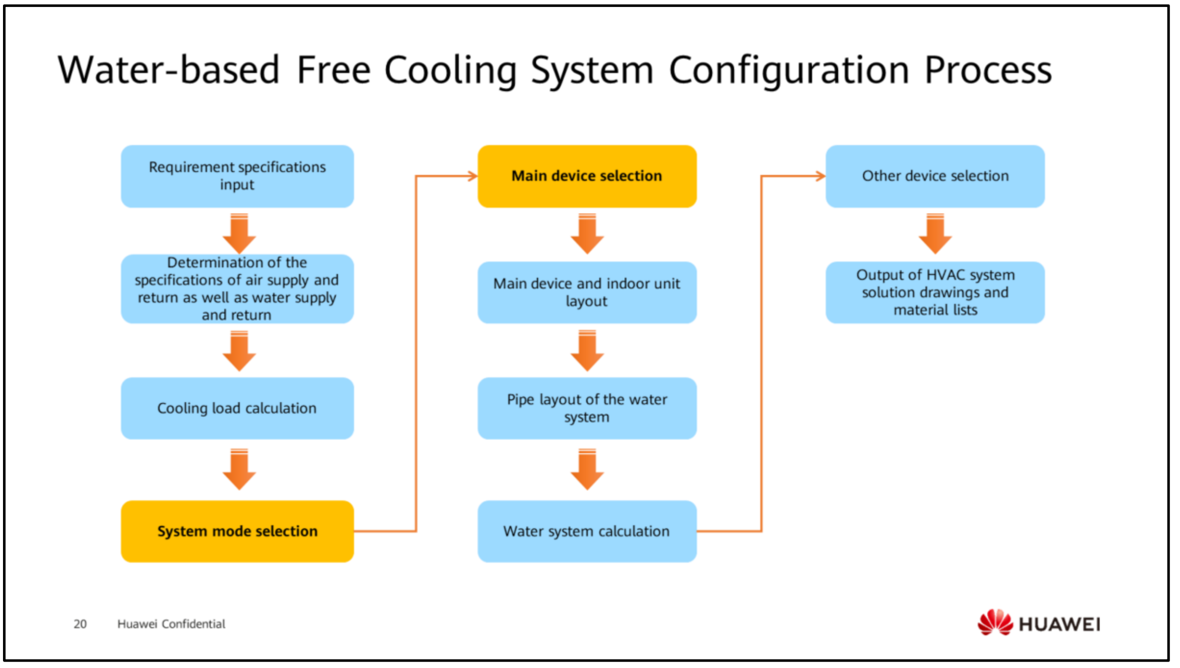


- The water-cooled chilled water free cooling system consists of the chiller, plate heat exchanger, cooling tower, water pump, thermal storage tank, and other auxiliary components (water pipes and meters).
    - The chiller is mainly used for mechanical cooling.
    - The plate heat exchanger is used to directly exchange heat between the cooling water and chilled water.
    - The cooling tower is used to cool the cooling water.
    - The water pump is used to provide power for the whole water-cooled liquid.
    - The thermal storage tank is used to cool the data center when the power supply is disconnected.
- The air-cooled chilled water free cooling system consists of the air-cooled chiller, water pump, thermal storage tank, and other auxiliary components (water pipes and meters). The coil pipe for free cooling is integrated with the outdoor unit. The functions of other components are the same as those of the water-cooled chilled water system.



- The yellow parts indicate the key points described in this slide for water-based free cooling system configuration and selection.
- Requirement specifications input: cabinet power density, cabinet quantity, data center area, whether free cooling is required, and reliability level
- System mode selection: 1. Output the chilled water system mode: air-cooled free cooling or water-cooled free cooling. 2. Output the subsystem mode. 3. Output the system diagram.
- Main device selection: 1. Cooling source device selection 2. Indoor unit selection
- Pipe layout of the water system: Output the air conditioner connection diagram.
- Water system calculation: Calculate the flow rate and pipe diameter of the chilled water system, cooling water system, and condensate water system.
- Other device selection: thermal storage tanks and auxiliary devices

Key Points of Water-based Free Cooling System Configuration (1)

- Design points

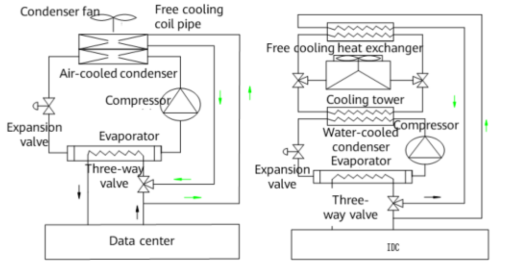
		Description
Determine the free cooling type.		Direct free cooling/Indirect free cooling
Determine the plate heat exchanger based on the outdoor unit.		Water-to-water plate heat exchanger/Air-cooled chiller with the free cooling function
Determine the medium.		Water/Glycol
Heat exchanger configuration	Inlet and outlet water temperatures on the primary and secondary sides	Inlet and outlet water temperatures on the primary side: 7°C for inlet water and 12°C for outlet water Inlet and outlet water temperatures on the secondary side: 10°C for inlet water and 5°C for outlet water
	Material	Alloy 304/Alloy 316
	Total heat transfer capacity	900 kW
	Pressure drop	10 m

- Design of air supply and return as well as water supply and return
  - Determine the air supply and return specifications of the indoor unit
  - Determine the supply and return chilled water temperatures on the cooling source side.
  - Supply and return water temperatures of cooling towers: supply and return water in summer and winter
  - Supply and return water temperatures on the primary and secondary sides of the plate heat exchanger

- In summer, the cooling tower is selected for water supply and return. The cooling tower is selected under the most unfavorable working conditions. The supply and return water temperatures in winter are determined when the control logic is designed, which are usually lower than the temperatures of the supply and return cooling water in summer.
- The operating mechanism of the air-cooled free cooling system is as follows: When the temperature of the cooling system is within the independent operating temperature range (the ambient temperature is higher than the return water temperature), the fan speed is adjusted based on the condensing pressure to ensure system reliability. When the cooling system and free cooling system are running at the same time (the ambient temperature is lower than the return water temperature but the outlet water temperature is higher than the preset value), the fan runs at full speed. The proportional three-way valve is fully opened to maximize the cooling capacity of the free cooling system. The compressor is started or shut down based on the outlet water temperature. In the temperature range where the free cooling system runs independently (the ambient temperature is lower than the return water temperature and the outlet water temperature is lower than the preset value), the fan speed is adjusted based on the outlet water temperature. The proportional three-way valve performs stepless adjustment based on the outlet water temperature to ensure that the free cooling system is fully utilized and the precision requirements of water temperature control are met.

Key Points of Water-based Free Cooling System Configuration (2)

- System mode selection
  - Determine whether to choose the air or water-cooled mode based on the following: 1. Whether the water source is sufficient 2. Whether the installation space meets the water cooling requirements 3. Cooling load



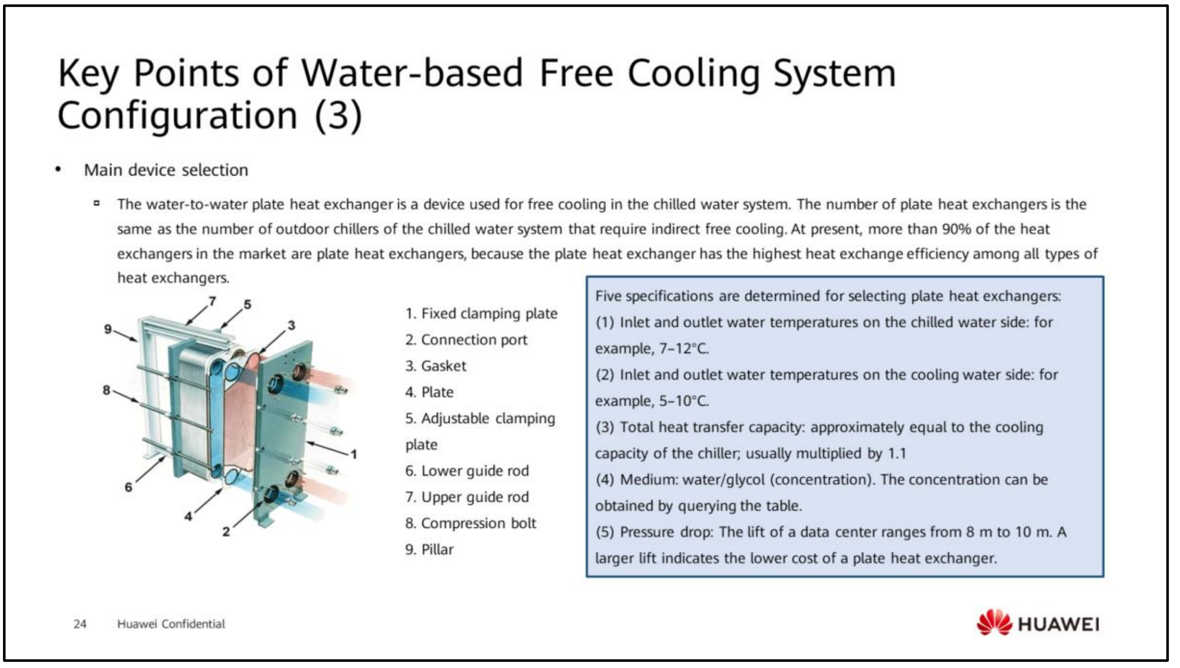
Air-cooled chilled water free cooling

Water-cooled chilled water free cooling

Note: For details about how to select a chilled water air conditioner system, see Data Center Chilled Water Air Conditioning System Configuration.

- In summer, the cooling tower is selected for water supply and return. The cooling tower is selected under the most unfavorable working conditions. The supply and return water temperatures in winter are determined when the control logic is designed, which are usually lower than the temperatures of the supply and return cooling water in summer.
- The operating mechanism of the air-cooled free cooling system is as follows: When the temperature of the cooling system is within the independent operating temperature range (the ambient temperature is higher than the return water temperature), the fan speed is adjusted based on the condensing pressure to ensure system reliability. When the cooling system and free cooling system are running at the same time (the ambient temperature is lower than the return water temperature but the outlet water temperature is higher than the preset value), the fan runs at full speed. The proportional three-way valve is fully opened to maximize the cooling capacity of the free cooling system. The compressor is started or shut down based on the outlet water temperature. In the temperature range where the free cooling system runs independently (the ambient temperature is lower than the return water temperature and the outlet water temperature is lower than the preset value), the fan speed is adjusted based on the outlet water temperature. The proportional three-way valve performs stepless adjustment based on the outlet water temperature to ensure that the free cooling system is fully utilized and the precision requirements of water temperature control are met.

- The water-cooled chilled water air conditioning system has the following three operating modes:
- (1) In summer, the cooling is completely performed by the chiller, and the plate heat exchanger does not work due to valve regulation.
- (2) In winter, only free cooling is adopted. The chiller is shut down and the chilled water and cooling water only pass through the plate heat exchanger by valve regulation.
- (3) Free cooling is partially adopted in spring and autumn. In this case, the cooling water and chilled water first pass through the plate heat exchanger and then the chiller. The resistance is higher, and the lift of the water pump should be larger during design (here the cooling water is glycol). Generally, the lift is 1.2 times of the original designed lift. (If water is used as the medium of cooling water, the lift remains unchanged.)



- For details about how to select other devices, see Data Center Chilled Water Air Conditioning System Configuration.
- In a water-cooled chilled water system, although the water quality on the chilled water side is good, the water quality on the cooling water side is usually poor because the cooling water side is connected to the cooling tower. If a brazed plate heat exchanger is used, dirt in water will be accumulated on the heat exchanger after a period of time. In addition, a brazed plate heat exchanger is not easy to maintain, resulting in a significant decrease in the overall heat exchange efficiency. Therefore, it is recommended that detachable plate heat exchangers be used in water-cooled chilled water systems.
- On the contrary, in an air-cooled chilled water system, one side of the system is chilled water, and the other side is air. Therefore, the medium in this case has relatively high cleanliness, and using a brazed plate heat exchanger can effectively improve overall heat exchange efficiency.

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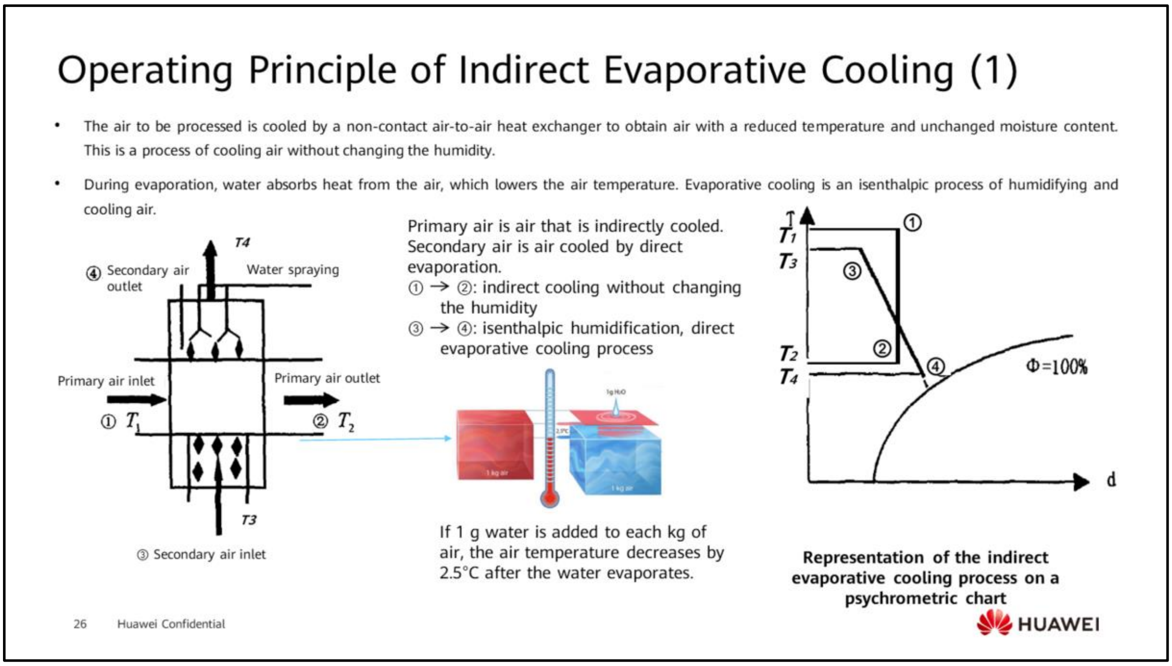
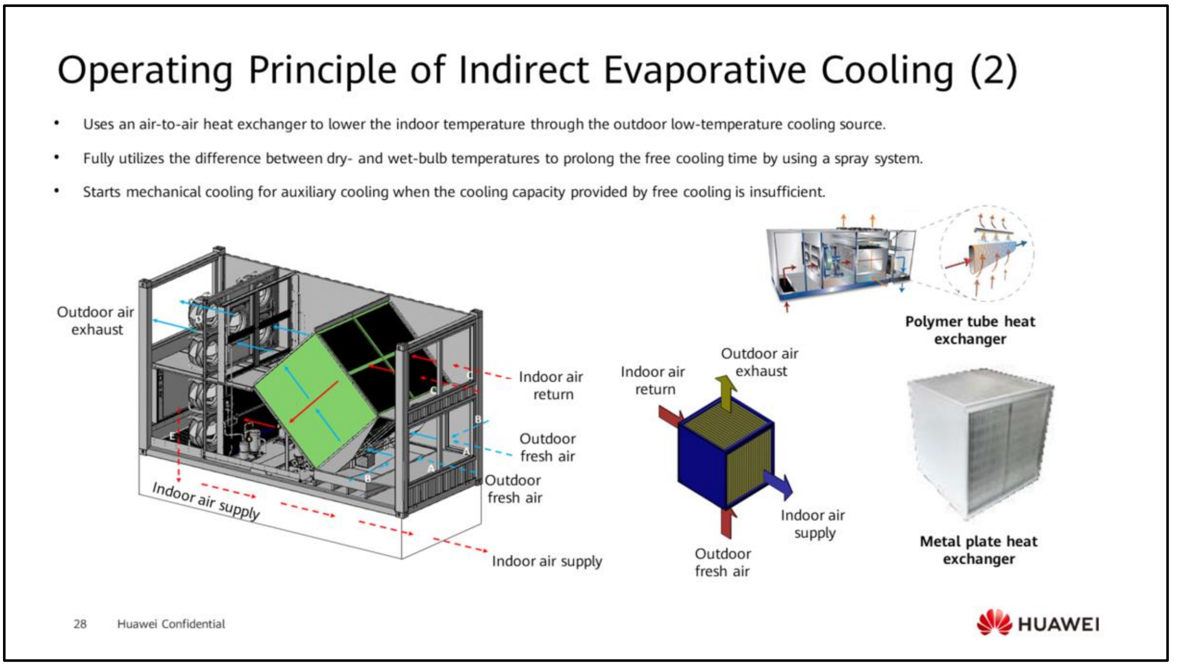


- Heat dissipation modes of cooling water in the cooling tower include contact heat dissipation and evaporative heat dissipation.
- Contact heat dissipation
  - When the cooling water meets the air, there are three types of heat transfer depending on the difference between the inlet water temperature Tw1 and the air temperature Tq1 of the cooling tower:
    - When Tw1 is greater than Tq1, the cooling water transfers heat to the air and gets cooled.
    - When Tw1 is equal to Tq1, there is no heat transfer between the cooling water and the air, and the cooling water temperature remains unchanged.
    - When Tw1 is less than Tq1, the air transfers heat to the cooling water, and the cooling water temperature increases.
  - Therefore, when the ambient temperature is equal to or higher than the cooling water temperature, the contact heat dissipation of the cooling tower fails. At this time, its cooling effect will depend entirely on the evaporative heat dissipation of the cooling water. Therefore, the cooling effect will be significantly reduced.

- Evaporative heat dissipation
    - Influence of meteorological factors on evaporative heat dissipation of cooling water: Influence of air temperature: The higher the air temperature (dry-bulb temperature), the stronger the evaporative heat dissipation. Influence of air humidity: The lower the relative humidity, the faster the evaporative heat dissipation. On the contrary, high ambient humidity results in poor evaporative heat dissipation. When water vapor in the air saturates, evaporation cannot be performed, and the evaporative heat dissipation capacity is equal to zero.
    - Influence of air pressure: The lower the air pressure, the easier the water evaporates. Increasing the ventilation of the cooling tower can effectively reduce the static pressure on the surface of the cooling water and facilitate the evaporative heat dissipation of the cooling water.
    - Influence of wind speed: The greater the wind speed, the greater the convection heat transfer coefficient. In addition to closed cooling towers, various open cooling towers require natural or mechanical ventilation.
    - To sum up, the cooling process of cooling water in a cooling tower is a process of exchanging heat with the air, and its cooling effect is greatly affected by atmospheric weather conditions.



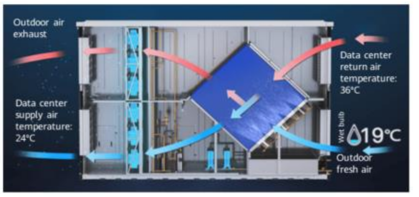
- The water-cooled chiller must use a cooling tower. The air-cooled chiller does not require a cooling tower.

Operating Mode of Huawei Indirect Evaporative Cooling Devices

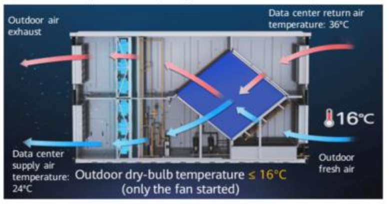
Different cooling components are started based on the outdoor fresh air.

Operating Mode	Outdoor Ambient Temperature (100% Load)	Fan	Water Pump	Compressor
Dry mode	Dry-bulb temperature ≤ 16°C	ON	OFF	OFF
Wet mode	Dry-bulb temperature > 16°C, wet-bulb temperature ≤ 19°C	ON	ON	OFF
Hybrid mode	19°C < Wet-bulb temperature ≤ 34°C	ON	ON	ON

Wet mode (fan and water pump started)



Dry mode (only the fan started)

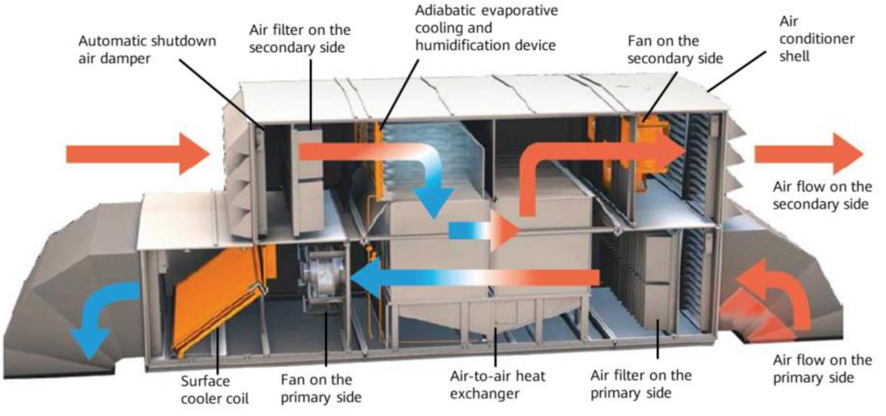


Hybrid mode (fan, water pump, and compressor started)

- Dry mode: When the dry-bulb temperature of the outdoor air is lower than a critical value, only the outdoor low-temperature air can be used to cool the thermal circulation air in the data center through an air-to-air heat exchanger.
- Wet mode: When the dry-bulb temperature of the outdoor air is higher than the critical value of the dry mode but the wet-bulb temperature is lower than a certain critical value, the evaporative cooling principle can be used to perform isenthalpic humidification and cooling on the outdoor air and then the thermal circulation air in the data center can be cooled through an air-to-air heat exchanger.
- Hybrid mode: When the wet-bulb temperature of the outdoor air is higher than the critical value of the wet mode, the evaporative cooling principle can be used to perform isenthalpic humidification and cooling on the outdoor air and then the thermal circulation air in the data center can be cooled through an air-to-air heat exchanger. At the same time, parts with insufficient cooling capacity are supplemented by the backup DX or chilled water mechanical cooling system.
- The critical temperature value generally depends on the structure, material, adiabatic evaporation mode, and heat exchange efficiency of a heat exchanger.

Indirect Evaporative Cooling System Composition

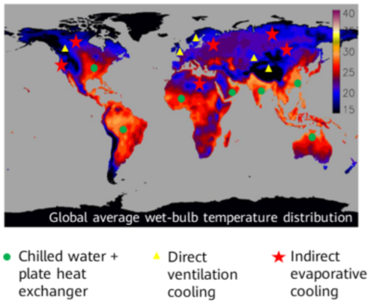
- The typical structure of an indirect evaporative cooling air conditioner is used as an example.



- Generally, an indirect evaporative cooling air conditioner consists of an air-to-air indirect heat exchanger, an adiabatic evaporative cooling device, fans on the primary and secondary sides, air filters, an air damper, and a backup mechanical cooling cycle.
- Main structures of air conditioners can be different, depending on the vendors' design.
- Air-to-air heat exchangers may have different structures and materials, but they are generally cross-air flow heat exchangers. The heat exchange efficiency of different heat exchanger types is different.
- The air inlet and outlet directions on the secondary side can be parallel and reverse to those on the primary side, as shown in the figure. They can also be vertical and cross-connected, depending on the design structure of the air conditioner.
- The evaporative cooling and humidification can use the adiabatic spray (or micro-mist) mode or a mode similar to the cooling tower operating principle. Water is directly sprayed on an air-to-air heat exchanger, which leads to higher heat transfer efficiency in wet working conditions than dry working conditions.
- A water treatment system and water circulation pump system are usually used together with an evaporative cooling system.
- The backup mechanical cooling cycle can be a DX compressor cooling cycle or a chilled water surface cooler coil type, depending on the design and actual application conditions of the air conditioner.

Application Scenarios of Indirect Evaporative Cooling

- The indirect evaporative cooling solution applies to the following scenarios:
  - Climatic environment: applicable to areas where the ambient temperature is low or the temperature is high and the humidity is low. The optimal average temperature is below 20°C.
  - Altitude: ≤ 1000 m (> 1000 m: requires derating design)
  - Geographical environment: abundant water resources and cheap water price
  - Typical regions: Europe, Central Asia, Russia, North China, and Northwest China
  - Outdoor installation design, large installation space needed for the large equipment, and suitable for newly-built buildings (equipment and building planned together)
  - Various air supply and return modes
  - Special designs, such as anti-corrosion, anti-explosion, and antiseismic designs
  - Suitable for the design and planning of projects with innovative requirements
  - Suitable for projects using government or international organization funds and with special demands on PUE



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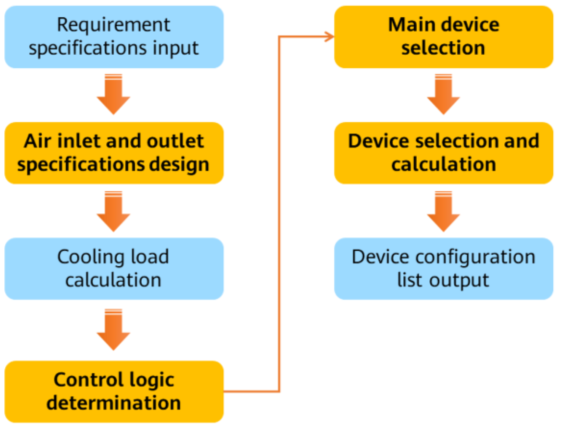
Indirect Evaporative Cooling System Configuration Process



Design Point		
Redundancy mode		N, (N+1), (N+X)
Main device type	Cooling source and refrigerant	Indirect evaporative cooling system + DX stepless load adjustment (R407C/R410A)
	Fan	Variable-frequency or constant-frequency fans on the primary and secondary sides
	Air-to-air heat exchanger	Metal plate or non-metal tube type
	Evaporative cooling	Water sprinkling/spraying
Control logic	Dry working condition	Outdoor air dry-bulb temperature ≤ Critical dry-bulb temperature under dry working conditions
	Wet working condition	Critical dry-bulb temperature under dry working conditions < Temperature after adiabatic evaporation of the outdoor air ≤ Critical wet-bulb temperature under wet working conditions
	Wet working condition + compressor hybrid working condition	Temperature after adiabatic evaporation of the outdoor air > Critical wet-bulb temperature under wet working conditions

- The yellow parts indicate the key points described in this slide for indirect evaporative cooling system configuration and selection.
- Requirement specifications input: cabinet power density, cabinet quantity, data center area, and data center environment specifications (dry-bulb temperature, relative humidity, particle concentration, and harmful gas concentration)
- Air inlet and outlet specifications design: After the air inlet and outlet specifications are determined, the air volume can be calculated to determine the supply air volume and exhaust air volume. Device selection information can be provided to the device vendor to configure the rotary wheel.
- Control logic determination: Determine the control logic of the full rotary wheel, hybrid, and full compressor working conditions.
- Main device selection: The integrated solution of the rotary wheel free cooling consists of many functional sections. Identify mandatory and optional sections, and determine the selection basis.
- Device selection and calculation: The selection specifications of the rotary wheel free cooling air conditioner include the air volume, air pressure, environment specifications, air inlet and outlet specifications, cooling capacity, humidification capacity, cleanliness, and noise requirements.
- Device configuration list output: Output the list based on the preceding selection solution.

Key points for Indirect Evaporative Cooling System Configuration (1)

- Specifications input

Specifications Input
Tier requirements
Total power consumption of computers (kW)
Common number of personnel in the data center
Cabinet power density (kW/rack)
Climate level and type
Area of each room in the data center (computer room, power room, and auxiliary area)
Outdoor temperature and humidity

- Air inlet and outlet specifications design
  - Supply and return air specifications for indirect evaporative cooling

- Control logic determination (The following is an example. The temperature for mode switching can be adjusted based on the actual situation.)
  - Outdoor air dry-bulb temperature ≤ 20°C

  The fan on the primary side runs at full speed, the compressor stops, and the evaporative cooling system does not run. The drive motor frequency of the fan on the secondary side is adjusted steplessly within the range of 5 Hz to 50 Hz based on the outlet air temperature of the fan on the primary side.

  - 20°C < Outdoor air wet-bulb temperature ≤ 22°C

  The fan on the primary side runs at full speed, the compressor stops, and the evaporative cooling system starts. The drive motor frequency of the fan on the secondary side is adjusted steplessly within the range of 5 Hz to 50 Hz based on the outlet air temperature of the fan on the primary side.

  - Outdoor air wet-bulb temperature > 22°C

  The fans on the primary and secondary sides run at full speed. The evaporative cooling system starts. The compressor starts and performs stepless load adjustment based on the outlet air temperature of the fan on the primary side.

Key points for Indirect Evaporative Cooling System Configuration (2)

- Main device selection

No.	Functional Section	Technical Description
1	Air filter	Filters and purifies the primary side return air and secondary side fresh air. The primary filter is of class G4.
2	Air-to-air heat exchanger	Performs indirect heat exchange between the primary air side and the secondary air side.
3	Evaporative cooling device	Performs evaporative cooling on the outdoor air on the secondary side.
4	Fan	Supplies circulating power to the circulating air on the primary side and the outdoor fresh air on the secondary side. DC inverter EC fans are adopted to minimize energy consumption and noise.
5	Backup mechanical cooling cycle	Includes DX and chilled water types; supplements the cooling capacity when indirect evaporative cooling provides insufficient cooling capacity in extreme outdoor temperatures.
6	Air conditioner shell	High-quality flame-retardant polyurethane thermal insulation materials are used in the middle of the double-layer panel, and cold bridges and condensation are prevented.
7	Control system	Controls the operation of the air conditioner and reserves ports for connecting to the teamwork control system.

- Air filter: Because of indirect heat exchange, the indoor air and outdoor air are completely isolated, and no cross pollution occurs. Generally, air filters of only one class need to be configured on both sides. The filtering level is usually G4.
- Air-to-air heat exchanger: Generally, metal plate heat exchangers and non-metal tube heat exchangers are used. Heat pipe heat exchangers are seldom used due to their high costs. During the selection of heat exchangers, the heat exchange efficiency requirements under dry and wet working conditions are mainly considered to select proper air-to-air heat exchangers.

- Evaporative cooling device: There are two types of evaporative cooling methods. One is similar to the principle of a cooling tower. Water is directly sprayed on an air-to-air heat exchanger and contacts with the outdoor air on the secondary side to absorb heat and lower the temperature. The other is adiabatic spray, in which water does not directly contact with the air-to-air heat exchanger. Water is sprayed on the outdoor air on the secondary side for adiabatic humidification and cooling, and then the heat of the cooled air is exchanged with that of the indoor air on the primary side through an air-air heat exchanger.
- Fan: includes fans on the primary and secondary sides. Motors are configured for the fans.
- Backup mechanical cooling cycle: includes DX evaporator and chilled water coil types.
- Air conditioner shell: The panel material, thickness, thermal insulation material, structure strength, anti-air leakage, anti-cold bridge, and anti-condensing function are mainly considered for the shell. The maximum air leakage rate of the air conditioner should not be greater than 1%. The cold bridge factor should reach TB2 or higher of the EN 1886 standard. There should be no cold bridge.
- Control system: usually delivered with the air conditioner. The PLC controller can be integrated with the air conditioner or remotely installed indoors. The control system has a color touchscreen whose size is not less than 7 inches, provides anti-freezing and anti-condensing control functions, and provides RS232 and RS485 ports (Modbus protocol) that support remote control and centralized management.

Key points for Indirect Evaporative Cooling System Configuration (3)

- Main device selection: The main design specifications of the indirect evaporative cooling air conditioner include air volume, air pressure, environment specifications, air inlet and outlet specifications, cooling capacity, adiabatic humidification capacity, cleanliness, and noise requirements, as shown in the following tables.

Type	Item	Design Specifications
Ventilation system	Air volume on the primary side	Calculated based on the cooling load and supply and return air specifications
	External static pressure of the fan on the primary side	Calculated based on the resistance of the air duct system
	Motor power consumption	Determined based on the air volume, total fan pressure, and efficiency
	Air volume on the secondary side	Generally, the maximum air volume is the same as that on the primary side.
	External static pressure of the fan on the secondary side	It is used to overcome the resistance of the components in the system.
	Motor power consumption	Determined based on the air volume, total fan pressure, and efficiency
Indirect evaporative cooling system	Cooling capacity supply	Determined based on load calculation
Compressor cooling system	Cooling capacity	If 100% backup is required, the cooling capacity is the indirect heat exchange cooling capacity. If only partial load backup is required, the cooling capacity is determined based on the actual proportion.
	Compressor power consumption	Configured based on the system

Key points for Indirect Evaporative Cooling System Configuration (3)

- Main device selection: The main design specifications of the indirect evaporative cooling air conditioner include air volume, air pressure, environment specifications, air inlet and outlet specifications, cooling capacity, adiabatic humidification capacity, cleanliness, and noise requirements, as shown in the following tables.

Evaporative cooling and humidification system	**Humidification capacity**	**Calculated based on the maximum air volume and maximum humidity difference on the secondary side**
	Water consumption	Determined based on the humidification capacity, humidification efficiency, and water circulation logic

Provided Specifications	Customization	Key Device
Air volume	Fan	Fan on the primary side
Air pressure		Fan on the secondary side
Noise		Muffler (optional)
Environmental specifications	Air-to-air heat exchanger	Air-to-air heat exchanger
Air intake and exhaust specifications		
Cooling capacity	Cooling system	Compressor
		Evaporator
		Condenser
Humidification capacity	Adiabatic evaporative humidifier	Adiabatic evaporative humidifier
Cleanliness	Filtering section	G4 bag filter

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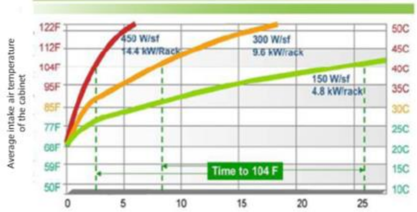
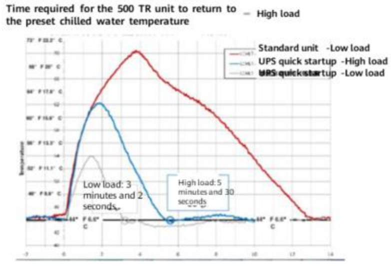
Continuous Cooling Concept

- A data center that requires high reliability or high density must have the continuous cooling function.
  - Short-time cooling interruption may be tolerated in low-density data centers, but may cause faults or even service interruption in medium- and high-density data centers.
- A diesel generator (DG) alone cannot guarantee continuous cooling.
  - When the mains supply is cut off, cooling is also interrupted. It takes 5 to 15 minutes for the DG to start, the compressor to restart, and the cooling to recover.

Once the air conditioning system in a data center is interrupted, the temperature of the data center rises rapidly, which may cause server faults or even breakdown.



Cooling duration without air conditioners



- When the air conditioner stops running, the time for server breakdown is calculated as follows:
  - < 2 kW/cabinet (< 500 W/m^2): The server breaks down 12 minutes after the air conditioner stops running.
  - 3 kW/cabinet: The server breaks down 8 minutes after the air conditioner stops running.
  - 6 kW/cabinet: The server breaks down 3 minutes after the air conditioner stops running.
  - 9 kW/cabinet: The server breaks down 2 minutes after the air conditioner stops running.
  - 15 kW/cabinet: The server breaks down 1 minute after the air conditioner stops running.
- It takes at least 2 minutes for the chiller to resume cooling after shutdown.

Uptime White Paper – Continuous Cooling (1)

- The main function of continuous cooling is to eliminate the short-time cooling capability loss during the transfer between the mains and the DG.

Basic requirement	**Only Tier IV data centers require continuous cooling. It is recommended that continuous cooling be configured if the rated power density exceeds 4 kW/rack regardless of the data center tier.**
Continuous cooling time	• Regardless of technical factors, continuous cooling is defined as **the capability of providing stable and uninterrupted cooling for IT devices and UPSs.** • During the UPS backup time, the continuous cooling system provides stable cooling capability. • For example, the static UPS system provides 15-minute backup power. The continuous cooling system should provide stable cooling during the 15 minutes. If there are redundant modules and batteries, the backup time of 15 minutes may be extended to 30 minutes or longer. • Customers must exercise caution when determining whether to configure continuous cooling based on the specified backup time or available backup time. • The cooling system recovery time must be set no matter what types of cooling and UPS technologies are used. For example, in a chilled water system, although the power supply of the DG can be recovered within several seconds, it takes 15 minutes or even longer for the chiller to recover after a power failure. Therefore, the cooling storage time must be considered based on the backup time and the time required for the cooling system to restore stable cooling.

- According to the white paper on the continuous cooling system for high-density data centers discussed by the Uptime Institute, cooling systems are classified into classes A, B, and C. Class A is the uninterruptible cooling system, which requires UPSs to be configured for fans and secondary pumps of precision air conditioners, and also requires a thermal storage tank. Class B is the continuous cooling system, which requires UPSs to be configured for fans and secondary pumps of precision air conditioners, but does not require a thermal storage tank. Class C is the interruptible cooling system, which requires no UPS and is stopped when the power supply is faulty.
- Suggestions of Uptime:
  - When the power consumption exceeds 4 kW/cabinet, continuous cooling (cooling storage) can be considered.
  - When the power consumption exceeds 6 kW/cabinet, continuous cooling is recommended.

Uptime White Paper – Continuous Cooling (2)

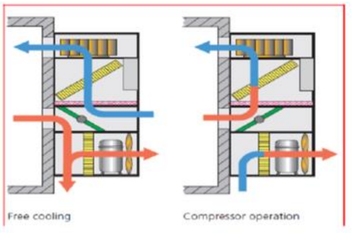
- The main function of continuous cooling is to eliminate the short-time cooling capability loss during the transfer between the mains and the DG.

Chilled water system	• **It has the cooling storage capability. The secondary pump and indoor unit are powered by the UPS. It uses the same UPS with the IT device or a separate UPS that supports online maintenance and fault tolerance.** • **If a primary pump is used, it must be powered by the UPS.**
DX system	• Both indoor and outdoor units are powered by the UPS that is maintained online and is fault-tolerant. The same requirement applies to split-type air conditioning systems.
100% free cooling system	• Fans or other systems that transfer outdoor cold air indoors must be powered by the UPS.

- According to the white paper on the continuous cooling system for high-density data centers discussed by the Uptime Institute, cooling systems are classified into classes A, B, and C. Class A is the uninterruptible cooling system, which requires UPSs to be configured for fans and secondary pumps of precision air conditioners, and also requires a thermal storage tank. Class B is the continuous cooling system, which requires UPSs to be configured for fans and secondary pumps of precision air conditioners, but does not require a thermal storage tank. Class C is the interruptible cooling system, which requires no UPS and is stopped when the power supply is faulty.
- Suggestions of Uptime:
  - When the power consumption exceeds 4 kW/cabinet, continuous cooling (cooling storage) can be considered.
  - When the power consumption exceeds 6 kW/cabinet, continuous cooling is recommended.

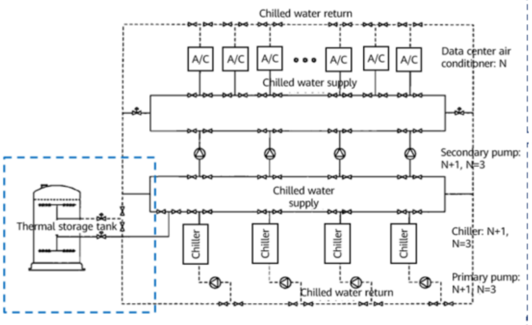
Solutions for Continuous Cooling in High-Density Data Centers

- For a data center that uses the chilled water system, the continuous cooling measures are as follows: Install a thermal storage device for the cooling source system (the cooling storage time should be at least 15 minutes). Use UPSs to supply power to the control system, indoor unit chilled water circulating pump, and air conditioner fan.
- For a data center that uses the air-cooled DX air conditioning system, the continuous cooling measure is as follows: Use UPSs to supply power to the indoor and outdoor units.
- For a data center that uses a direct or indirect evaporative cooling system, the continuous cooling measure is as follows: Use UPSs to supply power to the indoor unit cooling water pump and distributed fan.
- For a data center that uses the direct fresh air cooling system, the continuous cooling measure is as follows: Use UPSs to supply power to the inlet and outlet fans that support cooling.



Continuous Cooling Configuration for the Chilled Water Air Conditioning System (1)

- Cooling architecture of a Tier 3 data center with a thermal storage tank



- A thermal storage tank is a chilled water storage device. It uses the water distribution system to layer water of different temperatures based on the different densities of water at different temperatures. This prevents cooling loss caused by mixing of cold water and warm water. Generally, the thermal storage tank includes the water tank body, water distributor, liquid level meter, temperature measuring components, thermal insulation layer, ladder, railings, and surge protection devices.

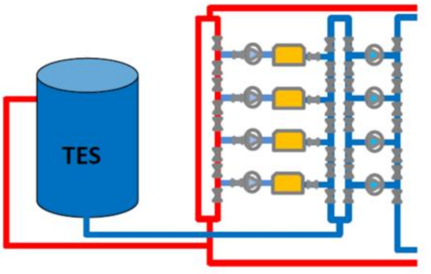
- Parallel running:
- In cooling storage mode, chilled water flows in from the bottom and out from the top.
- In cooling release mode, chilled water is supplied from the bottom and returned from the top.
- Set the temperature sensor along the vertical direction of the thermal storage tank.
- In the Tier 3 architecture, the thermal storage tank does not require redundancy. You can perform online maintenance as planned by disconnecting the motorized valve.
- In the Tier 4 architecture, the thermal storage tank does not require redundancy and meets the 2N architecture requirements.
- Automatic cut-off valves are configured for the water inlet and outlet pipes of the thermal storage tank.

Continuous Cooling Configuration for the Chilled Water Air Conditioning System (2)

- Calculation of the volume of the water storage tank
  - The volume of the water storage tank can be calculated as follows:

$$L = \frac{3600Q}{K \cdot \rho \cdot c \cdot \Delta t}$$

  - L: designed volume (m^3) of the water storage tank
  - Q: designed cooling storage capacity (kWh) of the water storage tank
  - K: performance index of the water storage tank. It refers to the ratio of the output energy to the input energy of the water storage tank in a cooling storage and release period. The value ranges from 0.85 to 0.9.
  - ρ: water density (kg/m^3)
  - c: specific heat capacity of water [kJ/(kg·K)]
  - Δt: temperature difference (K) between the supply and return water of the water storage tank



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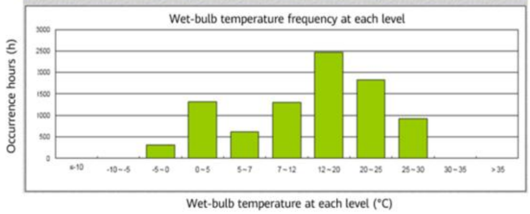
Overview of the Air Conditioning System in a Data Center - Outdoor Environment

- Outdoor air calculation specifications

Construction Site	Calculated Dry-Bulb Temperature of the Air Conditioner		Calculated Dry-Bulb Temperature for Ventilation		Calculated Outdoor Wet-Bulb Temperature of the Air Conditioner in Summer	Calculated Relative Humidity of the Air Conditioner in Winter	Calculated Outdoor Relative Humidity for Ventilation in Summer	Calculated Average Daily Temperature of the Air Conditioner in Summer	Outdoor Average Wind Speed in Winter
Guiyang	Winter: –2.5°C	Summer: +27.1°C	Winter: –2.5°C	Summer: +27.1°C	+23°C	80%	64%	+26.5°C	2.1 m/s

No.	1	2	3	4	5	6	7	8	9	10
Node	-10	-5	0	5	7	12	20	25	30	35
<-10	-10~-5	-5~0	0~5	5~7	7~12	12~20	20~25	25~30	30~35	>35
0	0	315	1323	613	1296	2471	1821	921	0	0



- The annual outdoor wet-bulb temperature in Guiyang is less than or equal to 7°C for about 2251 hours, accounting for 25.7% of the year. The free cooling source can be fully used for about 93 days.

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Overview of the Air Conditioning System in a Data Center - Data Center Overview

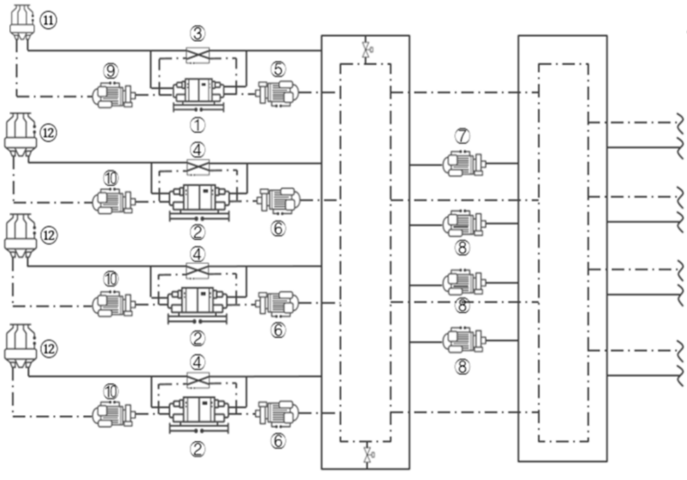
- Indoor calculation specifications

Item	Description	Remarks
Temperature in the cold aisle or the air intake area of the cabinet	18–27°C	Dew formation is not allowed.
Relative humidity and dew point temperature in the cold aisle or the air intake area of the cabinet	The dew point temperature ranges from 5.5°C to 15°C, and the relative humidity is less than or equal to 60%.	
Temperature and relative humidity of the auxiliary area (when equipment is powered on)	Temperature: 18–28°C; relative humidity: 35%–75%	
Temperature of the UPS and battery room	20°C–30°C	

- Data center scale
  - The data center is planned to house 2202 IDC cabinets. If the power of each cabinet is 7 kW, the total IT power consumption is 12,331 kW, and the total cooling load of air conditioners in summer is about 15,400 kW.
- Air conditioning system planning analysis
  - A cooling source system with large- and small-capacity air conditioner chillers is adopted. In the early stage of the building, the small-capacity chiller is used when the installed capacity is small. This prevents the large-capacity chiller from running at low load, which improves the cooling efficiency of the air conditioner, reduces energy consumption of the air conditioner, and lowers the PUE value at the initial phase of data center construction. When the installed capacity reaches a certain value, the large-capacity chiller is used to ensure that the air conditioner works in a high-efficiency range. This prevents the centrifuge chiller from generating surges when the load is low. The chillers are started based on the load. The large-capacity chiller runs at full load.

- The centrifugal chiller generates surge at a load rate below 30%.

Overview of the Air Conditioning System in a Data Center - Solution Configuration (1)



- The figure on the left shows the flowchart of the chilled water air conditioning system in a data center of a project in Guiyang.

1. Centrifugal chiller: 700 USRT
2. Centrifugal chiller: 1400 USRT
3. Plate heat exchanger: 2800 kW
4. Plate heat exchanger: 5600 kW
5. Primary chilled water pump: 390 m^3/h
6. Primary chilled water pump: 780 m^3/h
7. Secondary chilled water pump: 390 m^3/h
8. Secondary chilled water pump: 780 m^3/h
9. Cooling water pump: 540 m^3/h
10. Cooling water pump: 1080 m^3/h
11. Cooling tower: 2500 kW in summer
12. Cooling tower: 5900 kW in summer

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Overview of the Air Conditioning System in a Data Center - Solution Configuration (2)

- In this project, a single data center is planned to house three high-voltage variable-frequency 1400 RT chillers, one low-voltage variable-frequency 700 RT chiller, and related auxiliary devices. Air conditioner devices, such as chillers, are placed in the bottom-layer chiller plant, and the open crossflow cooling tower is placed on the roof. The supply and return chilled water temperatures are 10°C and 16°C, respectively. The supply and return cooling water temperatures are 30°C and 35°C, respectively. When the data center is running with full load, start the 4200 RT chillers. The following table lists the solution configuration.

No.	Device Name	Device Model	Device Quantity	Rated Capacity of a Single Device
			(PCS)	(kW)
1	Centrifugal chiller (10 kV)	Rated cooling capacity: 1400 USRT 10°C/16°C	3	815
	Centrifugal chiller (380 V)	Rated cooling capacity: 700 USRT 10°C/16°C	1	381
2	Plate heat exchanger	Heat exchange capacity: 5600 kW 10°C/16°C and 8.5°C/13.5°C	3	N/A
		Heat exchange capacity: 2800 kW 10°C/16°C and 8.5°C/13.5°C	1	N/A
3	Primary chilled water circulating pump	Flow rate: 780 m^3/h Lift: 18 m	3	55
		Flow rate: 390 m^3/h Lift: 18 m	1	37

- Chiller configuration
  - The total cooling load is 15,400 kW. Generally, two to four chillers are recommended. For a small-or medium-sized data center, two chillers are recommended. For a large-sized data center, three chillers are recommended. For a hyperscale data center, four chillers are recommended. In this example, three 1400 RT (4923 kW) chillers are selected. Besides, one 700 RT unit (2461 kW) is configured to meet the cooling requirements for low-load operation in the early stage.
- Plate heat exchanger configuration
  - Determine the heat exchange capacity: Q1 = 4923 x 1.1 ≈ 5600 kW; Q2 = 2461 x 1.1 ≈ 2800 kW.
  - Determine the supply and return water temperatures on the primary side: 10°C/16°C.
  - Determine the supply and return water temperatures on the secondary side: 8.5°C/13.5°C.
- Primary chilled water circulating pump
  - Determine the flow rate: 0.86 x 4923 x 1.1/6 = 776 m^3/h; 0.86 x 2461 x 1.1/6 = 388 m^3/h.
  - Determine the lift: 18 m (estimated).

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Overview of the Air Conditioning System in a Data Center - Solution Configuration (3)

- In this project, a single data center is planned to house three high-voltage variable-frequency 1400 RT chillers, one low-voltage variable-frequency 700 RT chiller, and related auxiliary devices. Air conditioner devices, such as chillers, are placed in the bottom-layer chiller plant, and the open crossflow cooling tower is placed on the roof. The supply and return chilled water temperatures are 10°C and 16°C, respectively. The supply and return cooling water temperatures are 30°C and 35°C, respectively. When the data center is running with full load, start the 4200 RT chillers. The following table lists the solution configuration.

No.	Device Name	Device Model	Device Quantity	Rated Capacity of a Single Device
			(PCS)	(kW)
4	Secondary chilled water circulating pump	Flow rate: 780 m³/h Lift: 25 m	3	75
		Flow rate: 390 m³/h Lift: 26 m	1	55
5	Cooling water pump	Flow rate: 1080 m³/h; lift: 30 m	3	110
		Flow rate: 540 m³/h Lift: 30 m	1	75
6	Cooling tower	Heat dissipation capacity: 5900 kW in summer (30°C/35°C; T_s = 25); 5100 kW in winter (8.5°C/13.5°C; T_s = 4)	3	74
		Heat dissipation capacity: 2500 kW in summer (30°C/35°C; T_s = 25); 2600 kW in winter (8.5°C/13.5°C; T_s = 4)	1	37

- Secondary chilled water circulating pump
  - Determine the flow rate: The calculation method is the same as that of the primary pump. (You can also calculate the flow rate based on the heat exchange capacity of the plate heat exchanger and the temperature difference between the supply and return water on the secondary side.)
  - Determine the lift: 25 m and 26 m (estimated).
- Cooling water pump
  - Determine the flow rate: 0.86 x (4923 + 815) x 1.1/5 ≈ 1080 m³/h.
  - 0.86 x (2461 + 381) x 1.1/5 = 540 m³/h
  - Determine the lift: 25 m and 26 m (estimated).
- Cooling tower
  - Heat dissipation capacity: 5900 kW in summer; 5100 kW in winter
  - Heat dissipation capacity: 2500 kW in summer; 2600 kW in winter

Summary

- Data Center Air Conditioning System Performance Optimization Method
- Free Cooling Solution Configuration for Data Center Air Conditioners
- Continuous Cooling Solution Configuration for Data Center Air Conditioners
- Configuration Cases for Data Center Air Conditioning Systems

Quiz

1. (Single) In the water-cooled chilled water + indirect free cooling solution, which equipment can implement heat exchange between cooling water and chilled water without consuming power?
   A. Cooling tower
   B. Chiller
   C. Chilled water tank
   D. Plate heat exchanger

- Answer: D

Thank you.

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每个组织，构建万物互联的智能世界。

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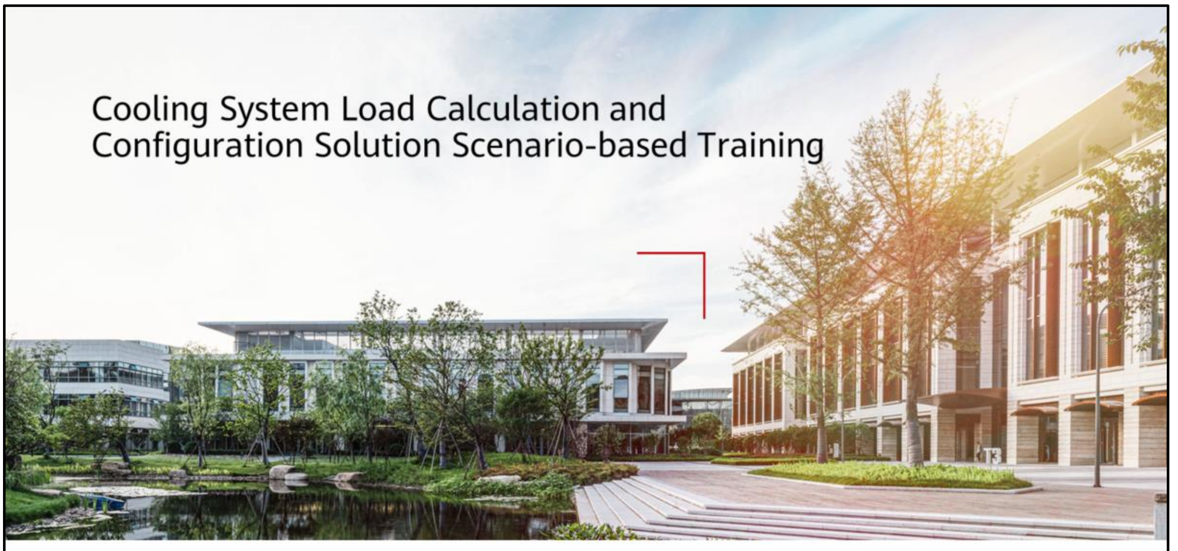
Cooling System Load Calculation and Configuration Solution Scenario-based Training



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Foreword

- In the preparation phase of data center construction, a feasibility study report on the cooling system is provided to help select a proper cooling system. In this phase, we need to develop a basic configuration solution of the cooling system. This training will guide you to develop a configuration solution for a data center cooling system.

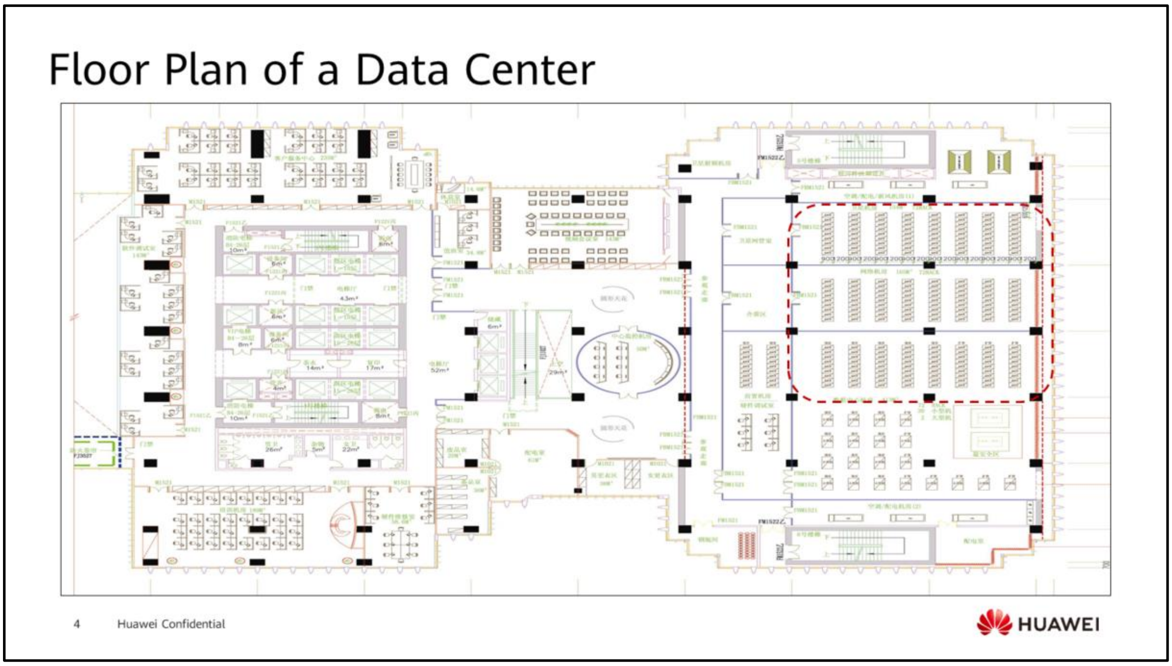
Objectives

On completion of this course, you will be able to:

- Calculate data center cooling system loads.
- Select data center air conditioner configurations and optimize the configuration solution.
- Understand the configuration and selection principles of a chilled water system and chillers.
- Optimize a cooling system and understand its simple configurations.

Trainee Grouping

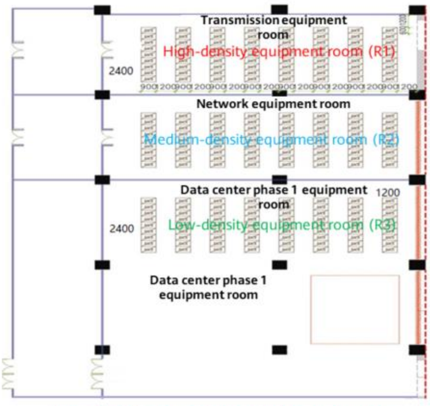
- Steps for grouping trainees
  - Before the training, the trainer prepares the same number of cards as the trainees. Each three cards have the same number.
  - Trainees draw lots and those who draw cards with the same number form a group.
  - Extra trainees are assigned to a group by the trainer.
  - Group members determine a group name.



- The floor plan is from the planning cases of [HCIE-DCF-Design] Data Center Cooling System Planning Part 3.

Background

- The figure on the right shows the layout of the second floor in a data center project. Most equipment cabinets in the equipment room are 800 mm and 900 mm deep cabinets. The aisle between devices is narrow and uneven, and onsite devices are placed in disorder.
- Now the original space needs to be re-planned for leasing. Based on different service requirements, three areas with high, medium, and low density are divided for deployment of different devices (blade servers, storage devices, and communication devices).
- All the existing cabinets must be replaced. The replaced cabinets will be stored in the warehouse and scrapped. The reconstruction follows the principle of **standardized and modular**. In addition, **more cabinets need to be deployed** and the **cooling airflow organization** needs to be optimized. The limited area of the equipment room must be properly used and **aisle containment** is adopted to reduce energy consumption. In the high-density area, **in-row cooling** is recommended. In the low-density area, **in-room cooling** is recommended. The air conditioner configuration is designed in N+1 redundancy mode.
- As the technical support of the project, Tom needs to make a feasibility study report on the cooling system to facilitate the company's decision-making.



Layout of the second floor in the equipment room of the xx project

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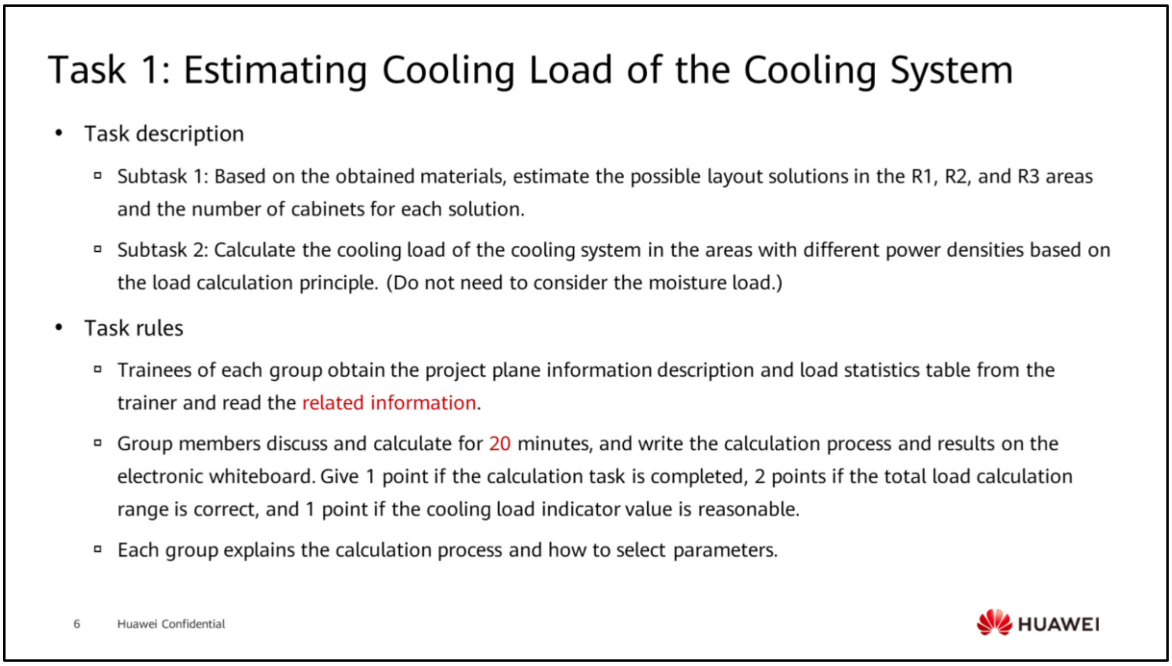
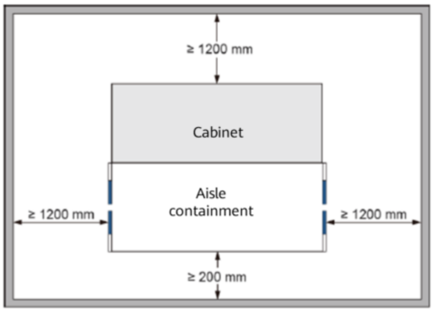
- As shown in the preceding figure, the customer equipment room consists of the transmission equipment room, network equipment room, and phase 1 equipment room of the data center. Most equipment cabinets in the equipment room are 800 mm and 900 mm deep cabinets, and the aisle between devices is narrow. Due to the lack of an unified deployment plan, installation personnel often deploy server cabinets, storage devices, and communication devices in the nearby idle cabinets. As a result, the layout is not neat, and the direction of hot and cold supply airflow is inconsistent with that of exhaust airflow. After re-planning, the customer's equipment room is divided into R1, R2, and R3 areas. Different services are deployed in different areas.



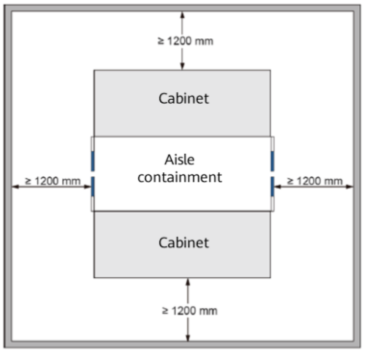
- The cabinet power density varies depending on the area. Trainees can flexibly select the cabinet power density in the table. The UPS and battery cabinet can be deployed inside the aisle containment or not.

Layout Requirements for the Modular Data Center

- Based on the smart module layout, the following solutions are available:



Single-row scenario



Dual-row scenario

Load Statistics Table of the Modular Data Center

Room Name	Number of Racks	Power Density of a Single Rack (kW)	(Optional) UPS Power (kW)	Simultaneous Coefficient (Recommended Value)	Comprehensive Coefficient (Aisle Containment or Open)	Total Cooling Capacity (kW)
High-density equipment room (R1)		10 kW–20 kW				
Medium-density equipment room (R2)		6 kW–10 kW				
Low-density equipment room (R3)		3 kW–5 kW				
...						
...						
Total cooling load (kW)						

Task 2: Completing the Air Conditioner Configuration Reference Table

- Task description
  - Subtask 1: Discuss in group and determine the technical parameters and factors that affect the configuration of air conditioners when the total cooling load is determined.
  - Subtask 2: Read the recommendation table and use Huawei NetCol5000-A025/NetCol5000-A042 as an example to complete the table (derating is not considered).
- Task rules
  - Group members discuss the question for 20 minutes
  - Write the discussion results on the electronic whiteboard after discussion. Give 2 points for each correct factor or parameter.
  - Give 4 points for completing the table and 2 points for drawing a conclusion. Additional points can be given if the analysis of other models is completed.

- In many projects, the devices deployed on the customer side are not planned. In this case, we can infer the cooling requirements based on the IT cabinet and planned power density. In the actual implementation phase, we can then perform forward verification. The main advantage of the bidirectional calculation is that the whole process is self-proper. The biggest challenge of this project is that the equipment room area on the customer side is fixed and the overall layout is not planned based on the IT power density requirements. It is to find the best solution in limited space. The contradiction in this case is that the power density needs to be maximized on the customer side, but the space is limited. One more equipment cabinet means one less cooling cabinet. The number of cooling cabinets is in direct proportion to the IT power density and in inverse proportion to the number of IT cabinets. We should find a balance point between the two factors.
- Exhaustion and iteration is one of the ways to solve this problem and find the optimal solution.

Recommended Selection Table

- The cooling source of air conditioners is selected based on the cooling capacity, cooling range, customer requirements, and TCO.

Scenario	Floor Area	Power Density	Outdoor Unit Space	Outdoor Unit Height Difference	Recommended Cooling Solution	Remarks
Micro data center	≤ 50 m²	≤ 7 kW	N/A	+20 m to –5 m	FusionModule800 + Rack-mounted air conditioner	
Small and medium-sized DC	50–500 m²	≥ 5 kW	Enough	+20 m to –5 m (+30 m to –8 m)	NetCol5000-A	
	50–500 m²	≥ 5 kW	Insufficient or water chillers are available in the building.	N/A	NetCol5000-C + Purchased air-cooled chiller	
	50–500 m²	≤ 5 kW	Enough	+20 m to –5 m (+30 m to –8 m)	NetCol5000-A	Smart module preferred, in-room air-cooled solution with downflow air supply
	50–500 m²	≤ 5 kW	Insufficient or water chillers are available in the building.	N/A	NetCol8000-C+ Purchased air-cooled chiller	
Large data center	≥ 500 m²	≥ 5 kW	N/A	N/A	NetCol5000-C + Purchased air-cooled/water-cooled chiller	
	≥ 500 m²	≤ 5 kW	N/A	N/A	NetCol8000-C + Purchased air-cooled/water-cooled chiller	

Task 3: Determining the Configuration Solution

- Task 3: Based on the cooling load estimation result, equipment room level requirements, and the configuration table obtained in **task 2**, each group develops a suitable air conditioner configuration solution and layout solution, fills in the following table (humidification and power distribution are not considered), and demonstrates the table on the stage.

Configuration Description	Number of Air Conditioners (Recommended: N+1)	Redundancy Description	Cabinet Usage Description
For example, NetCol5000A-42 kW full-sized air-cooled air conditioner	4+1	One standby for each module	13 + 5 (13 IT cabinets and 5 air conditioner cabinets)

- Discussion rules
  - Group members discuss and draw a simple layout diagram, read the configuration principles, and output the recommended configuration solution.
  - Each group assigns a representative to present the configuration solution, and explain the basis for selection. The trainer gives 10 points if the configuration is reasonable and makes a summary.
  - Output at least two different solutions and compare them in terms of layout and advantages.
  - Discussion time: 30 minutes

- Use the table in task 2 to perform exhaustion and iteration to determine the optimal solution. For different air conditioners, use a table to list all possibilities and find the optimal solution on the premise that the maximum number of cabinets is met. The answer is usually in the table.

Configuration Principles for Air Conditioners

- Principles for selecting air conditioners
  - Determine whether to use in-row or in-room air conditioners based on the cost, space, and service requirements (power density of a single cabinet).
  - In-row air conditioners are recommended when the power density of a single cabinet is high (higher than 5 kW).
  - When air is supplied under floors or inside walls, select in-room air conditioners.
  - Generally, select air conditioners of the same type in the same area.
- Principles for selecting full-sized and half-sized air conditioners
  - A half-sized indoor unit's footprint is only 1/2 that of a full-sized indoor unit. When the floor area is determined, the full-sized indoor unit is preferred.

Configuration Principles for Air Conditioners

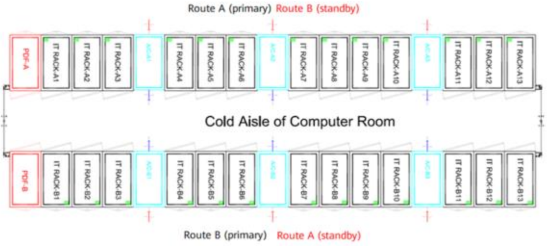
- Principles for determining the number of air conditioners
  - The number of air conditioners is generally calculated by dividing the total cooling load by the cooling capacity of a single air conditioner. The number is rounded up using the RoundUp function.
  - In the DX solution, the cooling capacity of a single air conditioner needs to be calculated using software or referring to charts based on the temperature and humidity of the indoor unit (23/35° C is the recommended working condition), outdoor unit temperature and humidity, and extreme ambient temperature and humidity.
  - In the CW solution, the cooling capacity of a single air conditioner needs to be calculated using software or referring to charts based on the temperature and humidity of the air conditioner (23/35° C is the recommended working condition) and chilled water supply and return (such as high-temperature chilled water) working condition.
  - For example, assume that the total load is 125 kW, and the cooling capacity of a single air conditioner is 39 kW (calculated based on the software model).

    RoundUp (125/39,0) = RoundUp (3.206,0) = 4
  - When determining the number of air conditioners, backup air conditioners need to be considered. You can comply with the backup requirement of customers. If there is no requirement, configure one backup air conditioner (N+1) when there are less than or equal to seven air conditioners, and two air conditioners (N+2) when there are more than eight air conditioners.

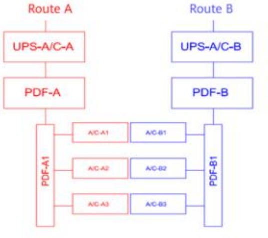
- Software link: http://3ms.huawei.com/hi/index.php?app=Group&mod=Core&act=showSectionData&id=1469723&gid=2031921

Configuration Principles for Air Conditioners

- Principles of configuring the power supply
  - Air conditioners with dual power supplies (one serves as the primary supply and the other serves as the standby supply) are preferred. During power distribution, half of air conditioners use route A as the active route and route B as the standby route. The other half of air conditioners use route B as the active route and route A as the standby route. This works for both in-room air conditioners and in-row air conditioners.
  - If continuous cooling is required, a UPS can be deployed in addition to the preceding two routes of power supply.



Power supply solution



Dual power supply solution

Configuration Principles for Air Conditioners

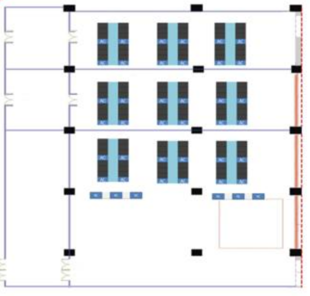
- Humidification solution selection principles
  - In most cases, deploy two humidification (heating) air conditioners in the same area. If one air conditioner is faulty, the other air conditioner keeps working. Air conditioners are interlaced and kept a certain distance in between.
  - Humidification capacity calculation formula: $W = \rho \times V \times (d1 - d2) \times 1.2$

  where ρ indicates the air density 1.2 kg/m^3, V indicates the dehumidification space volume (m^3), d1 indicates the air moisture content after humidification, d2 indicates the air moisture content before humidification, and 1.2 is the insurance coefficient.
  - For example, assume that the volume of a room is 700 m^3. Before humidification is performed, the temperature is 25° C, and the relative humidity is 30% (the absolute humidity d2 is 5.983 g/kg as specified in the psychrometric chart). After humidification is performed, the temperature is 25° C, and the relative humidity is 50% (the absolute humidity d1 is 10.037 g/kg as specified in the psychrometric chart).

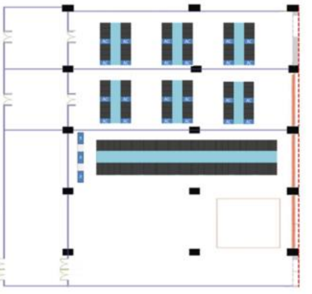
  Humidification capacity $W = \rho \times V \times (d1 - d2) \times 1.2 = 1.2 \times 700 \times (10.037 - 5.983) \times 1.2 = 4.086$ kg

Task 3: Reference Layout

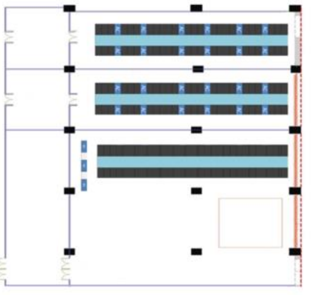
- Solution layout (Illustration)



Layout 1
Maximum number of cabinets

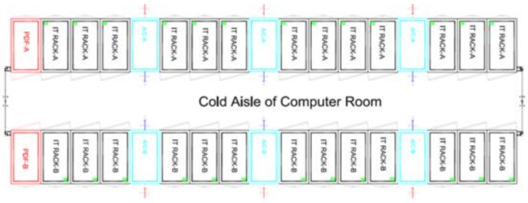


Layout 2
Average

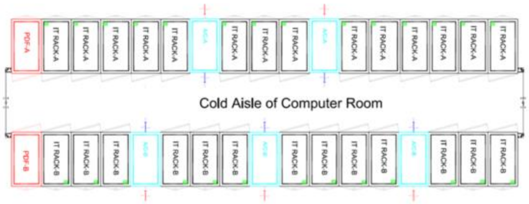


Layout 3
Best airflow organization

Task 3: Reference Layout



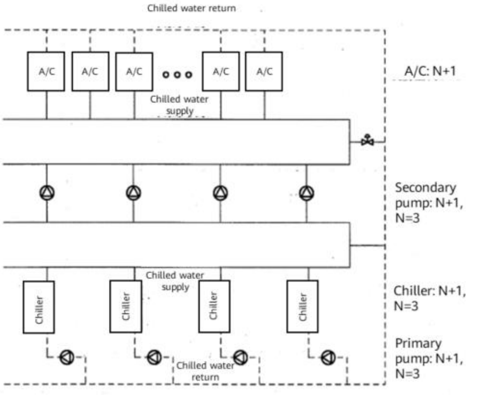
Symmetric layout



Unsymmetric layout

Task 4: Discussing and Determining a Chilled Water System

- Task description
  - Discuss in groups about the following questions: According to the five classification methods of chilled water system of air conditioners in intensive lectures, what factors need and need not to be considered in the feasibility study phase when a chilled water system is selected in this project? If the chilled water system shown in the figure on the right is configured, can the system meet the fault tolerance requirement and why?
- Task rules
  - Each group discusses the two questions for 15 minutes and writes the discussion results on the electronic whiteboard.
  - Each group presents its answers and reasons. Give 1 point for each correct factor.



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Reference Answers to Task 4

- Reference answer to question 1
  - Closed or open chilled water system: The open chilled water system has a high lift and consumes a large amount of energy. Water in the cooling system is in direct contact with the air, which easily causes pipe corrosion.
  - Supply or return water mode: Only cooling is considered for air conditioners in data centers. Therefore, two pipe systems are used.
  - Direct return system or reverse return system: This item needs to be considered in the drawing design phase and is not considered in the feasibility study phase.
  - Constant flow system or variable flow system: The water flow is determined according to the maximum load. The water supply volume of air conditioners is greater than that the water volume required by the actual load in most of the time. The energy consumption of the water pump is always in designed maximum value, which does not meet the energy saving requirements of the data center and needs to be considered.
  - Primary pump system or secondary pump system: The secondary pump system can adapt to the situation with high differences in the lift capacity and water supply radius of each area. It can save the transmission energy, but the initial investment is large. The primary pump system is simple, but it cannot adapt to the situation with high differences in the lift capacity and water supply radius. It is applicable to small- and medium-sized cooling systems.

Task 5: Selecting Devices and Optimizing the Chilled Water System

- Task description
  - Subtask 1: Assume that the chilled water in-row solution is selected and two chillers listed in the table are selected. Discuss in groups whether the chillers can meet the requirements.
  - Subtask 2: If the data center is built in a subfrigid zone and the time when the temperature is lower than 20° C accounts for more than half of a year, what methods can be used to save energy and reduce the PUE?
  - Subtask 3: If the customer uses the direct ventilation solution, calculate the required cooling capacity.

$$L_s = \frac{3600 \times K_1 \times Q}{\rho c_p (t_1 - t_2)}$$

Technical
cations of xxx Ce

- Task rules
  - Group members discuss whether the chillers can meet the cooling requirements in the high-, medium-, and low-density areas, and whether the redundancy and device selection are reasonable. What are the supply and return water temperatures?
  - Each group discusses and proposes some feasible energy-saving solutions from the perspective of the system.
  - Discussion time: 20 minutes

Reference Answers to Task 5

- In winter, the outdoor low-temperature air can be used for cooling (known as free cooling technology).
  - Add an energy-saving heat exchanger to the system. The heat exchanger is not used in summer. When the outdoor temperature is 2° C lower than the outlet temperature of the chillers, the central cooling system dissipates heat in the equipment room through the chilled water pipes, energy-saving coil pipes, and cooling tower to outdoors and reduces the equipment room temperature. In this way, the runtime of chillers can be reduced and the operating costs of the cooling system can be saved.
- Variable-frequency water pump technology
  - Variable-frequency pumps are commonly used in China. Compared with constant-frequency pumps, variable-frequency pumps feature less power consumption, regulated pressure function, less impact on the power system, less noise, and low temperature rise of pump motors. However, its investment is twice that of common constant-frequency pumps.
- Optimized airflow organization in the equipment room
  - Based on the rack layout and heat dissipation requirements, the low-density downflow air supply and upflow air return is used. In the high-density area, the cold aisle containment and in-row solution are adopted, and isolated aisles are configured. In the medium-density area, a proper airflow organization mode is used according to the heat dissipation capacity.
- Optimized control policy: Improve the efficiency of the chillers and reduce the energy consumption of the water pump. Set the supply and return water temperatures to 10° C/16° C.

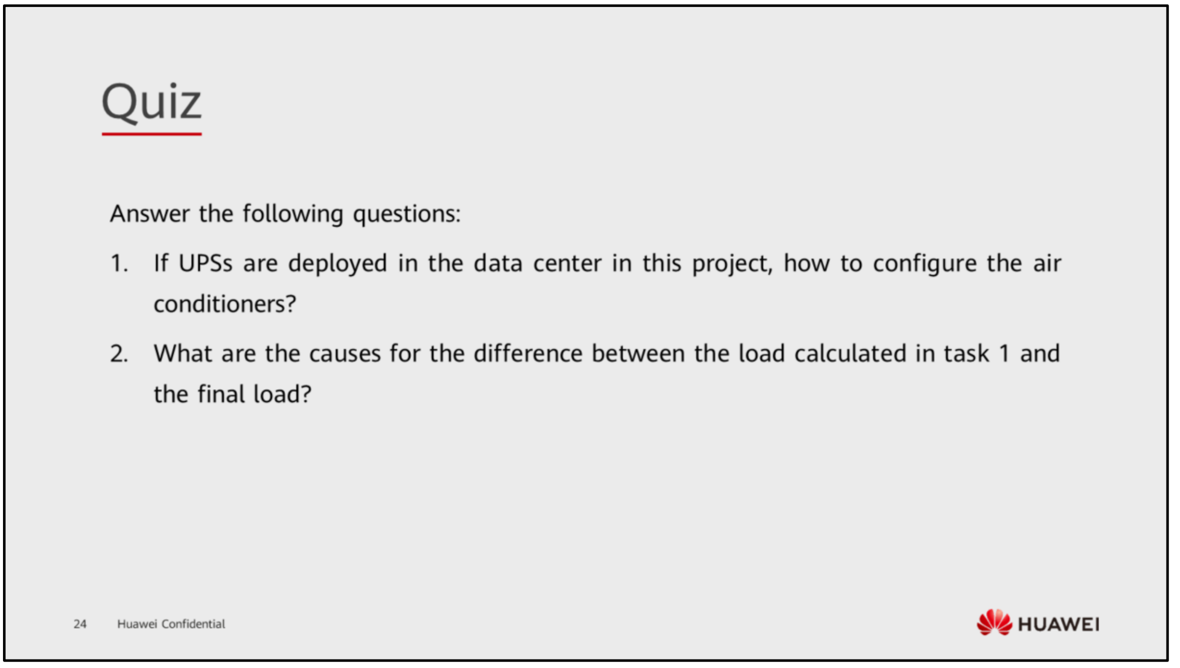
- Pay attention to the use of the indirect evaporation technology and direct ventilation free cooling technology.

Task 6: Providing Cooling System Configuration Suggestions

- Task description
  - According to the answers of tasks 1 to 5, determine the configuration of the cooling system and provide suggestions about the following aspects.
    - Cooling source type: water-cooled cooling system or air-cooled DX system
    - Energy-saving technical specifications: indirect free cooling technology or variable-frequency water pump technology
    - Power density planning for a single cabinet
    - Technology adopted to improve the utilization of cold air: Cabinets are deployed in face-to-face and back-to-back mode. In addition, the cold or hot aisle containment technology is used.
    - The indoor units are configured in N+X mode by room or module.
    - The pipes of the cooling system are deployed in redundant (or backup) mode.
    - The cooling sources are also configured in N+X mode.
    - Comprehensively consider system reliability and other requirements.
  - Group members discuss and complete the table from the perspective of the system. Give 2 points to the group that completes the table.

Task 6: Reference Table

Item	Description	Others
Configuration description		
Power density planning for a single cabinet		
Cooling source type		
Cooling source of the air conditioner: configured in N+1 mode		
Energy-saving technology		
Airflow organization mode		
The indoor units are configured by room or module.		
Pipe deployment for the cooling system		
Continuous cooling requirement		
Restrictions on the onsite environment		
Fresh air system		
Exhaust system		



- 1. UPS heat dissipation needs to be considered and calculated.
- 2.Different calculation coefficients and calculation methods are used. The supported power density is different.

Summary

- Calculate data center cooling system loads.
- Select data center air conditioner configurations and optimize the configuration solution.
- Understand the configuration and selection principles of a chilled water system and chillers.
- Optimize a cooling system and understand its simple configurations.

Thank you.

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Huawei DCF Certification Training

Cooling System Load Calculation and Configuration Solution

ISSUE:2.0

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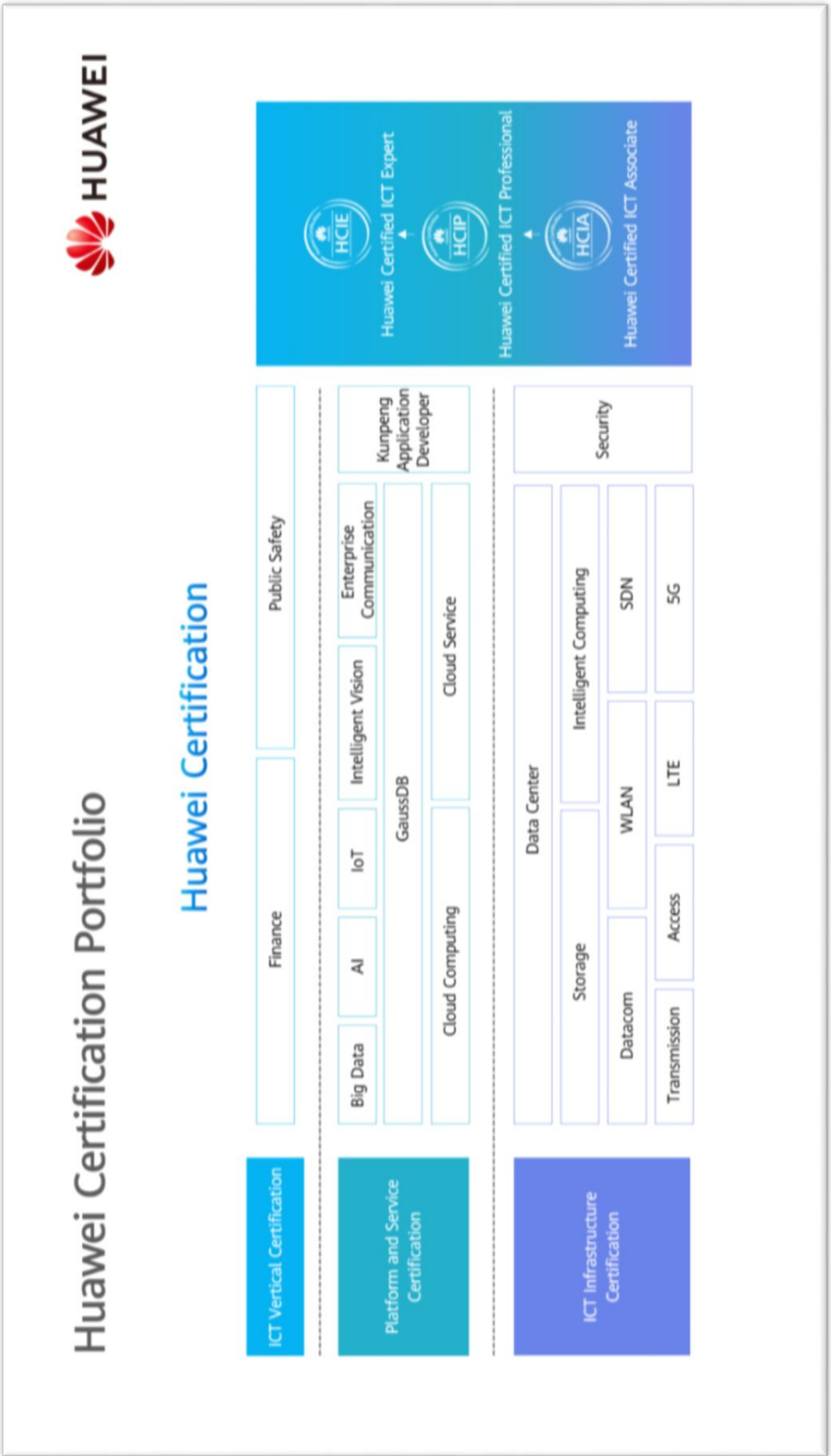
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Contents

1 Data Center Cooling System Configuration

1.1 Data Center Cooling System Requirements

1.1.1 Description of a Data Center Cooling System

In most cases, precision air conditioners dedicated for data centers ensuring a constant temperature and humidity are used based on the actual conditions. With such a cooling system, a stable and good data center environment can be built.

Environment devices in data centers produce a large amount of heat and little moisture. The heat is intensively distributed. That means 95% of the heat generated by data center devices is sensible heat. The heat is large, the humidity is small; therefore the heat humidity ratio is very high. In this case, air treatment is a cooling process with constant humidity. The enthalpy difference is small. Large air volume is an inevitable choice to eliminate the residual heat.

In addition, communications devices, network devices, and servers in data centers must run uninterruptedly around the clock. Therefore, the cooling system needs to run uninterruptedly throughout the year.

Therefore, it is a common practice in the industry to calculate the cooling capacity of a data center based on the enclosure features (including the wall, ceiling, ground, floor; other factor like building direction, material of external and internal walls, door and window type, gap, and heat dissipation), personnel heat, and lighting heat, fresh air load, and heat dissipation of each device in the data center, and then determine the air conditioner capacity. The air environment parameters of a data center cooling system need to be specified based on the actual situation.

It should be noted that the data center environment is implemented by air conditioners. The following requirements must be met to ensure the cleanness of the data center:

- Seal the enclosures of data centers to keep cleanliness.
- Maintain positive pressure in data centers to avoid erosion by dirty air. Purify fresh air must by two kinds of filters, that is, primary filter and sub-high efficiency filter. In this way, the air quality of data centers will be greatly improved.
- Install medium-efficiency filters in air conditioners and replace the filters periodically to ensure continuous air purification during air circulation.

2 Training

2.1 Training Description

2.1.1 About This Training

This training aims to help trainees select appropriate air conditioner models, develop a cooling system solution, and select a layout mode and air supply mode based on the requirements of an actual project to finally determine the cooling system configuration and complete the feasibility study on the customer side.

2.1.2 Training Objectives

- Air conditioner selection standards
- Configuration calculation method
- Load statistics and processing

2.1.3 Training Background and Requirements

The following figure shows the layout of the second floor in a data center project. Most equipment cabinets in the equipment room are 800 mm and 900 mm deep cabinets. The aisle between devices is narrow and uneven, and onsite devices are placed in disorder.

Now the original space needs to be re-planned for leasing. Based on different service requirements, three areas with high, medium, and low density are divided for deployment of different devices (blade servers, storage devices, and communication devices).

All the existing cabinets must be replaced. The replaced cabinets will be stored in the warehouse and scrapped. The reconstruction follows the principle of standardized and modular. In addition, cabinets need to be deployed as many as possible and the cooling airflow organization needs to be optimized. The limited area of the equipment room must be properly used and aisle containment is adopted to reduce energy consumption. In the high-density area, in-row cooling is recommended. In the low-density area, in-room cooling is recommended. The air conditioner configuration is designed in N+1 redundancy mode.

As the technical support of the project, Tom needs to make a feasibility study report on the cooling system to facilitate the company's decision-making.

The following figure shows the onsite layout.

The area is 7.9 m x 19.6 m. The areas of the three areas are almost the same. When reconstructing the layout, Tom needs to calculate the maximum number of IT cabinets supported in the area and finds the optimal solution through iteration in advance.

The specific layout requirements are as follows:

Cabinets are 2400 mm away from the entrance, 1200 mm away from the walls, and the distance between modules is 1200 mm.

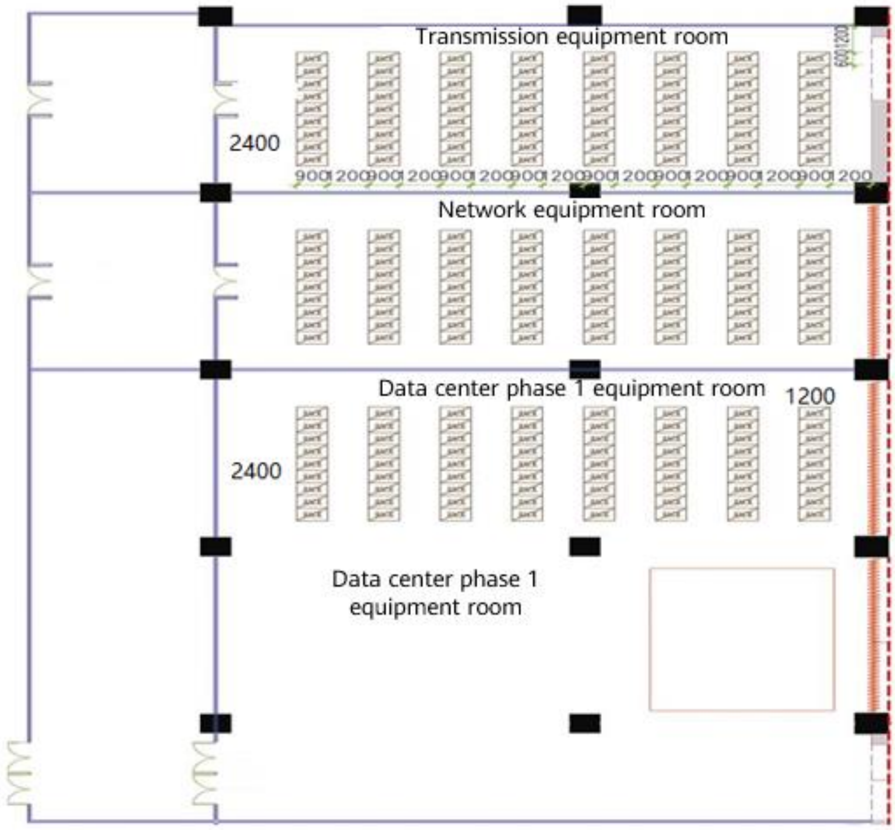


Figure 2-1 Data center layout diagram

The total area of the data center is about 155 x 3 square meters, and the net height is about 4.5 meters.

2.1.4 Planning Methods

The heat load of the data center mainly comes from the heat generated by the devices and the heat load of the maintenance structure. Therefore, you need to know the quantity and power consumption of the main devices to determine the capacity and configuration of the precision air conditioners. Based on previous experience, except for heat load of main devices, other heat load, such as lighting load, maintenance structure load, supplementary fresh air load, and personnel heat load can be determined by multiplying related coefficients. The error is acceptable to customers. If accurate calculation conditions are not met, you can calculate cooling load based on equipment room area and experience.

1. There is no complete layout plan for the data center. So the space is planned based on the module layout requirements.

2. Calculate the number of cabinets based on the layout and calculate the cooling requirement of the cabinets with full load.

3. Select appropriate air conditioners and meet the N+1 redundancy requirement.

2.1.5 Planning Steps

Step 1 Calculate the maximum number of cabinets that can be supported to obtain the general range of IT loads that can be supported.

Step 2 Configure the UPSs based on the IT load power. (You can choose whether to deploy the UPS in the aisle containment. It is recommended that the UPS not be deployed in the aisle containment.)

Step 3 Calculate the cooling loads in different areas.

Step 4 Analyze the application scenario type.

Step 5 Determine the air conditioner type. (Take Huawei air conditioners as an example. Select two in-row solutions.)

Step 6 Select air conditioners, develop a configuration solution, and verify whether the solution meets the requirements.

Step 7 Determine the air supply modes.

Step 8 Develop a feasibility study report.

2.2 Task Description

2.2.1 Task 1: Estimating Cooling Load of the Cooling System

2.2.1.1 Description

- Subtask 1: Based on the obtained materials, estimate the possible layout solutions in the R1, R2, and R3 areas and the number of cabinets for each solution.
- Subtask 2: Calculate the cooling load in the areas with different power densities based on the load calculation principle. (Do not need to consider the moisture load.)
- Task execution rules:

Trainees of each group obtain the plane information description and load statistics table of the project from the trainer and read the related information.

Trainees discuss and calculate for 20 minutes, and write the calculation process and results on the electronic whiteboard. Give 1 point if the calculation task is completed, 2 points if the total load calculation range is correct, and 1 point if the cooling load indicator value is reasonable.

Each group explains the calculation process and how to select parameters.

- Tip: You can use the load statistics table in the smart module layout slides.

2.2.2 Task 2: Completing the Air Conditioner Configuration Reference Table

2.2.2.1 Task Arrangements

- Subtask 1: Discuss in group and determine the technical parameters and factors that affect the configuration of air conditioners when the total cooling load is determined.
- Subtask 2: Read the recommendation table and use Huawei NetCol5000-A025/NetCol5000-A042 as an example to complete the table (derating is not considered).

Item	12	16	20	24	28	32	36	40

2.2.3 Task 3: Determining the Configuration Solution

- Task description: Based on the cooling load estimation result, equipment room level requirements, and the configuration table obtained in **task 2**, each group develops a suitable air conditioner configuration solution and layout solution, fills in the following table (humidification and power distribution are not considered), and demonstrates the table on the stage.

2.2.3.1 Air Conditioner Selection Rules

Determine whether to use in-row or in-room air conditioners based on the cost, space, and service requirements (power density of a single cabinet).

If the power density of a single cabinet is higher than 5 kW, select in-row air conditioners. If the power density of a single cabinet is 8 kW or lower, select in-room air conditioners.

When air is supplied under floors or inside walls, select in-room air conditioners.

Generally, select air conditioners of the same type in the same area.

2.2.3.2 Rules for Determining the Number of Air Conditioners

The number of air conditioners is generally calculated by dividing the total cooling load by the cooling capacity of a single air conditioner. The number is rounded up using the RoundUp function. The cooling capacity of a single air conditioner is calculated using software based on the indoor unit temperature and humidity (23/35° C is recommended in design working conditions) and outdoor unit temperature and humidity (extreme temperature and humidity).

For example, assume that the total load is 125 kW, and the cooling capacity of a single air conditioner is 39 kW (calculated based on the software model).

RoundUp (125/39,0) = RoundUp (3.206,0) = 4

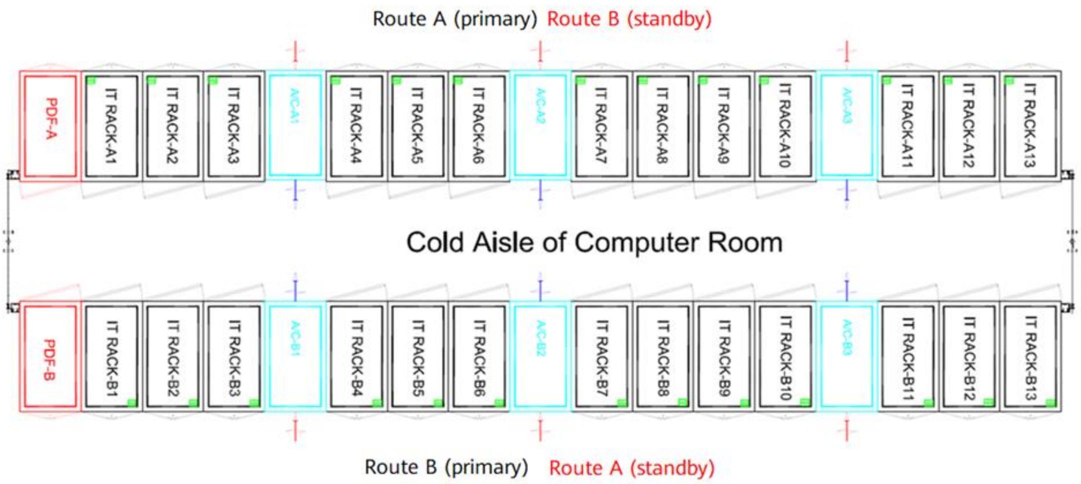
When determining the quantity of air conditioners, standby air conditioners need to be considered. If the quantity of air conditioners is less than or equal to 7, one air conditioner is added as the standby air conditioner (N+1). If the quantity of air conditioners is greater than or equal to 8, two air conditioners are added as standby air conditioners (N+2).

2.2.3.1 Rules for Selecting a Power Supply Solution

Air conditioners with dual power supplies (one serves as the primary supply and the other serves as the standby supply) are preferred. During power distribution, half of air conditioners use route A as the active route and route B as the standby route. The other half of air conditioners use route B as the active route and route A as the standby route. This works for both in-room air conditioners and in-row air conditioners.

If continuous cooling is required, a UPS can be deployed in addition to the preceding two routes of power supply.

Example:



2.2.3.2 Humidification Solution Selection Rules

In most cases, deploy two humidification (heating) air conditioners in the same area. If one air conditioner is faulty, the other air conditioner keeps working. Air conditioners are interlaced and kept a certain distance in between.

The formula for calculating the humidification capacity is as follows:

$W = \rho \times V \times (d_1 - d_2) \times C \times 1.2$

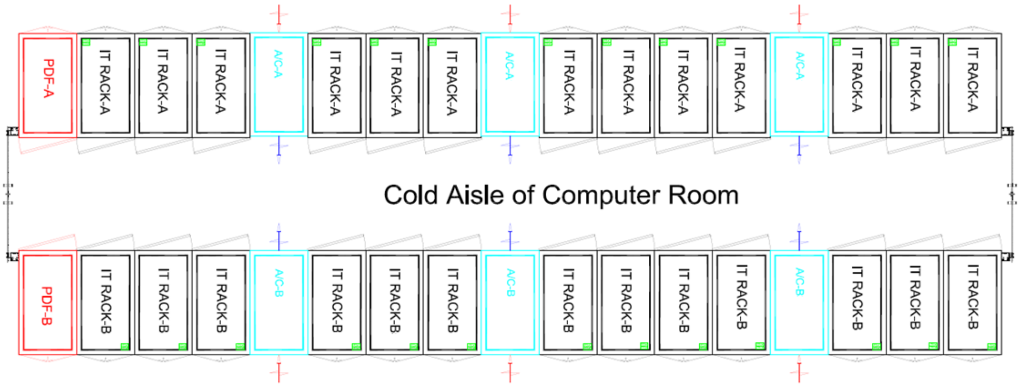
Where: ρ indicates the air density (1.2 kg/m), V indicates the dehumidification space volume m, d_1 indicates the air moisture content after humidification, d_2 indicates the air moisture content before humidification, and 1.2 is the safety coefficient.

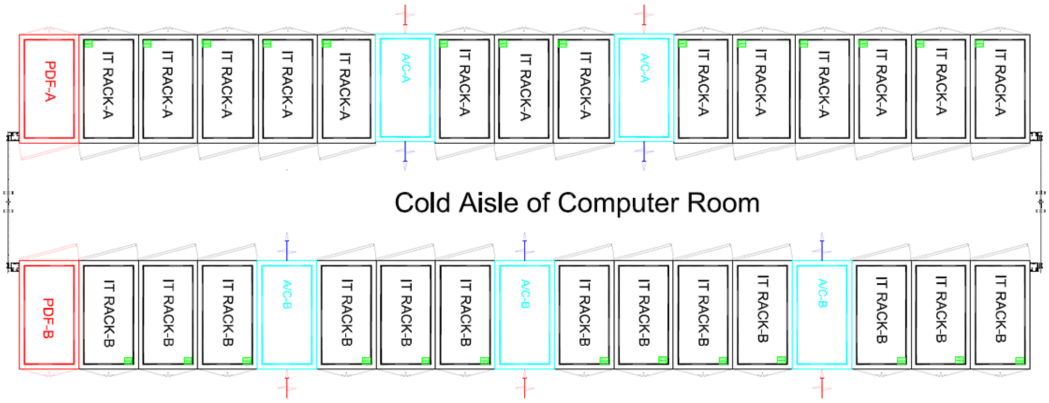
For example, assume that the volume of a room is 700 m^3. Before humidification is performed, the temperature is 25°C, and the relative humidity is 30% (the absolute humidity d_2 is 5.983 g/kg as specified in the psychrometric chart). After humidification is performed, the temperature is 25°C, and the relative humidity is 50% (the absolute humidity d_1 is 10.037 g/kg as specified in the psychrometric chart).

Humidification capacity $W = \rho \times V \times (d_1 - d_2) \times C \times 1.2 = 1.2 \times 700 \times (10.037 - 5.983) \times 1.2 = 4.086$ kg

If the humidification capacity of a humidifier is 4.5 kg/h, two dehumidifiers are required. One active and one standby.

The following figure shows the layout of precision air conditioners with the humidification function.





2.2.3.3 Outdoor Unit Selection Rules

Determine whether the outdoor unit is a T1 or T3 (for areas where the ambient temperature is greater than 45°C) unit based on the local ambient temperature.

If the ambient temperature is less than –20°C, add a low-temperature component.

Select A, B, C, and D outdoor units according to local environmental classes.

2.2.3.4 Selection Process

Use the blue column in the following table as an example. If the total number of cabinets is 12, this column lists all possible situations in the 25 kW air-cooled scenario. You only need to select a solution as required. In other scenarios, you can obtain the final solution by making an exhaustion table like this.

Reference solution:

For a single smart module, if the total number of cabinets is 18, you can deploy 12 or 16 IT cabinets. It is recommended that you select an even number of cabinets to facilitate symmetrical installation and layout. You can also list the solutions with odd number of cabinets in the table.

For example, if 16 IT cabinets are installed, you can only deploy four Netcol5000-A25 kW air conditioners, and the power density of a single cabinet is 3 kW.

Item	Quantity	Remarks
Netcol5000-A25 kW	4	One redundancy beside the module
Netcol5000-A26 kW	4	
Accessories	Xx	

2.2.4 Task 4: Discussing and Determining a Chilled Water System

- Discuss in groups about the following questions: According to the five classification methods of chilled water system of air conditioners in intensive lectures, what factors need and need not to be considered in the feasibility study phase when a chilled water system is selected in this project? If the chilled water system shown in the slide is configured, can the system meet the fault tolerance requirement and why?

2.2.5 Task 5: Selecting Devices and Optimizing the Chilled Water System

- Subtask 1: Assume that the chilled water in-row solution is selected and two chillers listed in the table are selected. Discuss in groups whether the chillers can meet the requirements.

Device Name	Specifications	Quantity	Input Power
Centrifugal chiller	300 RT	2	xxx kW

- Subtask 2: If the data center is built in a subfrigid zone and the time when the temperature is lower than 20°C accounts for more than half of a year, what methods can be used to save energy and reduce the PUE?
- Subtask 3: If the customer uses the direct ventilation solution, calculate the required cooling capacity.

2.2.6 Task 6: Providing Cooling System Configuration Suggestions

2.2.6.1 Summary

Air conditioner configuration suggestions

Cooling source type: ____

Power density of a single cabinet: ____________________________________

Technology adopted to improve the utilization of cold air: _________________

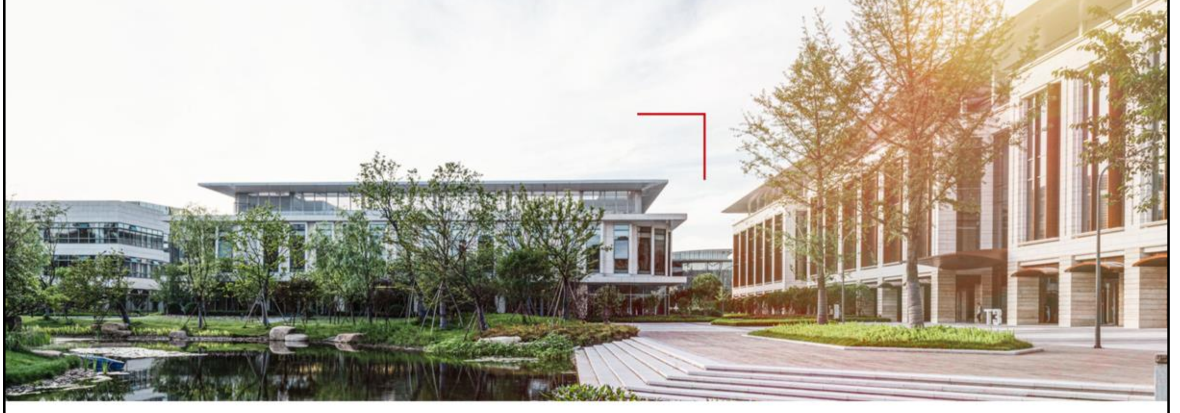
Pipeline deployment:____

Cooling source of the air conditioner:__________________________________

The following uses the high-density area as an example. The configurations of air conditioner loads and cooling sources are as follows:

No.	Item	Air Conditioner Load
1	Air conditioner load	
2	Air conditioner configuration	
3	Chiller configuration	
Others		

DCIM System Planning Overview



Foreword

- With the development of information technologies, data center facility has become increasingly important. The reliability of the facility determines service continuity. The management of key facilities in data centers has gradually evolved from traditional monitoring to unified management and intelligent operation and maintenance (O&M), that is, Data Center Infrastructure Management (DCIM). Designing the DCIM system properly will be the core work of data center O&M teams.
- The slides describe the DCIM concept, differences between DCIM and traditional power and environment monitoring systems, and DCIM development trend, and introduce knowledge related to the DCIM system planning.

Objectives

On completion of this course, you will be able to:

- Describe the DCIM concept.
- Distinguish the DCIM and traditional power and environment monitoring systems.
- Understand the DCIM development trend.
- Describe the DCIM planning considerations and process.

Contents

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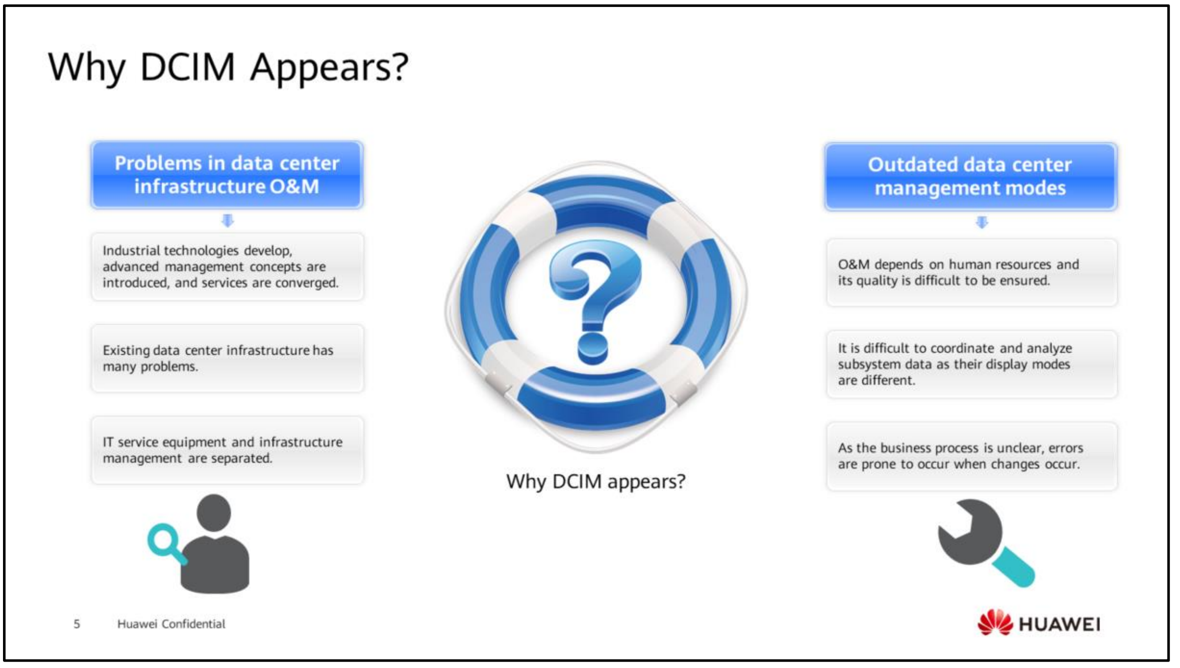
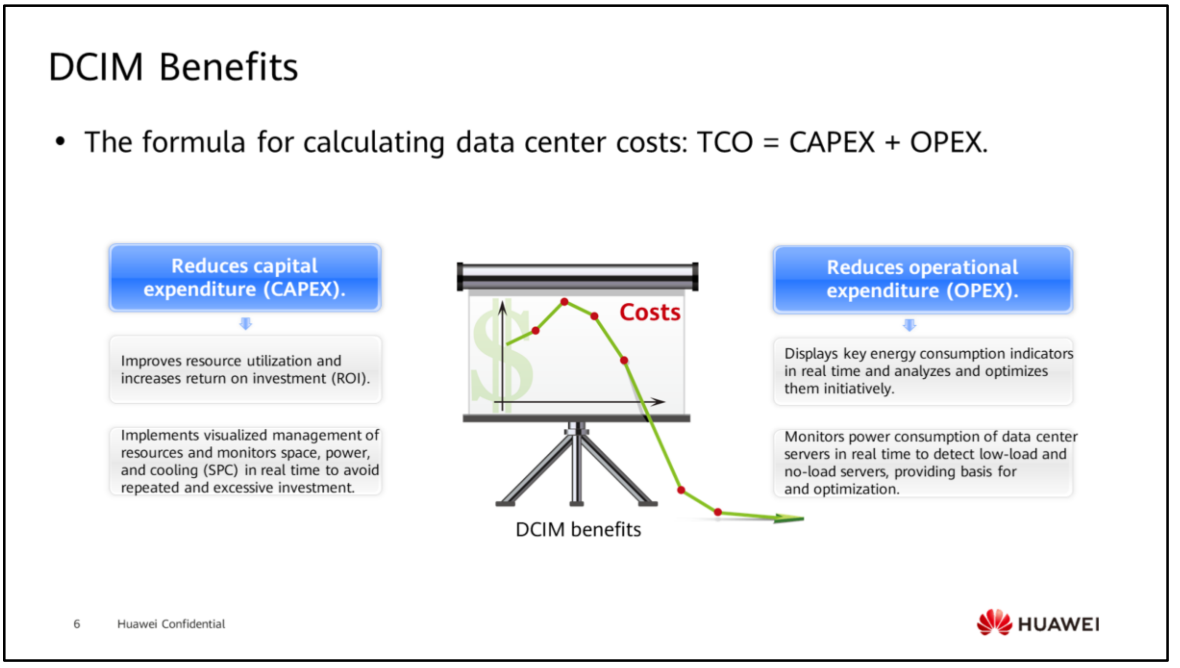
What is DCIM?

- Data center infrastructure management (DCIM) is a unified management platform for data center infrastructure and IT equipment. It can maximize data center operation efficiency and improve data center availability through data analysis and aggregation.

- DCIM is a hot topic in the data center operation and management field in recent years. It originated from countries outside China. Different organizations have different definitions of DCIM. However, it is widely recognized that the DCIM system or tool can build a bridge between data center infrastructure and IT equipment to help operators manage data centers and improve operation efficiency.
  - Gartner defines DCIM as follows: DCIM tools monitor, measure, manage, and/or control data center utilization and energy consumption of all IT-related equipment (such as servers, storage and network switches) and facility infrastructure components (such as power distribution units and computer room air conditioners [CRACs]).
  - Wikipedia defines DCIM as follows: DCIM is the integration of information technology (IT) and facility management disciplines to centralize monitoring, management and intelligent capacity planning of a data center's critical systems. Achieved through the implementation of specialized software, hardware and sensors, DCIM enables common, real-time monitoring and management platform for all interdependent systems across IT and facility infrastructures.
- Gartner: Gartner Group is the first company to conduct information technology research and analysis, providing specialized services for technology users in need.

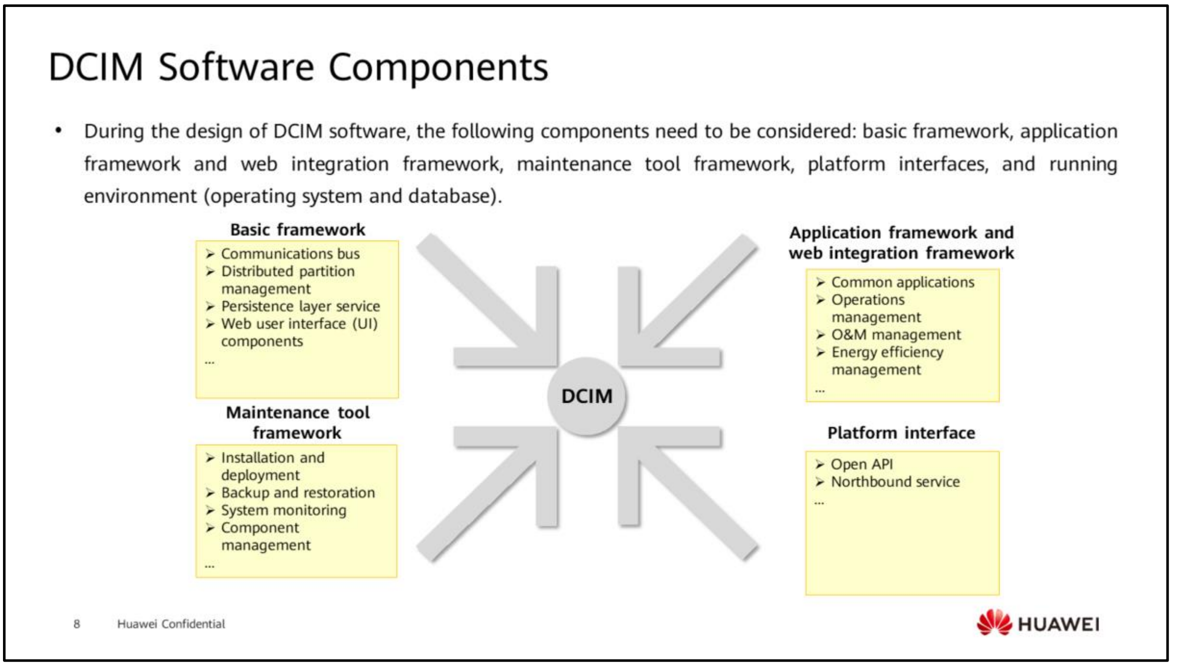


- Problems in O&M of traditional data center infrastructure
    - With the development of industrial technologies, introduction of advanced management concepts, and service convergence, the traditional power and environment monitoring mode that focuses on infrastructure management cannot meet O&M requirements of enterprises and organizations for data centers.
    - According to an Internet Data Corporation (IDC) report, 84% of data centers in the market face problems in cooling, power supply, space, and load bearing. These problems include prolonged application rollout time, increased operational expenditure (OPEX), and service interruption.
    - In a traditional data center, IT equipment and infrastructure are managed by different departments. Manual organization structure division facilitates personnel management and division of rights and responsibilities to some extent, but it increases communication costs between departments, reduces the O&M efficiency of a data center, and increases the risk of data center accidents to some extent.
- IDC: International Data Corporation, a world-renowned market consultation and event service provider in IT, telecommunications, and consumer technology. Its market tracking data in IT has become an industry standard.



- CAPEX = Strategic investment + Rolling investment.
- OPEX = Maintenance costs + Marketing costs + Labor costs (+ Depreciation).
- Reduces CAPEX:
  - Improved resource utilization and increased revenues: For data centers, each U space is a valuable resource. The ROI can be increased by improving equipment utilization and prolonging the service life of a data center.
  - Visualized modeling and quantitative monitoring of SPC: DCIM can perform visualized modeling for a data center and monitor its capacities, such as power, cooling, and space. In the design of a data center, redundancy is considered to improve reliability. In addition, the power consumption of a server cannot reach its nameplate specifications. Therefore, the actual capacity of each rack cannot be fully used. DCIM provides real-time and refined management, which enables users to learn about the resource usage of each rack and the entire data center in real time, thereby improving asset utilization, prolonging the service life of the data center, and saving investment.
- CAPEX: Capital Expenditure.
- OPEX: Operating Expense.
- PUE: Power Usage Effectiveness.
- WUE: Water Usage Effectiveness.
- CUE: Carbon Usage Effectiveness.

- Reduces OPEX:
  - Data centers are energy-hungry. Electricity costs account for a large proportion of O&M costs. Therefore, the DCIM system must monitor key energy consumption indicators such as the power usage effectiveness (PUE) of a data center and display energy consumption of IT equipment and infrastructure equipment in real time. In the future, it should also be able to monitor the water usage effectiveness (WUE) and carbon usage effectiveness (CUE).
  - The DCIM system can collect information such as server power consumption and CPU usage to identify low-load and no-load servers in a data center. These servers are consolidated or removed from racks to improve equipment utilization and reduce power consumption of the data center. In addition, by combining life cycles of IT equipment and energy consumption information of servers, the DCIM system can eliminate some old servers with weak computing capabilities but high energy consumption to further save energy and improve efficiency.



- Basic framework:
  - Communication bus: refers to communication trunk lines that transmit information among functional components of the DCIM software.
  - Distributed partition management: The system framework provides multiple processing threads and service partitions.
  - Persistence layer service: allows users to query, insert, update, and delete data.
  - Web UI component: a component of the web user interface (UI).
- Application framework and web integration framework:
  - Common applications: involve fault management, topology management, equipment access management, security management, and performance management.
  - Operation management: includes asset management and capacity management.
  - Energy efficiency management: manages the energy efficiency of managed objects or regions.

- Maintenance tool framework:
  - Installation and deployment: Maintenance tools should be able to install and deploy the DCIM software.
  - Backup and restoration: Maintenance tools should be able to perform system backup and restoration.
  - System monitoring: The DCIM software can be monitored and managed by maintenance tools.
  - Component management: DCIM software functions and services can be added or deleted through maintenance tools.
- Platform interfaces:
  - Open API: An API is an application programming interface. In the Internet era, services of websites or software are encapsulated into a series of data interfaces that can be easily identified by computers and opened to third-party developers. This behavior is called open API. The platform that provides open APIs is called an open platform.
  - Northbound service: Interconnects with northbound third-party management systems.

DCIM Hardware Components

- DCIM hardware consists of intelligent interfaces, sensors, collection devices, servers (processing and storage), network transmission devices, and display devices.

Intelligent interfaces and sensors

Display devices

Collection device

Network transmission devices

Server

Contents

Relationship Between DCIM and Power and Environment Monitoring

- A data center consists of a power supply and distribution system, cooling system, fire extinguishing system, power and environment monitoring system, integrated cabling system, lightning protection and grounding system, cabinet system, and decoration system.
- A power and environment monitoring system monitors and controls power and environment equipment. A DCIM system implements unified management and dynamic optimization of all infrastructure in a data center. The DCIM system is an upgraded version of the power and environment monitoring system.

System Functions	Traditional Power and Environment Monitoring System	DCIM System
Real-time signals	√	√
Alarm management	√	√
Access control management	√	√
Battery monitoring	√	√
System management	√	√
Video management	√	√
Report management	√	√
Capacity management	×	√
Asset management	×	√
Personnel management	×	√
Energy efficiency management	×	√
Process management	×	√
Cooling optimization	×	√
Tenant management	×	√

- From the perspective of operation management, the main differences between the DCIM system and the power and environment monitoring system lie in data association, analysis, and optimization capabilities. The power and environment monitoring system focuses on real-time signals and alarms of key infrastructure, such as the method to converge and manage alarms timely after a fault occurs. The DCIM system focuses more on the integrity of O&M business. In addition to basic functions, the DCIM system supports comprehensive analysis of data center infrastructure based on collected data and provides service assistance and support from multiple dimensions, such as planning, optimization, prediction, and change.

Relationship Between DCIM, BMS, and ITSM

- Relationship between DCIM and BMS:
  - In the early stage, a building management system (BMS) was used to implement power and environment monitoring for data center. In addition, subsystems such as access control management, video surveillance, and lighting control were integrated.
  - The DCIM and BMS have same functions in critical infrastructure monitoring. However, in addition to that, the DCIM focuses more on monitoring, analysis, and comprehensive view display of key equipment such as cooling and power supply and distribution equipment.
- Relationship between DCIM and ITSM:
  - With changes of data center O&M requirements, the traditional power and environment monitoring system gradually evolves to the DCIM system. IT monitoring management gradually evolves from traditional network monitoring to IT service management (ITSM).
  - ITSM focuses on logical infrastructure (such as operating systems, applications, and networks) management, while DCIM focuses on physical infrastructure management.

- BMS: Building Management System.
- ITSM: IT Service Management.
- The DCIM system provides data center floor plan and asset capacity managements that are not involved in traditional BMS and ITSM, integrates multiple separated subsystems in a data center, and provides a unified management platform.

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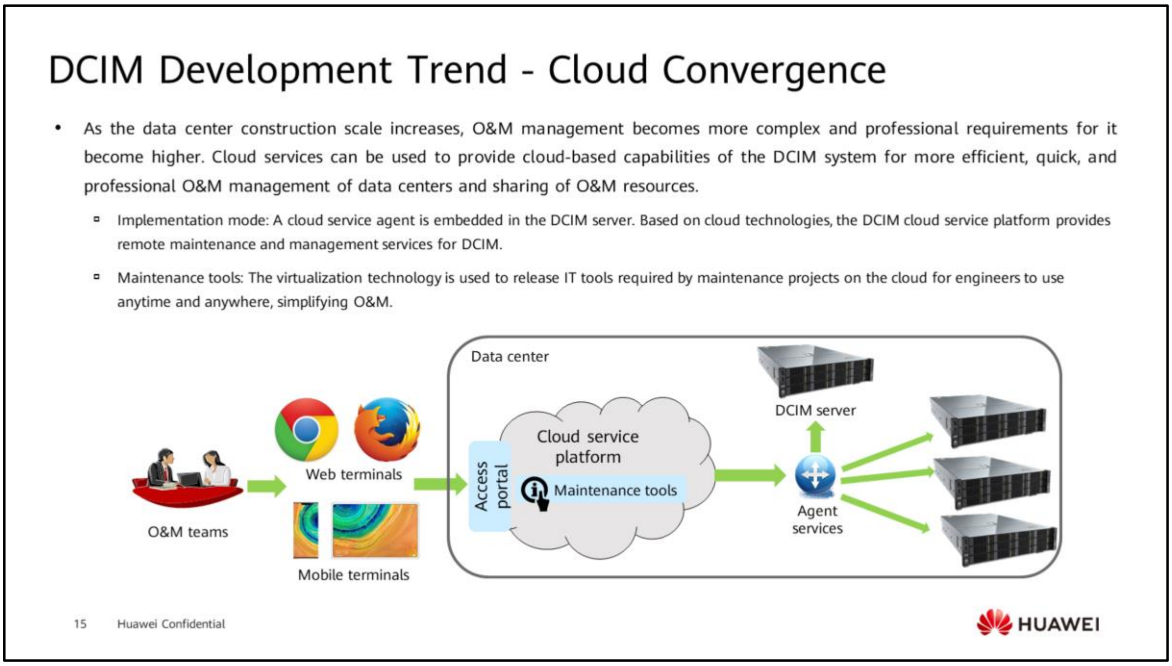
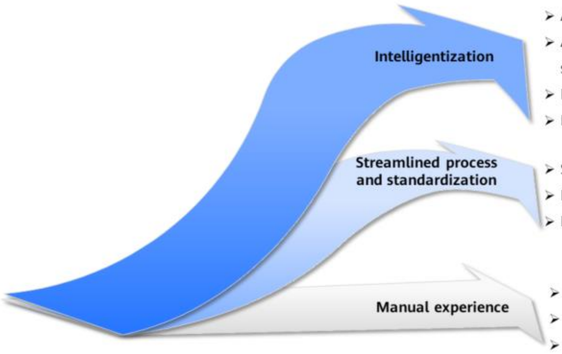


- Cloud services: They are adding, usage, and interaction models of Internet-based services. Cloud services are used to provide dynamically scalable and virtualized resources over the Internet. The term "cloud" is a metaphor for networks and the Internet. In the past, it was used to represent telecommunication networks. Later, it was also used to represent the Internet and an abstraction of underlying infrastructure. Cloud services refer to on-demand and scalable services obtained through networks. The services can be related to IT, software, and the Internet, and can also be other services.
- A cloud service agent is embedded in the DCIM server. Based on cloud technologies, the DCIM cloud service platform provides remote maintenance and management for DCIM. In this way, functions of the DCIM server can be released as cloud services. Authorized maintenance personnel can log in to the DCIM cloud service platform anytime and anywhere. From the perspective of maintenance personnel, it is as convenient as operating or viewing local equipment, and has high security and traceability. The cloud service agent builds management and data transmission channels between the data center target equipment and the DCIM cloud service platform. Users can configure the list of equipment that needs to be managed and controlled in the cloud service agent.

DCIM Development Trend - Intelligent O&M

- Data center infrastructure O&M has gradually shifted from manual experience to process-based and standardized O&M, and will be intelligent in the future, improving O&M quality and efficiency greatly.



Intelligentization:
- An automation system is responsible for repetitive O&M works.
- Analytical works are completed with the aid of new technologies, such as cloud computing.
- Reduces human resource investment greatly.
- Promotes the transformation of O&M personnel.

Streamlined process and standardization:
- Solidifies experience and knowledge based on standards and processes.
- Develops a mechanism and system tools to drive manual work.
- Performs quantitative analysis of human resource allocation.

Manual experience:
- A large number of O&M personnel are required.
- Experience and knowledge cannot be transferred in a standardized manner.
- The O&M quality completely depends on personal experience and stability.

Intelligent O&M - Electronic Inspection

- Electronic equipment room inspection and auxiliary mobile apps greatly reduce routine O&M labor hours.

Inspection route planning

- Allows users to customize inspection routes, bind inspection equipment or areas, and edit the inspection sequence.
- Generates and dispatches scheduled and automatic inspection tasks to related owners.
- Allows inspection owners to use mobile apps to automatically receive inspection tasks.

Mobile room inspection

- Allows users to submit inspection results in one-click mode.
- Performs proactive notification of inspection tasks and content integrity self-check to ensure that the room inspection is completed timely with high quality.
- Meter reading can be automatically and remotely completed, eliminating the need for manual meter reading and greatly reducing labor hours for manual inspection.

One-click inspection report

- Automatically generates an inspection report to evaluate the room health.
- Traces and collects statistics on room inspection progress in real time, and displays expired tasks timely.

Intelligent O&M - Unattended Inspection

- Inspection items of a traditional data center include collection of signals, sound, images, odor, and others (such as appearance). DCIM uses new technology to implement unattended inspection, simplifying inspection and reducing manual **workload**.

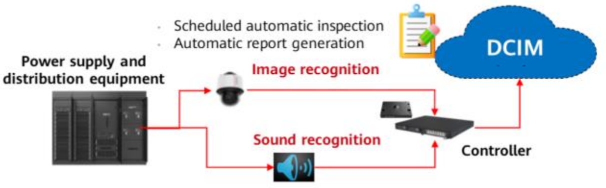


Image recognition

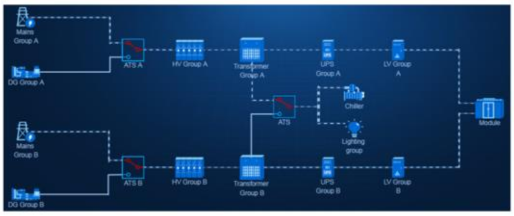
- New technologies are introduced to provide 24/7 monitoring.
- Accurately identifies indicator status and switch status on power distribution panels to provide warnings in advance.
- Identifies exceptions such as battery leakage and swelling to facilitate prompt handling.

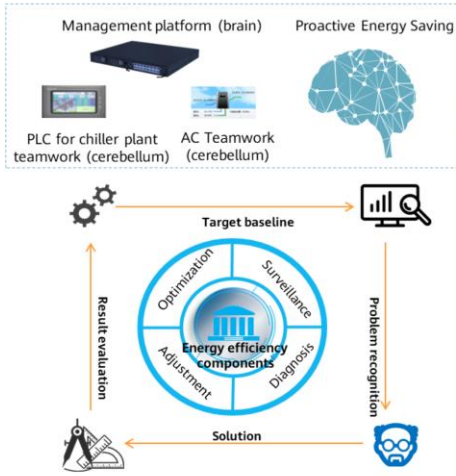
Sound recognition

- New technologies help implement noise reduction, feature extraction, and exception identification in real time.
- Intelligently identifies abnormal sounds of equipment and locates causes (for example, dirty or blocked UPS fans and foreign object intrusion).

Intelligent O&M - Proactive Energy Saving

- DCIM promotes surveillance, diagnosis, adjustment and optimization of data center energy efficiency, continuously reducing energy consumption.
  - The DCIM automatically optimize chilled water systems and proactively reduces the PUE.
  - End-to-end visualization and diagnosis of energy efficiency allow users to identify PUE exceptions and determine energy saving improvement directions.





- PLC: Programmable Logic Controller.

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DCIM Planning Considerations (1)

- Two major considerations for DCIM are industry standards and O&M objectives.

Industry standards

According to selected rating criteria, the availability design of the DCIM system should be greater than or equal to the availability level of data center infrastructure.

Equipment rooms for different services in the same data center should be designed based on different availability according to their importance. Corresponding management systems should also match the design.

O&M objectives

O&M objectives of a data center must be considered in the planning and construction phase. As the DCIM is the main platform and tool for data center O&M, its planning and design should also match the O&M objectives.

Major DCIM planning considerations

DCIM Planning Considerations - Industry Standards

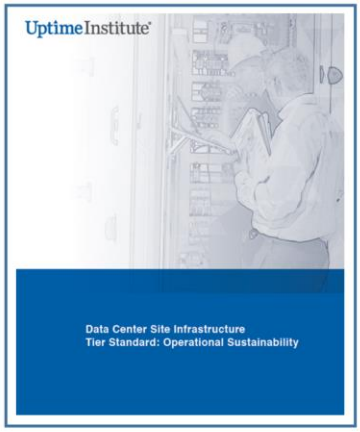
- According to the Uptime Institute *Date Center Site Infrastructure Tier Standard*, data centers are classified into four levels: Tier Ⅰ, Tier Ⅱ, Tier Ⅲ and Tier Ⅳ, which are in ascending order.

Uptime	Redundancy	Performance Requirements - Uptime
Tier Ⅳ	Fault tolerant	A Tier Ⅳ data center has multiple independent redundant equipment and paths that are physically isolated from each other. All facilities and paths work concurrently, eliminating single points of failure. All computers have dual power supplies and are connected based on the site topology. Its cooling system also requires uninterrupted operation.
Tier Ⅲ	Equipment and path redundancy	A Tier Ⅲ data center has redundant equipment and paths. All computers have dual power supplies and are connected based on the site topology. Tier III requires that only one path be used at any time.
Tier Ⅱ	Redundancy	A Tier Ⅱ data center has redundant equipment, but they are connected by a single path.
Tier Ⅰ	Meets basic requirements	A Tier Ⅰ data center meets basic requirements for data center running and has no redundancy.

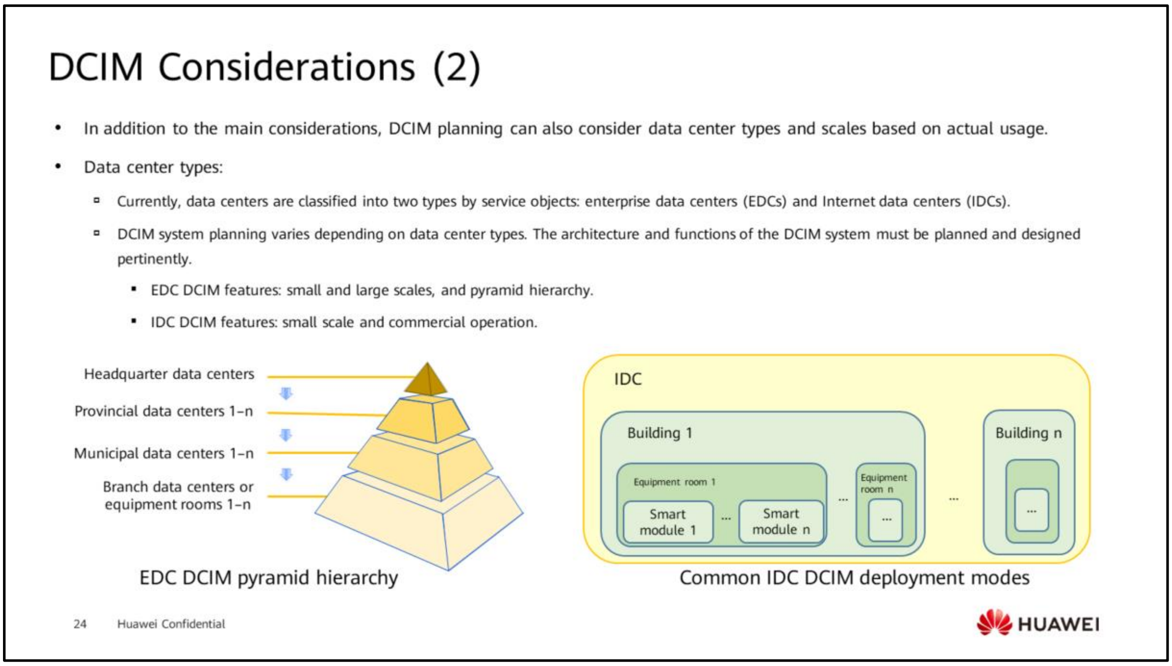
- The availability design of systems must match the availability level of data center infrastructure. The availability design of the DCIM system should be greater than or equal to the availability level of the data center infrastructure.
- Redundancy: Some or all components of the system are repeatedly configured. When a fault occurs in the system, the redundant components take over the work of the faulty components, thereby prolonging the mean time between failures (MTBF) of the system.
- Fault tolerance: There are two or more systems. At least one system is working properly at the same time. The infrastructure configured based on the fault tolerance system can still meet basic requirements for the normal running of electronic information equipment after a serious equipment fault or misoperation.

DCIM Planning Considerations - O&M Objectives

- *Data Center Site Infrastructure Tier Standard: Operational Sustainability* released by Uptime Institute illustrates O&M management objectives as follows:
  - It is recommended that O&M objectives be incorporated into project design, construction, commissioning, and operations to ensure full realization and implement the objectives throughout the entire O&M life cycle of the data center. Good O&M objectives help achieve the full performance potential of the installed infrastructure.



- Data center infrastructure O&M teams should discuss with the owner management, IT department, and related business departments to determine O&M management objectives. O&M management objectives can be set for different levels of data center infrastructure based on availability objectives of different applications.

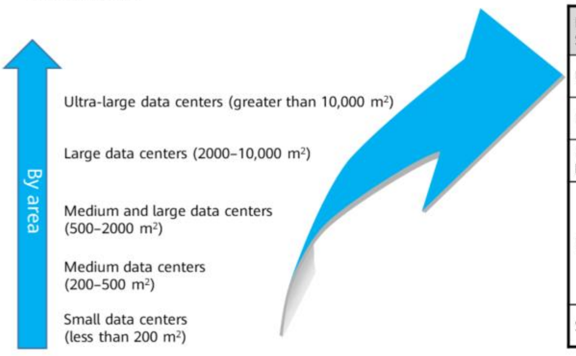


- EDC features:
  - EDCs include data centers of enterprises and institutions such as finance, electric power, oil, and research institutes, and government data centers. EDCs are constructed, managed, and used by organizations, and use self-built or leased network resources to form a relatively closed private wide area network (WAN) (also called internal network) to provide an information-based support platform for services and management of the respective organizations. One or more data centers can be deployed based on the service scale. Data centers can be deployed in a centralized or hierarchical manner.
  - An organization can have a data center. A large organization usually has multiple data centers that are distributed in different regions and has certain management relationships because its services or management scopes cover the whole country or even the world. Based on the management architecture (decision-making layer, management layer, execution layer), EDCs can be classified into data centers, sub-data centers, level-1 data centers, level-2 data centers, level-3 data centers ...
  - An EDC of a large organization is usually deployed in a pyramid hierarchy to match the organization management architecture. Data centers in a lower level are more in number with a smaller scale.

- IDC features:
  - For enterprises, IDCs lease software and hardware resources related to data centers, such as equipment room sites, networks, storage, and computing resources, to make profits. They also provide infrastructure-as-a-service (IaaS), such as IT equipment hosting, and value-added services, such as IT system running monitoring, maintenance, and O&M management.
  - For mass market customers, IDCs provide Internet-based information services. Currently, there are two types of enterprises that have IDCs in China. One type is telecommunication operators that have (wired and wireless) network resources, and the other type is third-party IDC service providers.

DCIM Planning Considerations (3)

- Data center scales:
  - A larger data center has more objects to manage and requires stronger processing capability of the DCIM system.
  - Attendance modes vary depending on the data center scale. The attendance mode also affects the DCIM planning and design of a data center.



Data Center Scale	Attendance Mode	Recommended DCIM Configuration
Ultra-large	24/7 attendance	In addition to basic functions, functions related to attendance and routine O&M must be configured, such as remote alarm notification, mobile O&M, and electronic inspection.
Large	24/7 attendance	
Medium and large	24/7 attendance	
Medium	24/7 attendance (recommended)	In addition to basic functions, functions related to attendance and routine O&M should be configured, such as remote alarm notification, mobile O&M, and electronic inspection.
Small	No requirement	Basic functions can be used.

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- Generally, ultra-large and large IDCs are used. An ultra-large or large data center consists of multiple buildings. Each building contains multiple equipment rooms, and each equipment room contains multiple smart modules, virtual equipment rooms, and cabinets. The minimum management domain of objects managed by DCIM can be an U space of a cabinet.
- An ultra-large data center can consist of multiple buildings. Each building contains multiple equipment room modules, and each equipment room contains multiple smart modules, virtual equipment rooms, and rows. The minimum management domain of data center monitoring management can be a cabinet.
- An ultra-large data center consisting of multiple equipment rooms can consist of equipment rooms of different levels. This meets users' requirements for different availability levels with reasonable construction and O&M costs.
- Micro and small data centers are mainly access layer equipment rooms (such as equipment rooms of banks, securities outlets, and service offices of government departments) and aggregation-layer equipment rooms of organizations.
- Attendance modes: Based on the importance and operation management costs of data centers, onsite attendance is not arranged for independent small and ultra-small equipment rooms. For medium data centers, onsite attendance is arranged based on service requirements. 24/7 attendance is arranged for data center clusters, ultra-large and large data centers that are managed online.

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DCIM Planning Principles

- After a data center is put into use, the DCIM system is the core of data center infrastructure management. In addition to matching appropriate industry standards and O&M objectives, the DCIM system planning must comply with the following principles:

- Applicability: Mature and stable products or solutions should be used.
- Advancement: High-value new technologies are used to ensure that the system can keep technologically advanced and have good scalability in a certain period of time to meet requirements for future technology upgrade.
- Reliability: To ensure service continuity, the system must have extremely high physical and network security and reliability.
- Flexibility: The system capacity and processing capability can be easily expanded based on development requirements. In addition to supporting the access of multiple monitored objects, the system can be flexibly and quickly adjusted based on capacity expansion requirements to implement quick deployment.
- Commonality: The system must use interfaces and protocols that are commonly used in China or around the world. A unified platform should be used to support cluster or distributed network architecture and multi-level management, and should feature integration, development, and scalability.

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DCIM Management and Planning Objectives

DCIM system planning objectives

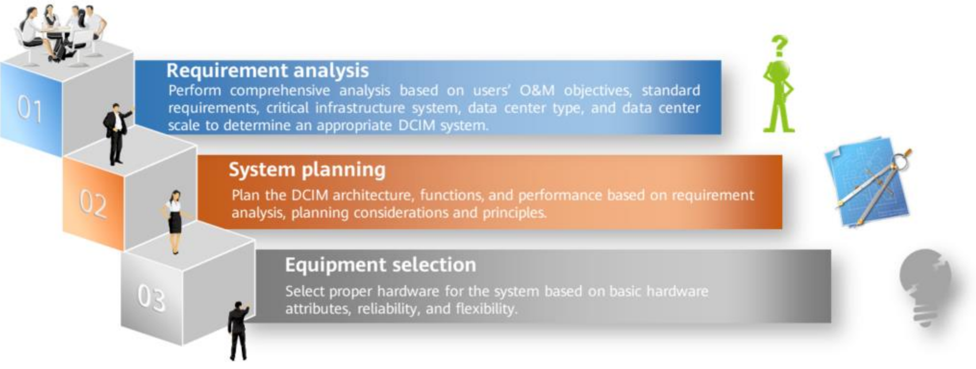
After the DCIM system is planned and implemented, the system can perform all-round real-time monitoring and management on data center infrastructure. Based on monitoring information, it performs unified information-based management on the infrastructure running, thereby implementing scientific management on a data center and improving management accuracy and efficiency.

DCIM management objectives

Achieves maximal availability of a data center with minimal operating costs.

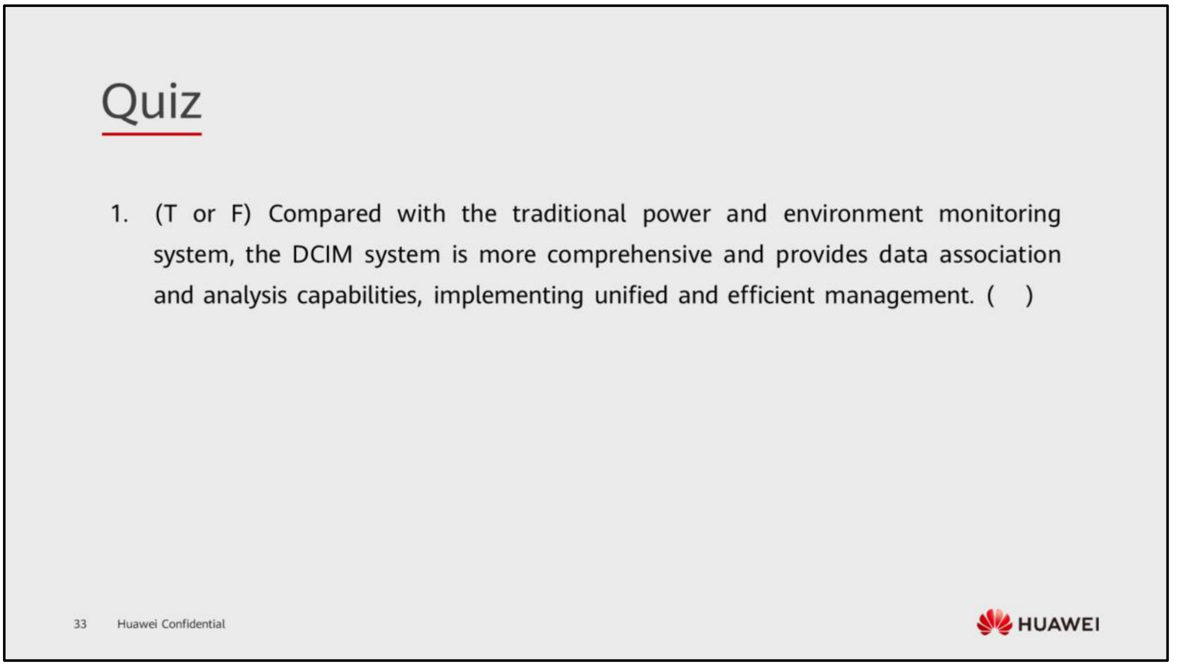
DCIM Planning Process

- After considering factors and principles that affect DCIM planning, specify planning objectives and complete the system planning by referring to the following basic process of DCIM.



Summary

- DCIM concept
- Relationship between DCIM and traditional power and environment monitoring, BMS, and ITSM
- DCIM development trend
- DCIM planning considerations and process


Quiz
1. (T or F) Compared with the traditional power and environment monitoring system, the DCIM system is more comprehensive and provides data association and analysis capabilities, implementing unified and efficient management. ( )
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- Answer:
  - A.

Thank you.

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每个组织，构建万物互联的智能世界。
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DCIM System Architecture and Functions

Foreword

- This chapter introduces the physical architecture, logical architecture, and system functions of DCIM.

Objectives

On completion of this course, you will be able to:

- Describe DCIM physical architecture.
- Describe DCIM physical deployment layers.
- Describe DCIM logical architecture.
- Describe DCIM system functions.

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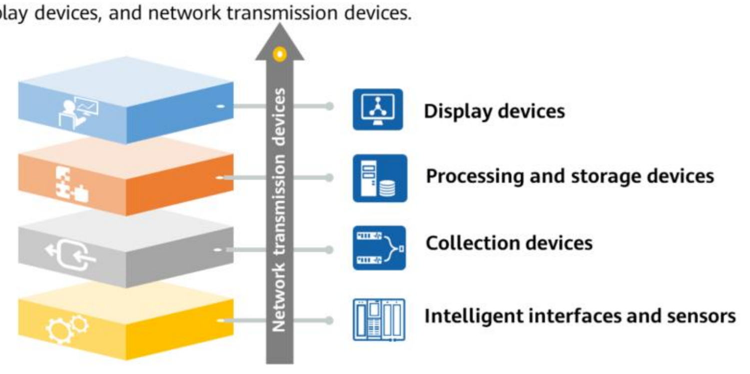
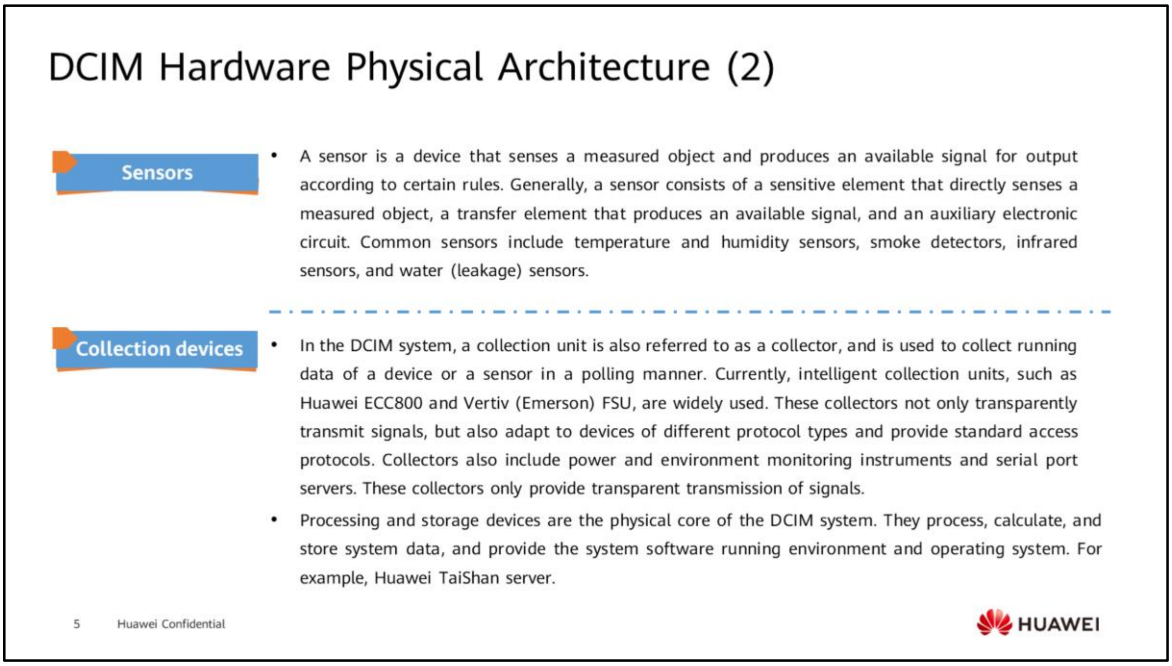
DCIM Hardware Physical Architecture (1)

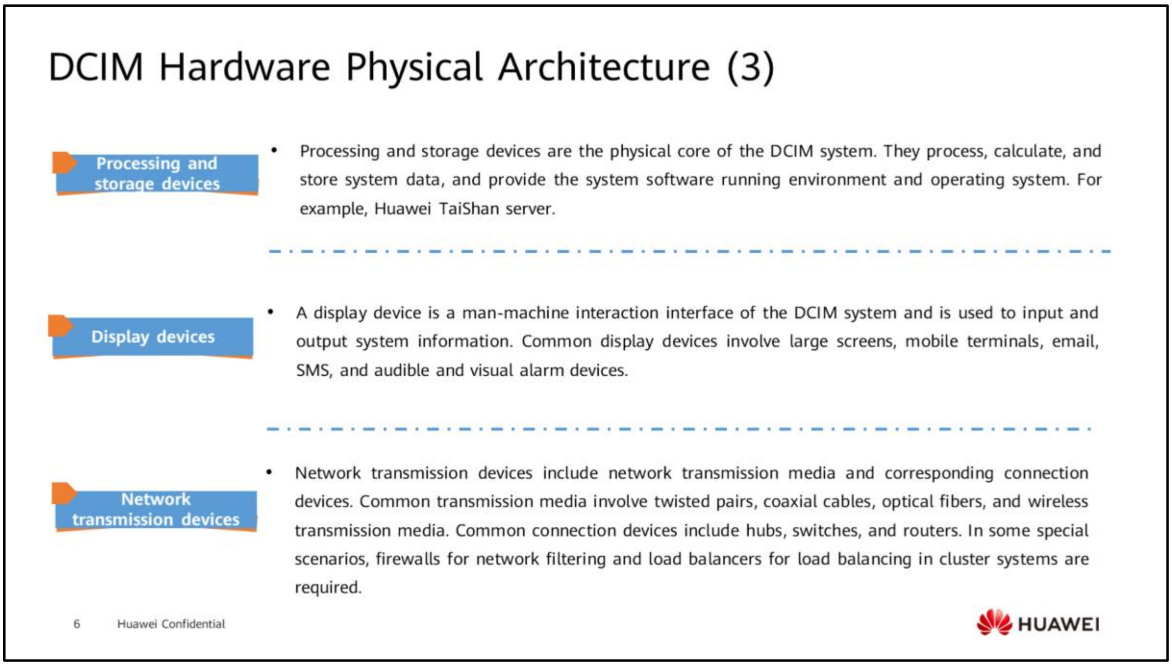
- The physical architecture reflects DCIM physical components and relationships between these components. In the DCIM system, components are deployed at physical layers to support system running.
- Generally, a complete DCIM system consists of intelligent interfaces and sensors, collection devices, processing and storage devices, display devices, and network transmission devices.



- Sensors: include temperature and humidity sensors, smoke sensors, infrared sensors, and water (leakage) sensors.
- Collection devices: Currently, intelligent collection units are most widely used. The collectors not only transparently transmit signals, but also adapt to devices of different protocol types and provide standard access protocols. Collectors also include power and environment monitoring instruments and serial port servers. These collectors only provide transparent transmission of signals.
- Processing and storage devices: Processing and storage devices are the physical core of the DCIM system. They process, compute, and store system data, and provide the system software running environment and operating system.
- Display devices: They are the man-machine interaction interface of the DCIM system and are used to input and output system information. Common display devices include large screens, email, SMS, and audible and visual devices.
- Network transmission devices: include network transmission media and corresponding connection devices. Common transmission media involve twisted pairs, coaxial cables, optical fibers, and wireless transmission media. Common connection devices include hubs, switches, and routers. In some special scenarios, firewalls for network filtering and load balancers for load balancing in cluster systems are required.

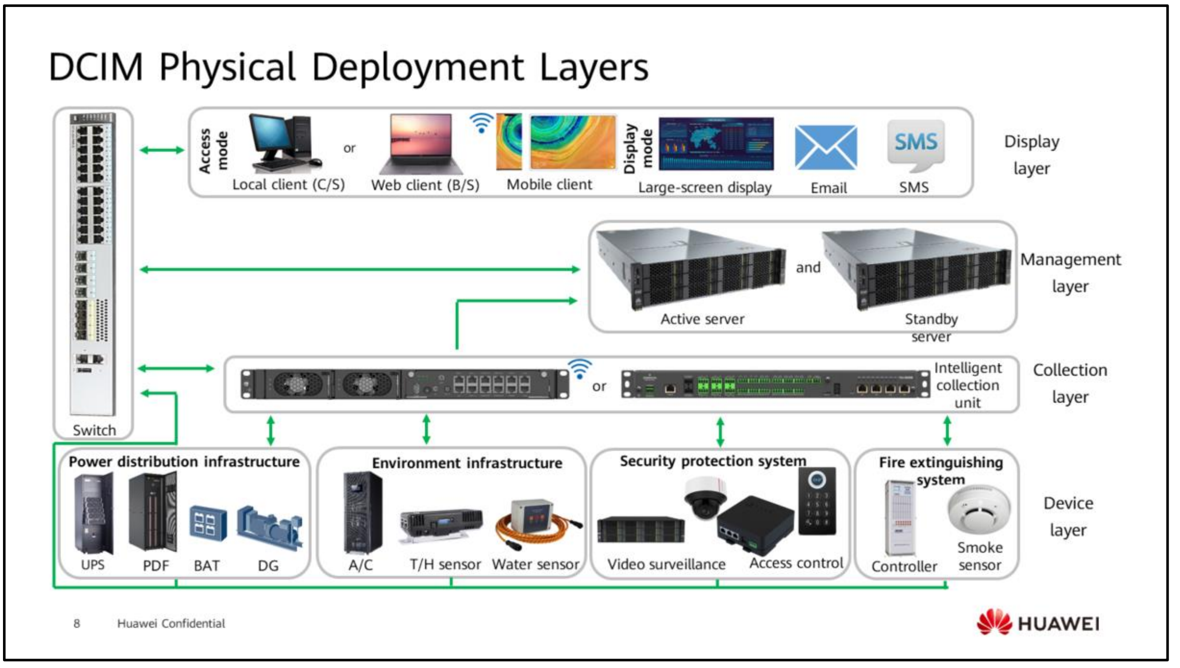


- Transparent signal transmission: In this mode, content is transmitted from the source address to the destination address without any change to its data.



- Hub: A hub is a basic communication device that physically connects nodes on a multi-point bus or loop. It is generally used in Ethernet and a Fibre Channel network to improve the manageability of physical cables. While forming a new hub-and-spoke star physical structure, the hub also maintains the logical loop structure of the network to which the hub belongs. Unlike switches, hubs do not aggregate network bandwidth. A hub generally supports the addition and removal of nodes on the bus.
- Switch: A switch is a basic network component that can connect multiple network nodes. Different from a hub, a switch generally has internal bandwidth, which is an integer multiple of the link bandwidth, and can quickly switch node connections. A typical switch can process full-link bandwidth transmission that occurs simultaneously between multiple pairs of nodes.

- Router: A device at the network layer. Routers can be used to select routes on the Internet. A router selects a proper route (through a network) based on the destination address of a received packet and sends the packet to the next router. The last router in the route sends the packet to the destination host. It can be used to connect a local network to another local network, a wide area network to another wide area network, or a local network to the Internet.
- Firewall: A collection of components configured between different networks or network security domains. A firewall monitors, restricts, and changes data flows across the firewall to shield the internal information, structure, and running status of the network. In this way, the network security is protected.
- Load balancer: A load balancer is a hardware device that distributes network requests to available servers in a server cluster, manages incoming web data traffic, and increases effective network bandwidth.



- This slide shows common DCIM physical deployment layers.

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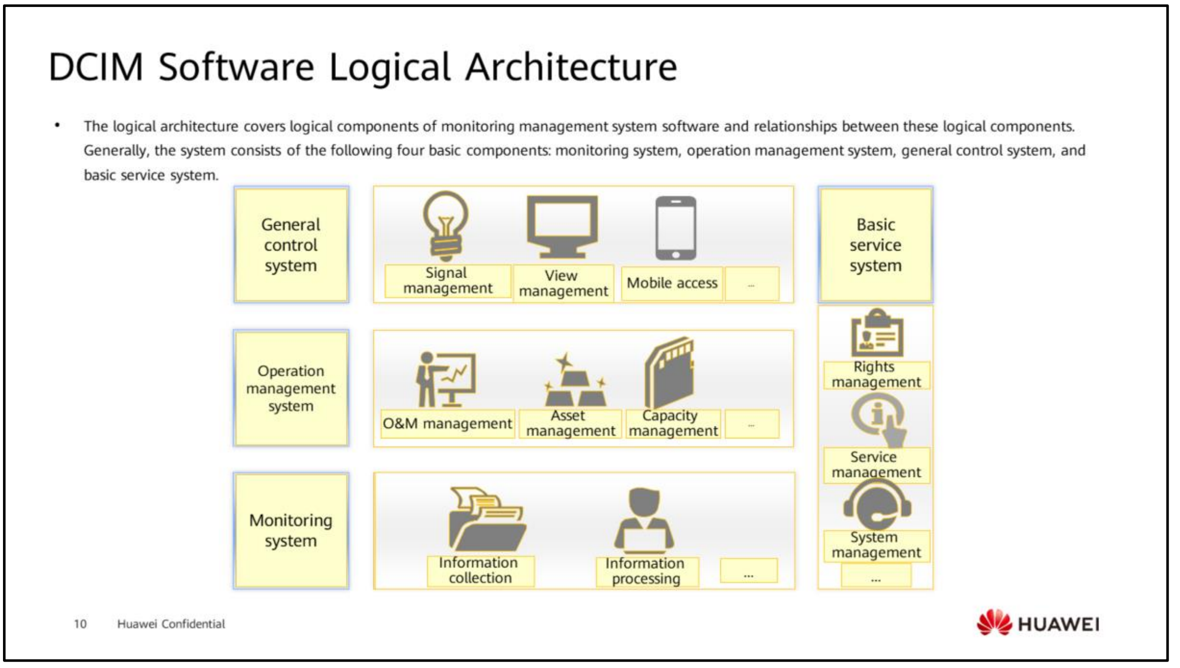
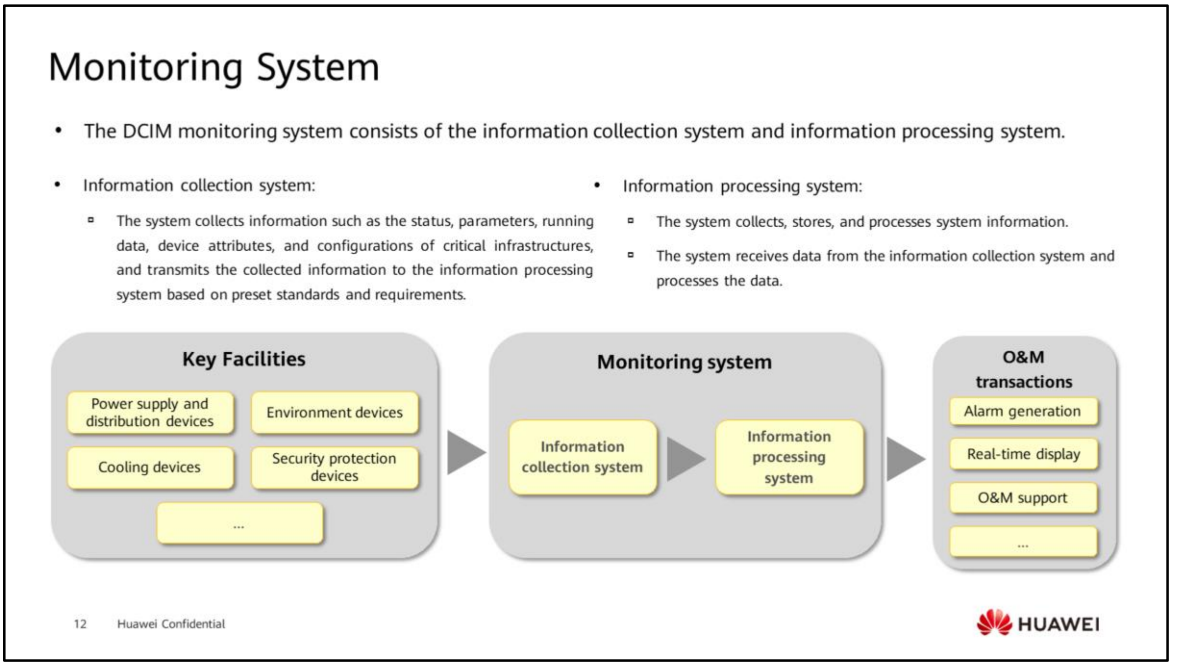
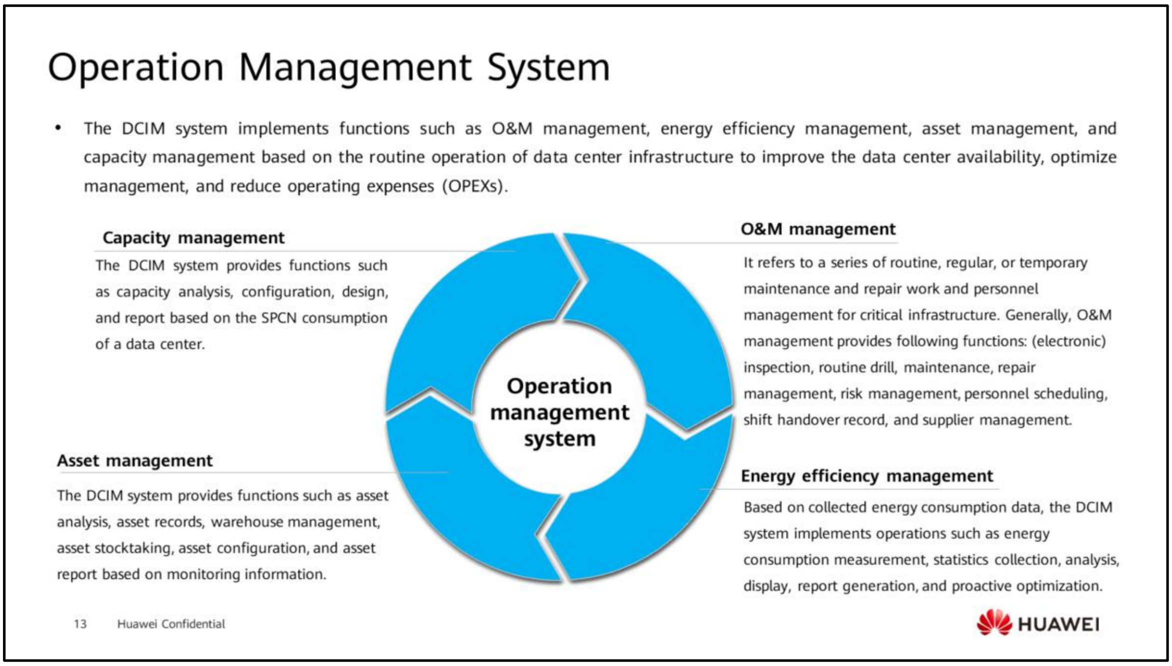


- Monitoring system:
  - Information collection system: To implement modular design, the information collection system is usually deployed in distributed mode to improve the stability of the monitoring and management system. The information collection system is basically hardware-based.
  - Information processing system: The information processing system is the core equipment or module that implements monitoring in the monitoring and management system. Instead of the traditional software-based information collection subsystem, the information processing system processes, calculates, and stores a large amount of data in real time, flexibly, and accurately.
- Operation management system:
  - Asset management: includes assets warehousing, allocating, unallocating, and scrapping.
  - Capacity management: refers to the capacity management of (U) space, power, cooling, network (SPCN), that is, the capability of supporting infrastructure such as power, cooling, space, and network of a data center.
  - O&M management: ensures the stable running of a data center and is also the main task of routine management of the data center. It supports activities such as troubleshooting, routine maintenance, periodic inspection, and personnel duty management of the data center.

- General control system:
  - Signal management: The system displays key device information in real time and allows users to filter, search for, and mask data.
  - View management: The system provides multiple methods to intuitively display data center device information, alarm information, O&M bulletins, and to-do tasks.
  - Mobile access: In addition to local access and interaction, the system also supports mobile terminal access to implement mobile information viewing and mobile O&M.
- Basic service system:
  - System management: The system provides user management, login management, security policy management, and software upgrade.
  - Service management: manages service licenses and network element (NE) mediations of the DCIM system.
  - Rights management: performs DCIM system user management and login control.



- The monitoring system can display the alarm information of the current data center in real time. In addition, it can perform alarm notification and convergence management based on the preset mode, such as SMS notification, email notification, and work order dispatch.
- The prerequisite for the DCIM system to complete data processing, analysis, and optimization is that the system has a complete information collection function.
- Information processing system:
  - Generates new alarm information based on alarm rules, and associates, compresses, and filters massive alarm information to locate faults.
  - Sends important monitoring information to the general control system for real-time display.
  - Manages related information to implement the corresponding management process.
  - Stores and manages other important data, generates historical data for the operation management system to invoke, and produces statistical analysis reports as required.



- SPCN: (U) space, power, cooling, network.

General Control System

- The general control system provides a user interface for O&M personnel to monitor the running status of a data center and interact with the data center. The user interface provides common routine O&M functions, such as view management, signal management, and service desk.

General control system

View management

After the DCIM system is configured, the general control system can display the physical topology, micro-module view, and cabinet view of a data center in multiple modes, such as 2D, 2.5D, 3D, and large screen.

Signal management

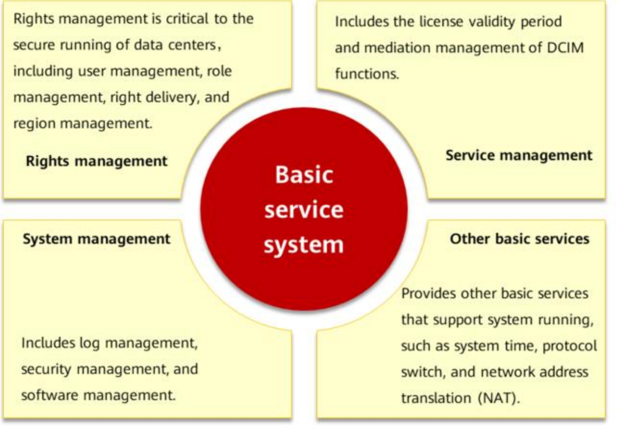
Key indicators such as the running and alarm information of key devices in a data center can be displayed on the signal management page. A user can filter, search for, and mask the indicators based on actual O&M requirements.

Service desk

O&M personnel can use the service desk to complete various O&M tasks, such as dispatching O&M tasks, tracking task progress, processing to-do tasks, and releasing project bulletins.

Basic Service System

- The basic service system provides some common basic services for the preceding logical components, such as unified permission management, service management, and system management.



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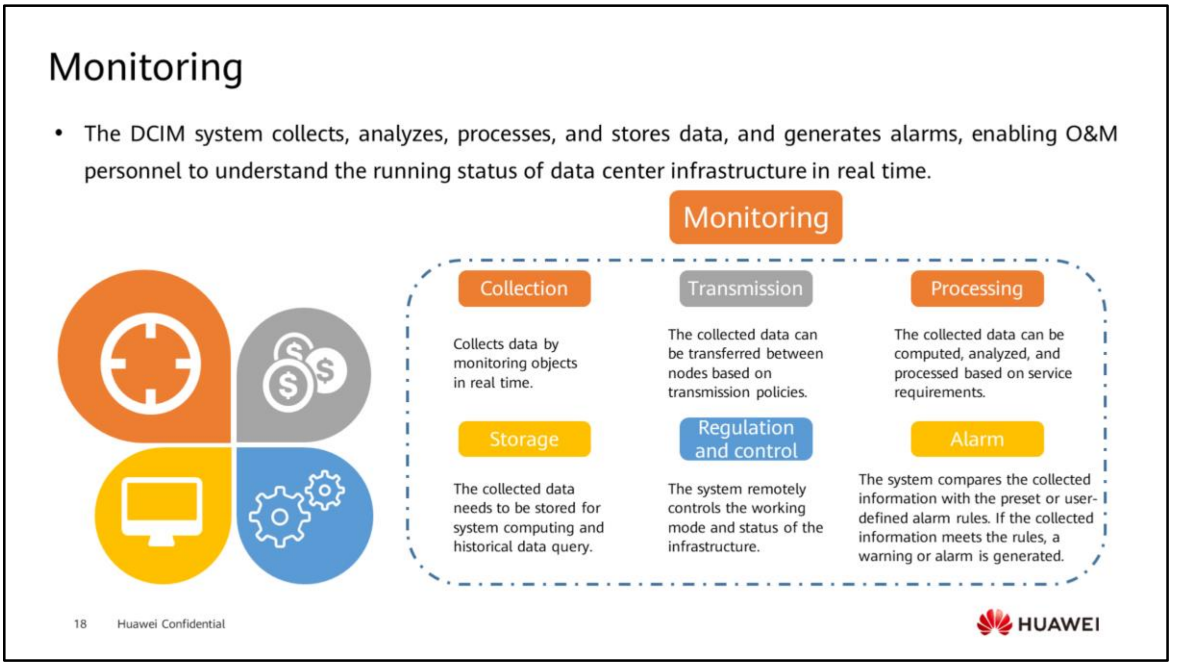
DCIM System Functions

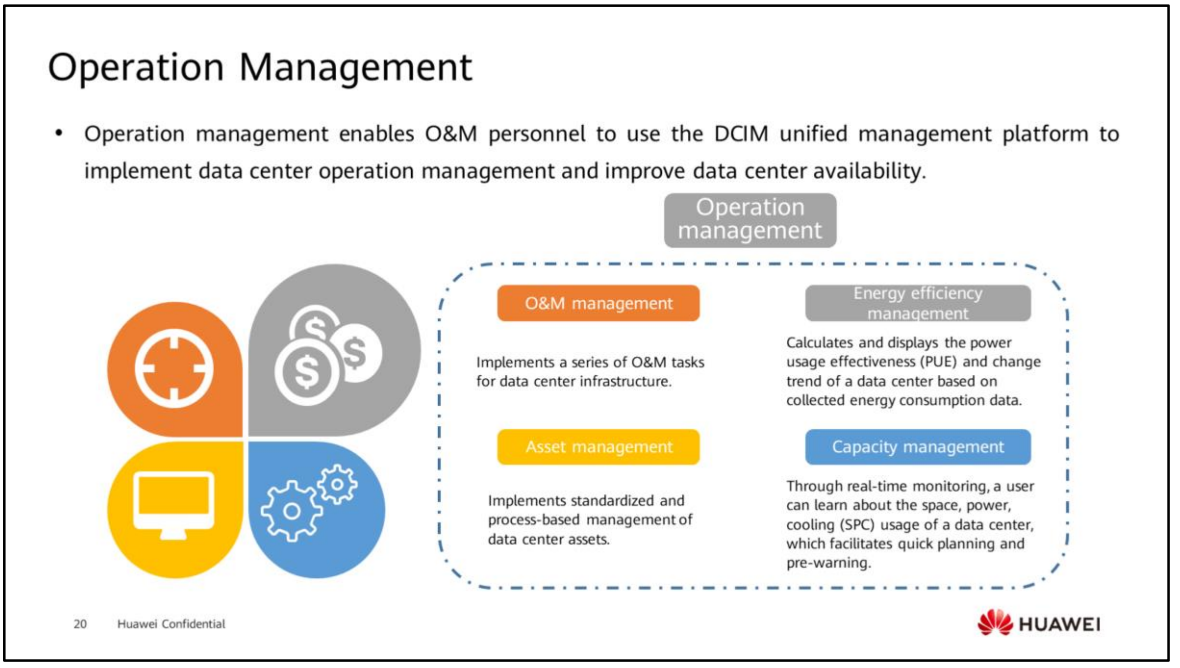
- To achieve management objectives, the DCIM system must provide various management functions. According to the logical architecture, the DCIM system functions can be divided into four parts: monitoring, operation management, general control, and basic services.

- DCIM management objective: To achieve maximal possible availability of a data center with minimal operating costs.
- Monitoring: The DCIM system collects, analyzes, stores, and displays data, enabling O&M personnel to understand the running status of data center infrastructure in real time.
- Operation management: O&M personnel use the DCIM unified management platform to implement data center operation management and improve data center availability.
- General control: It is the entrance to DCIM O&M management and provides an interaction portal for O&M personnel. Generally, it includes routine management functions such as service desk, view management, and signal display.
- Basic services: They refer to system functions provided by the DCIM system to implement management functions, including user and rights management, system management, and system service management.

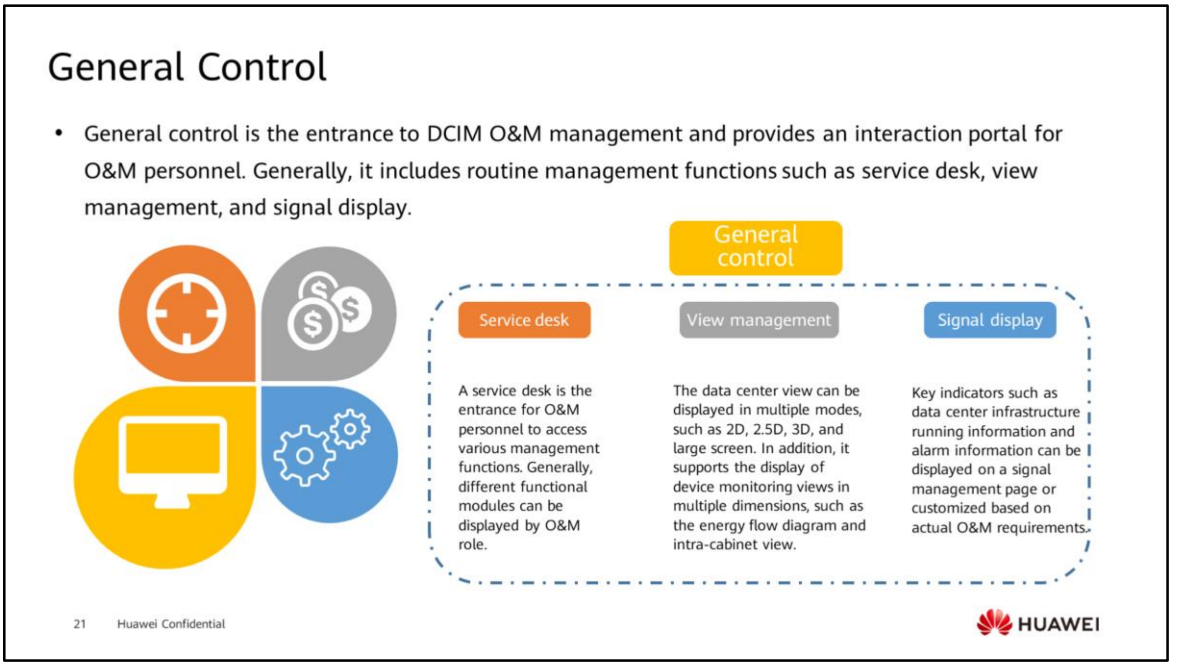


- Collection: The monitoring system monitors various objects in real time, collects data, and uploads the collected data in a unified format to the data processing layer for unified processing. The monitoring system also performs basic filtering on the collected data to avoid false alarms.
- Transmission: The collected data can be transferred between nodes in the system based on transmission policies. Multiple transmission policies and data processing modes are supported. Monitoring data streams can be transferred through conventional polling-based centralized transmission or more efficient proactive reporting transmission. To ensure the security of the information system, the system can encrypt monitoring data streams, especially sensitive data.
- Processing: The collected data can be computed, analyzed, and processed based on service requirements. The system can preset or customize data computing rules and complex event processing rules to meet various processing requirements.

- Storage: The collected data needs to be stored for system computing and historical data query. Generally, a data processing system needs to perform real-time computing, which requires a high real-time performance of a storage system. The real-time database stores the real-time data in the memory to ensure the real-time performance. In addition, the system needs to perform statistical analysis on historical data collected to generate data center-related reports, providing a basis for data center operation. In the system, a history database stores the collected data to the disk medium according to the time sequence for the system to invoke.
- Adjustment and control: The system can remotely control the working mode and status of infrastructure devices. The control mode can be manual or automatic.
- Alarm: The system can compare the collected information with the preset or user-defined alarm rules. When the conditions are met, a warning or alarm is generated. In addition, the system can send feedback notifications based on preset interaction modes, such as SMS, emails, and audible and visual alarms.



- O&M management: O&M management refers to a series of O&M tasks for data center infrastructure, including periodic maintenance and routine inspection of the infrastructure, fault management, system knowledge base, supplier management, and shift scheduling management. Planned preventive management effectively reduces the infrastructure failure rate. Through process-based event management, faults can be rectified as soon as possible.
- Energy efficiency management: Based on collected energy consumption data, the system calculates and displays the PUE of a data center, helping users understand the real-time energy consumption composition and change trend of the data center. Based on the application of new technologies, the system deeply analyzes the energy consumption data of a data center, captures energy consumption rules of the data center, proposes reasonable energy saving measures, and supports the implementation.
- Asset management: DCIM standardizes and streamlines common asset management (such as asset stocktaking, warehousing, distributing, and scrapping) in a data center.
- Capacity management: monitors the SPC usage of a data center in real time to comprehensively learn about the data center. When IT services are changed, a user can quickly plan and select a proper installation position. If the system capacity usage increases, a warning is generated in advance so that capacity expansion can be planned. In addition, it can query historical capacity data, analyze capacity changes, and support capacity planning.



- Service desk: O&M management personnel can complete various O&M tasks through a service desk, such as dispatching O&M tasks, tracking task progress, processing to-dos, and releasing project bulletins.
- View management: After the DCIM is configured, the general control system can display the physical topology, micro-module view, and cabinet view of a data center in multiple modes, such as 2D, 2.5D, 3D, and large screen.
- Signal display: Key indicators such as data center infrastructure running and alarm information can be displayed on a signal management page or customized based on actual O&M requirements. This function can be associated with O&M tasks such as alarm notification, work order function, and report generation.

Basic Services

- Basic services refer to system functions provided by the DCIM system to implement management functions, including user and rights management, system management, and system service management.

Basic services

User and rights management	System management	System service management
Provides DCIM system users and rights management. Based on data center requirements, system users can be managed by level or by physical area. In addition, login authentication modes and login nodes can be controlled and managed.	The DCIM system can be managed in real time, including security management, log management, and system software management.	Manages system services provided by DCIM. These services include function licenses, network element (NE) mediations, and various authentication certificates.

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DCIM System Performance

- DCIM system performance refers to the capability of the system hardware to complete tasks such as collection, processing, computing, and storage.
- DCIM system performance parameters include response time, management capability, processing capability, two-node cluster switchover duration, and storage capacity.
- Common DCIM system performance parameters are as follows:

Response Time (s)		Management Capability (number of test points)		Two-node Cluster Switchover Duration (s)	Processing Capability	Storage Capacity
Data Collection	< 5	Small data center	0–10000	< 60	System CPU runtime usage is less than 40%.	Data can be stored for more than three years.
Device control	< 5	Medium data center	10000–20000			
Video surveillance refresh	< 6	Large data center	> 20000			
Alarm generation time	< 6					

- The control response time refers to the duration from the time when the system initiates a control signal request to the time when the corresponding device responds to the signal request.
- The collection response time refers to the duration from the time when the value of a monitored object changes to the time when the collection device obtains the changed value.
- The video surveillance refresh time refers to the duration from the time when the value of a monitored object changes to the time when the monitoring image in the main control center displays the change of the value.
- The alarm generation time refers to the duration from the time when an alarm is generated by a monitored object to the time when the DCIM system displays the corresponding alarm status.
- The shorter the two-node cluster switchover duration is, the higher the system availability is.

Third-Party Integration - Introduction to Modbus Protocol

- Modbus protocol:
  - Modbus is the most commonly used industrial field bus protocol. It is a standard, open, and free-of-charge protocol that supports various interfaces, such as RS485 and RJ45.
  - There are two types: Modbus RTU and Modbus TCP.
  - Generally, Modbus refers to RTU mode, which is the most common Modbus mode.
  - It supports the master/slave mode. In this mode, the host calls a device and the device answers the call.
  - Analysis scope: register address, function code, read/write attribute (R/RW), data type, unit or enumerated value, proportion coefficient, value range (the value range must be confirmed for issued indicators and is optional for read-only indicators), and alarm severity (if the vendor cannot provide the alarm severity, the alarm severity needs to be customized based on experience).

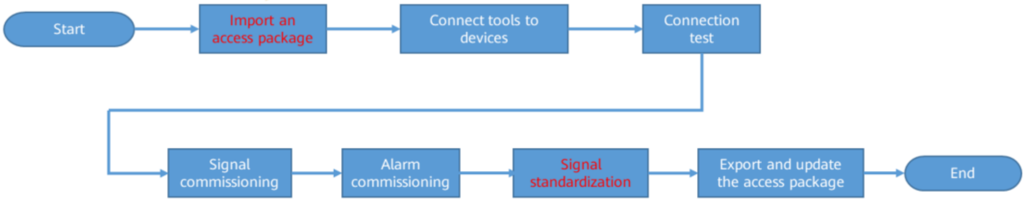
Third-Party Integration - Introduction to SNMP Protocol

- SNMP protocol:
  - Simple Network Management Protocol (SNMP) is used for network management and network device management.
  - SNMP is designed to work in the TCP/IP suite.
  - There are three versions: V1, V2, and V3. V1 and V2 support simple read and write, and V3 supports encryption.
  - Analysis scope: signal object identifier (OID), index OID (required for table signals), read/write attribute (R/RW), data type, unit or enumerated value, proportion coefficient, value range (the value range must be confirmed for issued indicators and is optional for read-only indicators), trap alarm reporting mode, and unit.

- The RS485 interface cannot use the SNMP protocol.
- OID: object identifier.

Common Process for Third-party Devices to Access the DCIM System

- Devices of different models from different vendors provide different northbound protocols based on their configurations. For example, Modbus and SNMP.
- By defining **access packages**, the DCIM system can parse access protocols of devices from different vendors, convert data, and manage and monitor the devices in a unified manner.



- From the perspective of customers, devices seem the same, reducing the learning cost.
- From the service perspective, devices seem the same, improving service development efficiency.

Summary

- DCIM physical architecture
- DCIM physical deployment layers
- DCIM logical architecture
- DCIM system functions

Quiz

1. (Multiple) Which of the following statements about the DCIM monitoring function is true?
   A. Through the collection function, the system can monitor various objects in real time, collect data, and upload the collected data in a unified format to the data processing layer for unified processing.
   B. The transmission function indicates that the collected data can be transferred between nodes in the system based on transmission policies.
   C. The storage function indicates that all the collected data is stored in the memory of the real-time database for system computing and historical data query.
   D. The processing function indicates that the collected data can be computed, analyzed, and processed based on service requirements.

- Answer: ABD. The description of the storage function in option C is incorrect. Generally, a data processing system needs to perform real-time computing, which requires a high real-time performance of a storage system. The real-time database stores real-time data in the memory to ensure the real-time performance. In addition, the system needs to perform statistical analysis on historical data collected to generate data center-related reports, providing a basis for data center operation. In the system, a history database stores the collected data to the disk medium according to the time sequence for the system to invoke.

Thank you.

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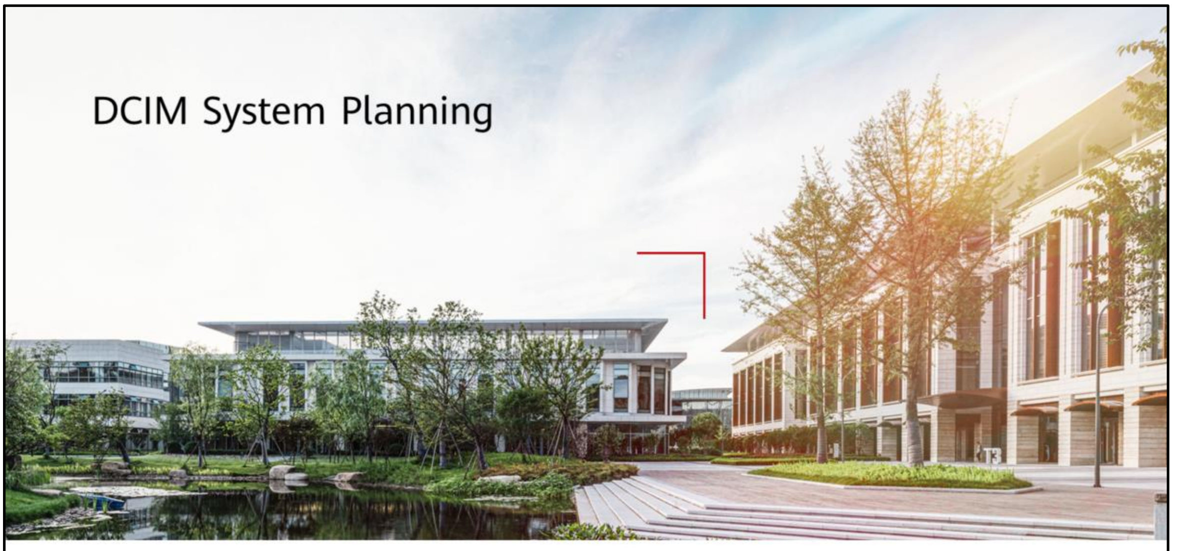
DCIM System Planning



Foreword

- The slides introduce the general process of DCIM system planning, including requirement analysis, system planning, and device selection.

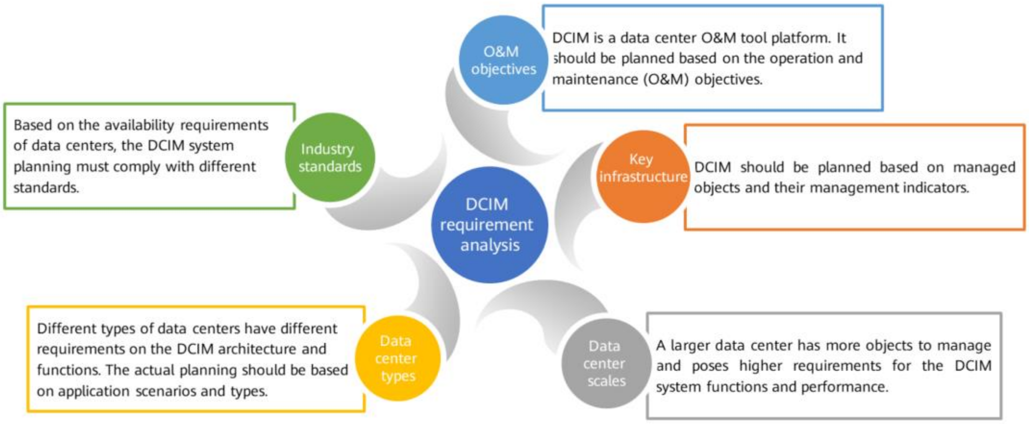
Objectives

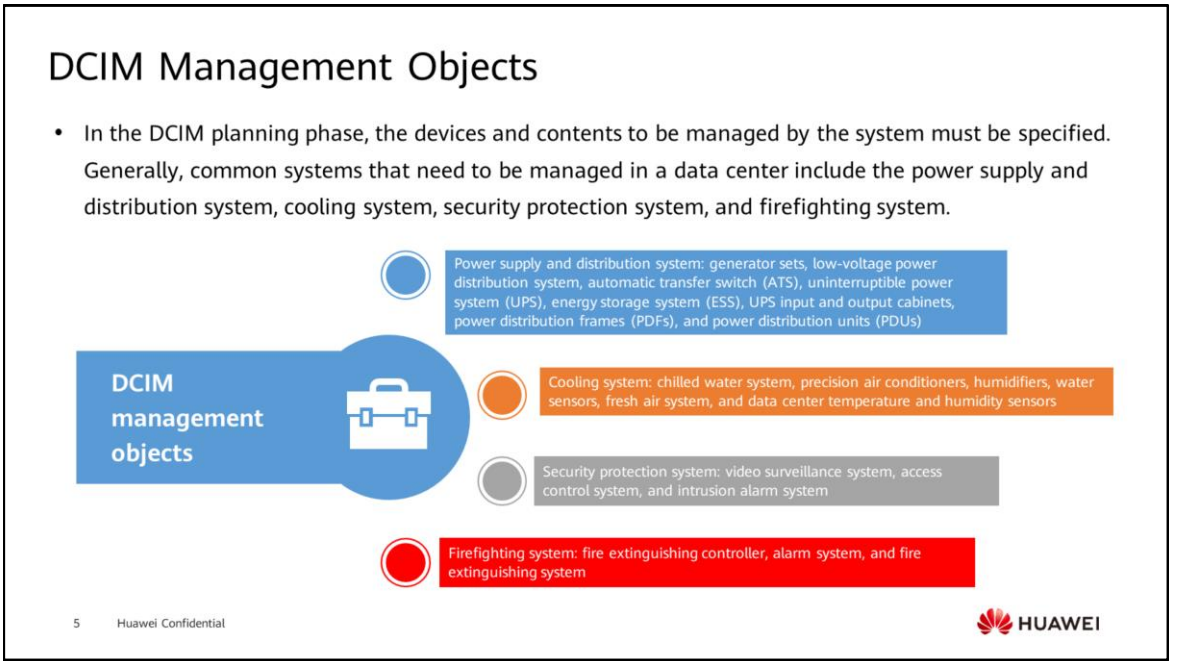
On completion of this course, you will be able to:

- Understand main management objects of the DCIM system.
- Have a good command of main monitoring parameters and control contents of the DCIM system management objects.
- Have a good command of DCIM architecture and function requirements for data centers at different levels.
- Have a good command of principles and precautions for DCIM hardware selection.

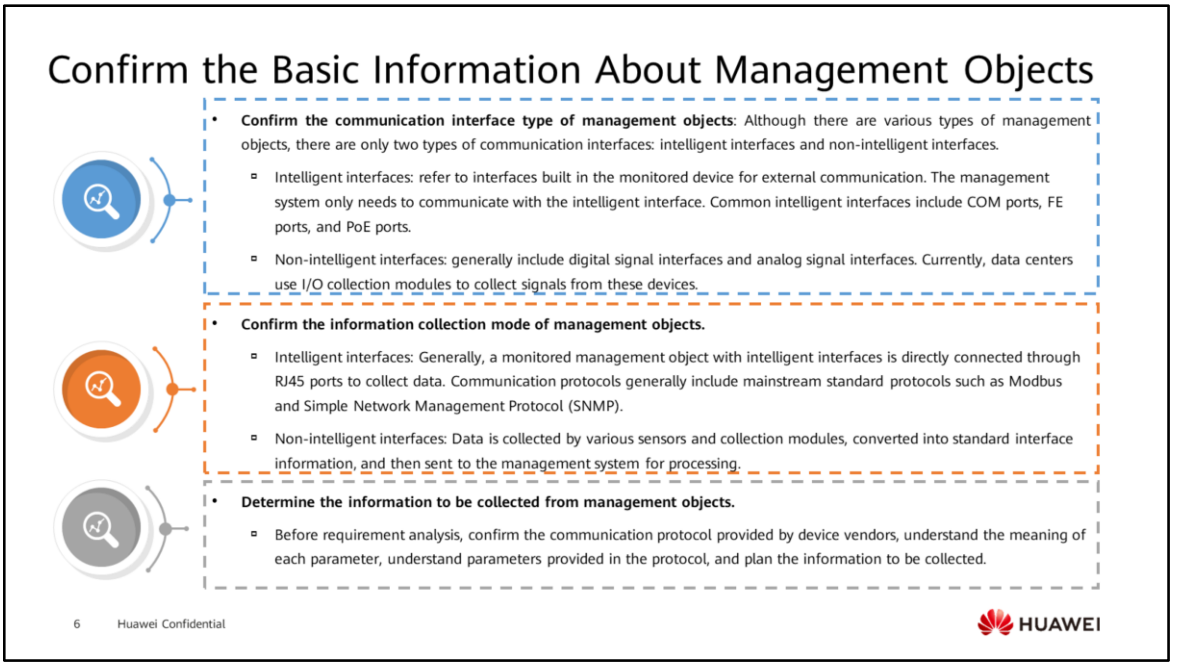
Contents

DCIM Planning Requirement Analysis





- Generally, common systems that need to be managed in a data center include the power supply and distribution system, cooling system, security protection system, and firefighting system.
- Data centers of different scales, types, and management objectives must be fully considered during system planning to match different management granularities.

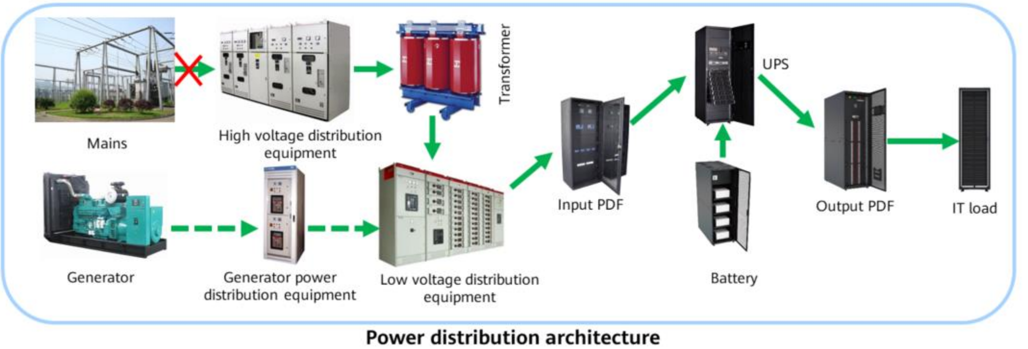


- Generally, digital signals include the power distribution switch status, surge protective device (SPD) status, and fresh air unit start/stop status.
- Generally, analog signals include 4–20 mA low-current signals and DC voltage signals.

Contents

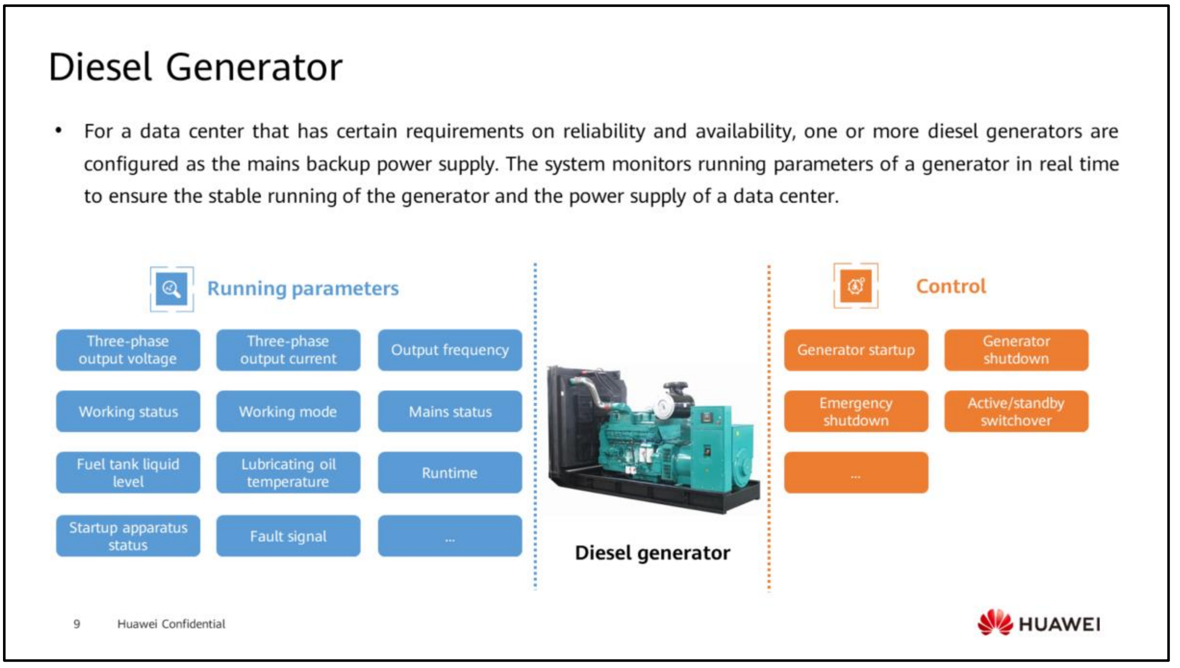
Power Supply and Distribution System

- The power supply and distribution system is the power basis of a data center. To ensure continuous and stable service running, the DCIM system must monitor the running status and parameters of each node in the power supply and distribution system in real time.



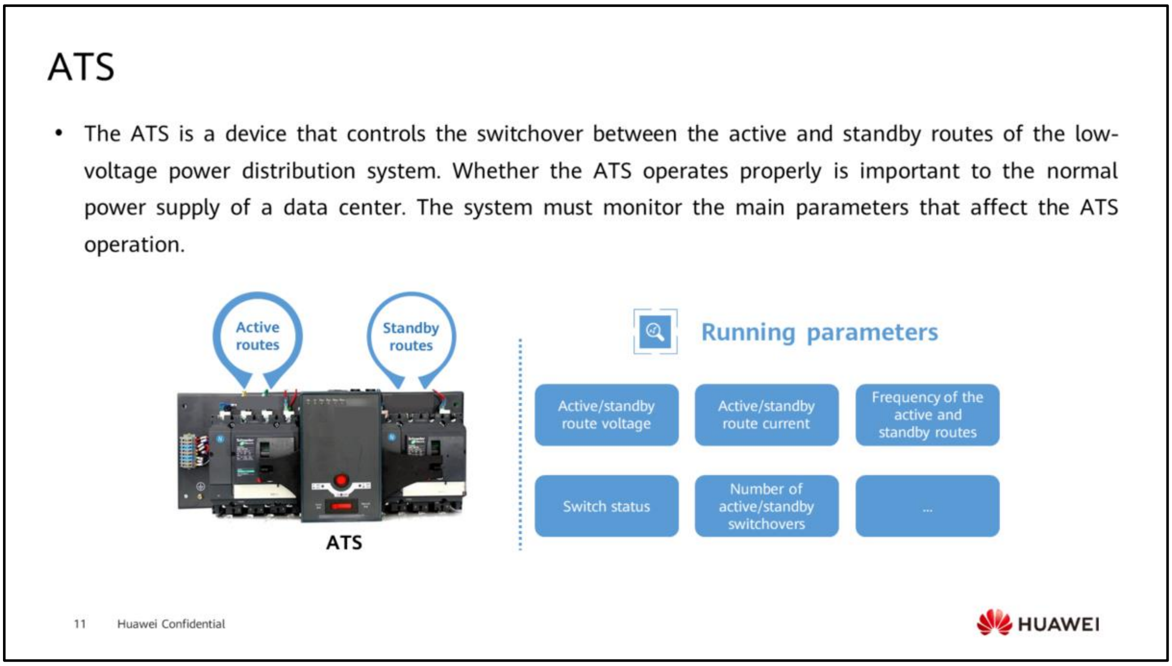
Power distribution architecture

- The picture above shows the basic power distribution architecture of a data center.



- Running parameters:
    - Three-phase output voltage: refers to the three-phase output voltage when a generator is running.
    - Three-phase output current: refers to the three-phase output current when a generator is running.
    - Output frequency: refers to output frequency when the generator is running.
    - Working status: running or shutdown.
    - Working modes: automatic or manual.
    - Mains status: The mains is faulty.
    - Fuel tank liquid level: When the fuel tank liquid level of a generator decreases to a low level, the system should generate a warning or an alarm.
    - Lubricant oil temperature: refers to the oil temperature when a generator is running. In addition to the oil temperature, the oil pressure is also monitored.
    - Runtime: refers to the running duration after a generator is started.
    - Startup apparatus: refers to the motor and battery that support the startup of a generator.
    - Fault signal: indicates whether an exception occurs when the generator is running.

- Remote control:
  - Generator startup: A generator can be started automatically or manually remotely based on operation requirements.
  - Generator shutdown: A generator can be shut down automatically or manually remotely based on operation requirements.
  - Emergency shutdown: A generator can be manually shut down when it is running.
  - Active/standby switchover: When multiple generators are configured, the active/standby switchover can be performed automatically or manually based on operation requirements.



- Active/standby route voltage: refers to the active/standby input voltage of the system.
- Active/standby route current: refers to the active/standby input current.
- Active/standby route frequency: refers to the primary/standby input frequency of the system.
- Switch status: refers to the current position of the ATS switch.
- Number of active/standby switchovers: refers to the total number of switchovers during the running of the ATS.

UPS

- No matter what kind of mains quality, a continuous, stable, and uninterruptible power supply cannot be ensured. Therefore, most data centers use the UPS to ensure service continuity and stability. The UPS is the core to ensure continuous power supply to IT loads in a data center. Real-time monitoring of the UPS is an important measure to ensure the UPS system reliability.

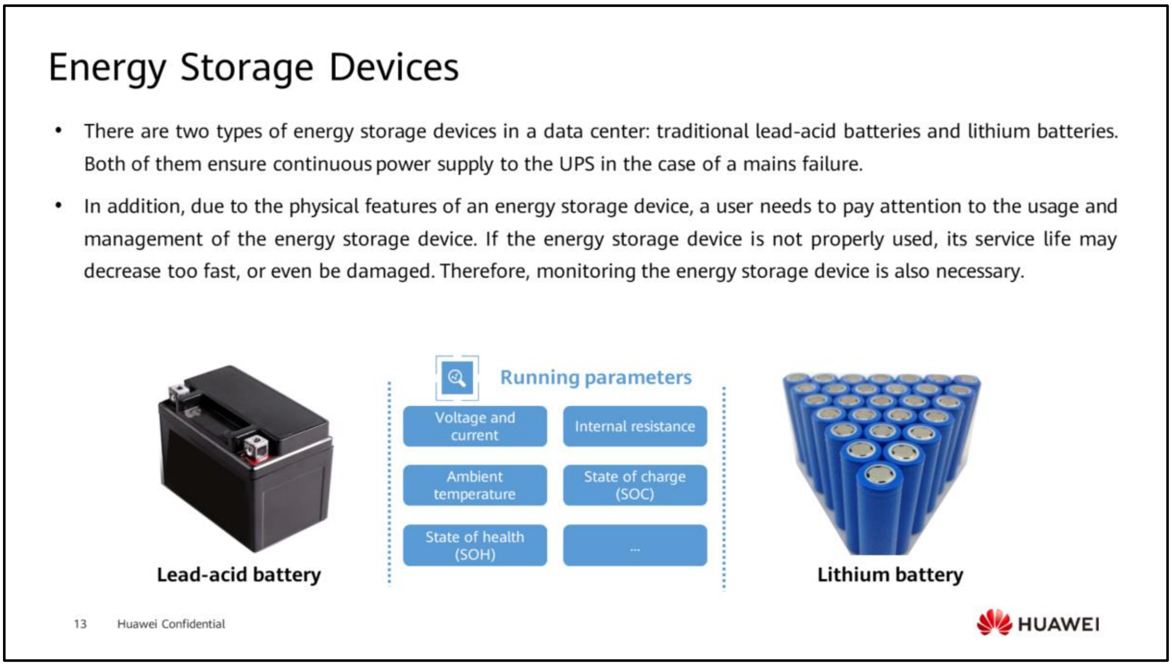
Running parameters

Three-phase input voltage	Three-phase input current	Input frequency	Input power
Three-phase output voltage	Three-phase output current	Output frequency	Output power
Bypass voltage	Bypass current	Working modes	Load rate
Inverter status	Rectifier status	Battery status	...

UPS

Control

- Inverter startup
- Inverter shutdown
- Emergency shutdown
- ...



- Ambient temperature: refers to the operating temperature of lead-acid batteries or lithium batteries. Generally, a temperature and humidity sensor or temperature sensor is used for monitoring.
- SOC: refers to the state of charge or the remaining power of batteries. It is the ratio of the remaining capacity of a battery that has been used for a period of time or has not been used for a long time to the capacity of the battery in the fully charged state. It is usually expressed in percentage.
- SOH: refers to the state of health of batteries. It is the ratio of the actual performance parameter to the nominal parameter after the battery is used for a period of time.

UPS Input and Output PDFs

- The UPS system is configured with input and output PDFs to form a complete UPS system.
- In addition to the basic power distribution function, the UPS output PDF is generally configured with a centralized bypass switch, maintenance bypass switch, and some low-voltage protection devices. By monitoring the UPS input and output PDFs, a user can learn about the UPS input and output data in real time and understand the power supply requirements of loads in a data center.

UPS input PDF

Running parameters

Phase voltage	Line voltage	Line current
Frequency	Power	Electric energy
Switch status	Power distribution branch temperature	...

UPS output PDF

- The UPS input PDF is a low-voltage PDF that distributes power to the downstream UPS. UPS output cables are connected to the UPS output PDF.

Cabinet PDU

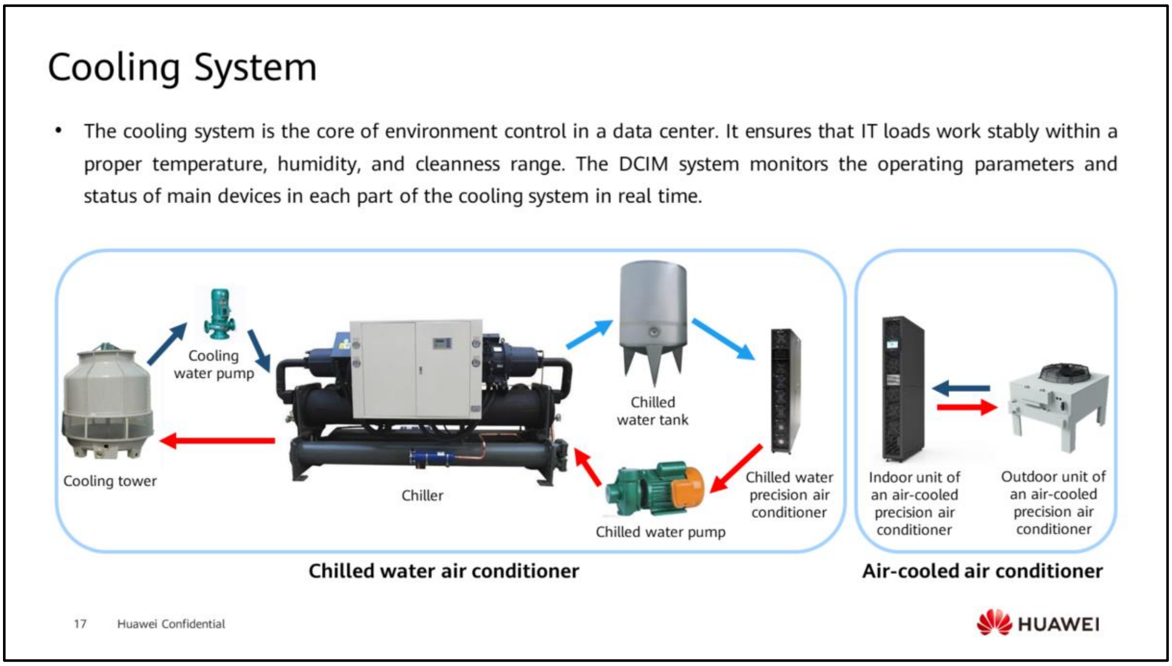
- Currently, the power distribution mode of most IT cabinets in a data center is cabinet PDU power supply. The deployment is simple and power supply is convenient. The cabinet PDU directly supplies power to IT loads. Its status should be monitored by the system in real time.

Cabinet PDU

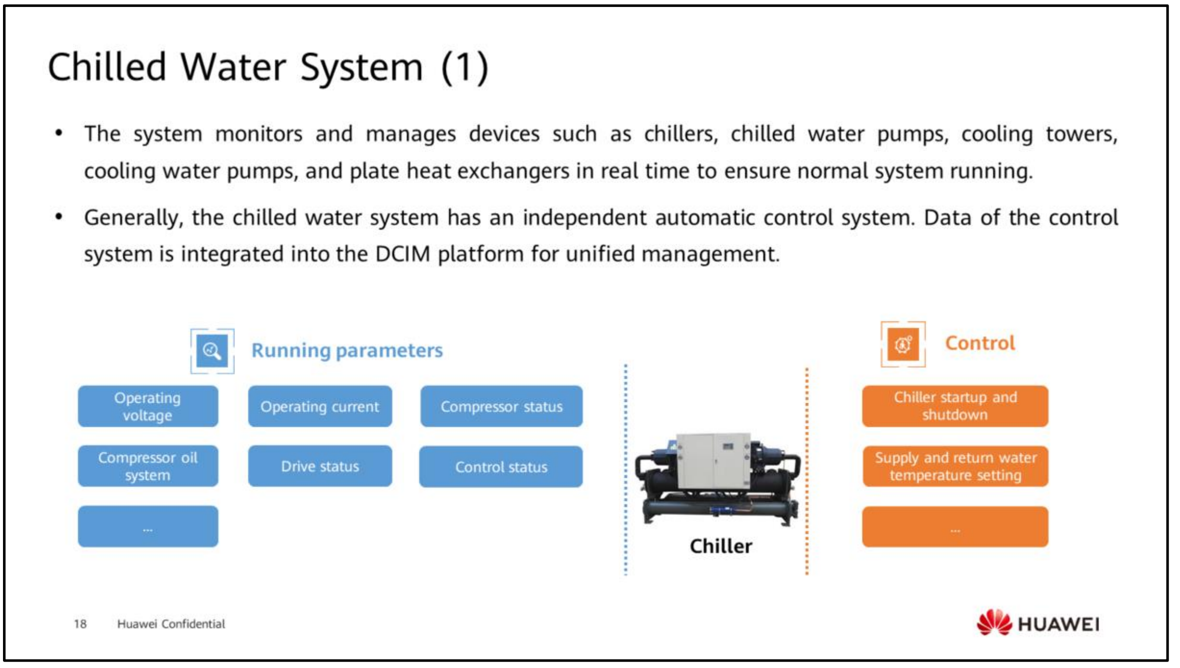
Running parameters

- Voltage
- Current
- Frequency
- Power
- Electric energy
- ...

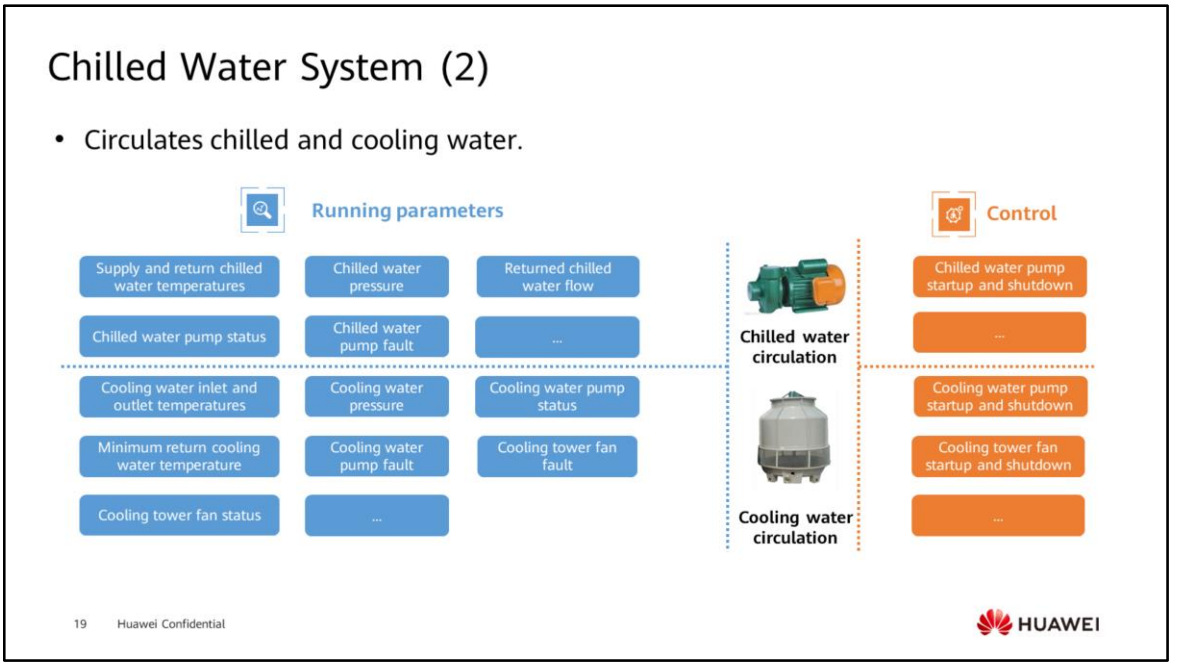
Contents



- This picture takes the primary pump system as an example to describe major equipment in the chilled water air conditioning system.



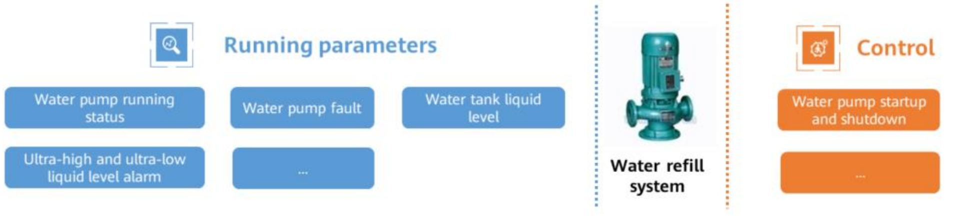
- Operating voltage and current: refer to the basic electrical parameters during the system running.
- Compressor status: refers to the operating parameters and running status of the compressor in the chiller system, such as the suction and discharge pressure, operating temperature, and runtime.
- Compressor oil system: refers to the lubrication and cooling system of the rotating parts of the chiller compressor.
- Drive status: refers to the equipment that supports the running of the inverter compressor.
- Control status: remote or local.



- Chilled water pump: refers to a device that ensures the system pressure during chilled water circulation.
- Supply and return chilled water temperatures: refer to the inlet and outlet water temperatures of the chiller in the chilled water circulation.
- Chilled water pressure: refers to the supply and return water pressure in the chilled water circulation.
- Cooling water pump: refers to a device that ensures system pressure in cooling water circulation.
- Cooling water pressure: refers to the inlet and outlet water pressure in the cooling water circulation.
- Cooling tower: refers to a device that absorbs system heat and discharges it into the atmosphere to lower the cooling water temperature.

Chilled Water System (3)

- The main functions of the fixed-pressure water refill system are as follows:
  - Reduces the water pressure fluctuation caused by the water temperature change, thereby stabilizing the pressure.
  - Refills the water to the pipe network system. When water leakage or drastic temperature drop occurs in the pipe network, the system refills water to the pipe network to prevent water shortage.



Precision Air Conditioner

- The precision air conditioner is a device that directly controls the temperature and humidity of a data center. Whether it works stably directly affects the IT load of the data center. Therefore, monitoring precision air conditioners is also essential.

Running parameters

Supply and return water temperatures	Current temperature and humidity	Fan status	Actuator status
Air filter status	Humidifier status	Electric heater status	Water leakage detection

Chilled water air conditioner

Control

- Air conditioner startup and shutdown
- Chilled water valve opening
- Setting temperature and humidity control points

Supply and return air temperature	Current temperature and humidity	Compressor status	Fan status
Water leakage detection	Air filter status	Humidifier status	Electric heater status
Outdoor unit status	...		

Air-cooled air conditioner

- Air conditioner startup and shutdown
- Outdoor unit startup and shutdown
- Setting temperature and humidity control points

Contents

Security Protection System

- The security protection system consists of the video surveillance system, access control system, and intrusion alarm system.

Video surveillance system

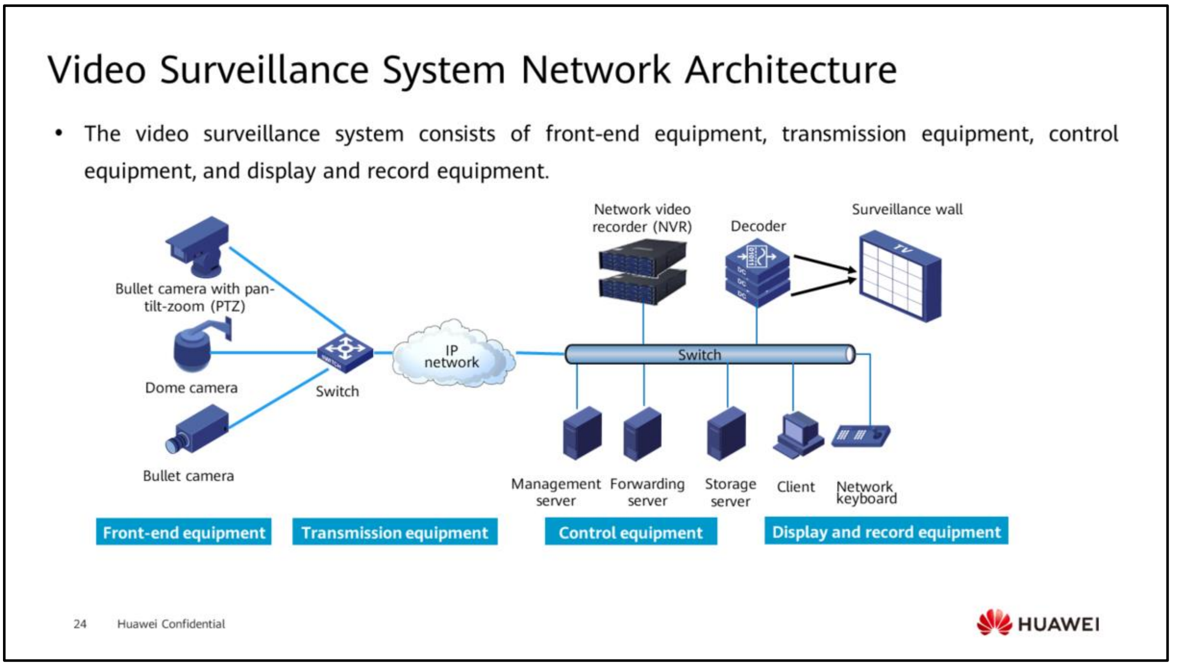
- The video surveillance system is an electronic system or a network that uses video technologies to detect, monitor, display, and record onsite images in real time.

Access control system

- The access control system uses modern electronic devices and software information technologies to control the access of people or objects at the entrances and exits of a data center. The control operations include allowing, rejection, recording, and alarming. The access control system is an effective measure to ensure area security and implement intelligent management.

Intrusion alarm system

- The intrusion alarm system is an electronic system or a network that uses sensor technologies and electronic information technologies to detect and indicate unauthorized access to a protected area, generate and process alarm information.



- The video surveillance system consists of front-end equipment, transmission equipment, control equipment, and display and record equipment.
  - Front-end equipment: includes one or more cameras and accompanying lenses, PTZs, shields, and decoding drivers.
  - Transmission equipment: includes electrical cables and/or optical cables, and possibly wired/wireless signal modulation and demodulation equipment.
  - Control equipment: includes video switchers, PTZ lens controller, keyboards, power supply, and accompanying consoles.
  - Display and recording equipment: includes monitors, video recorders, and multi viewers.

Video Surveillance System Monitoring Requirements

- The DCIM system must monitor the video surveillance system in real time to ensure data center security.
- Generally, the video surveillance system is an independent management system and is connected to the DCIM management platform in integration mode.

Video surveillance system

Running parameters

- Real-time browsing
- Multi-picture browsing
- Recording playback
- Remote video transmission
- Alarm triggering
- PTZ control
- Equipment linkage
- Access control
- ...

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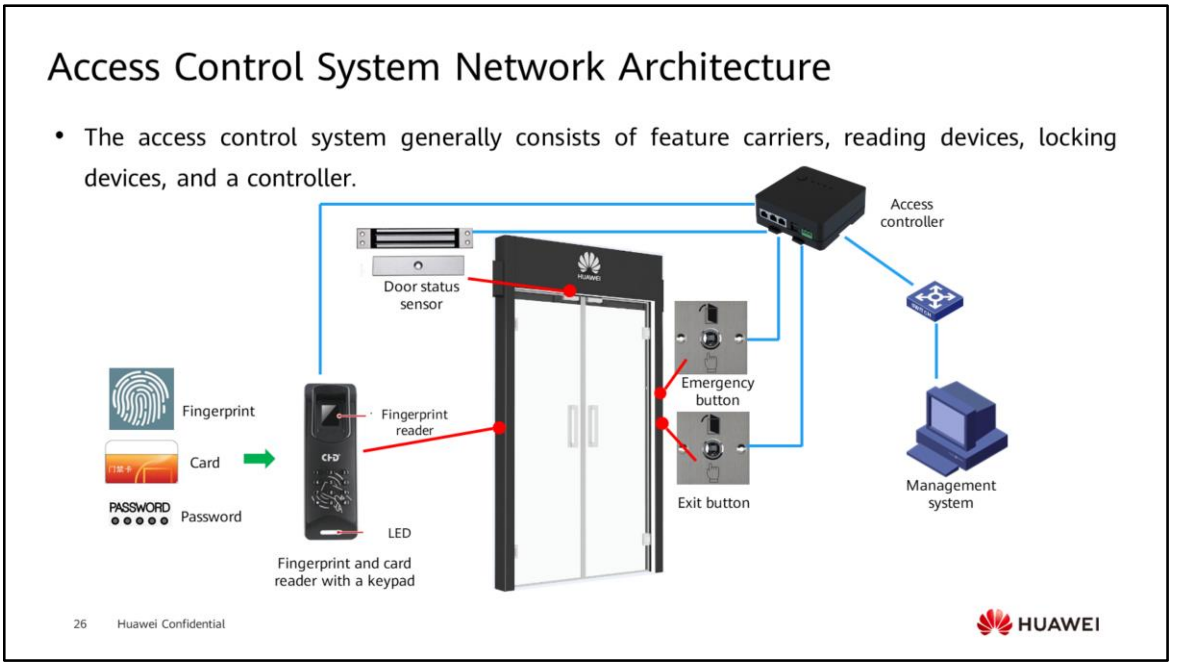
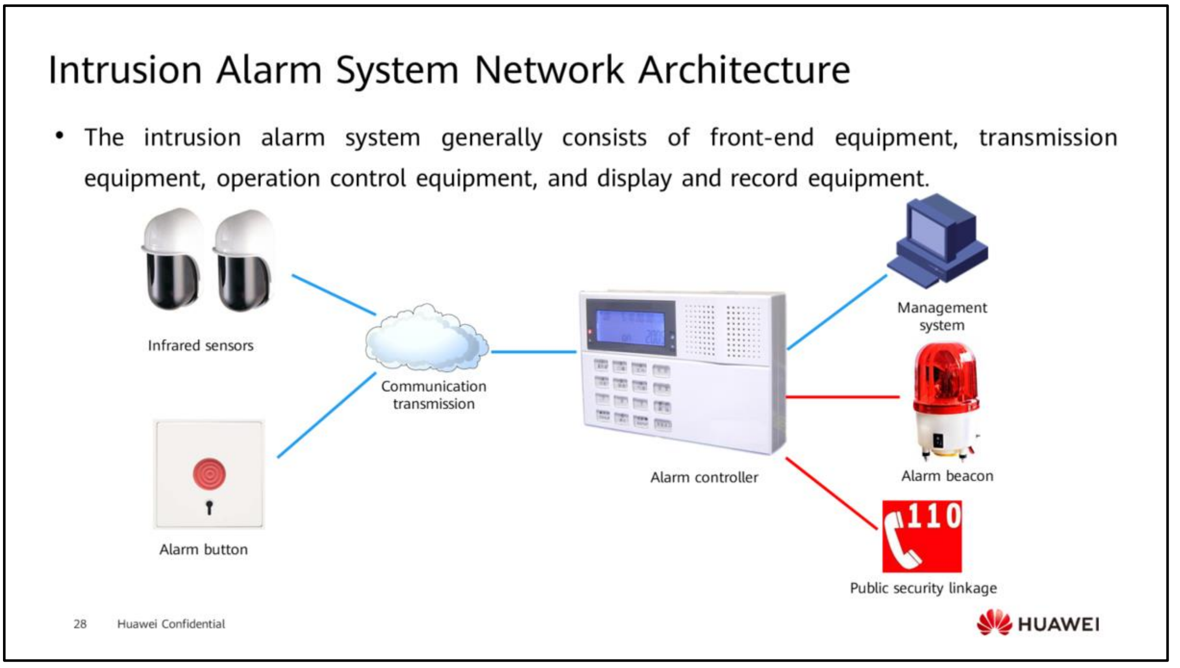


- The access control system generally consists of feature carriers, reading devices, locking devices, and a controller.
  - Feature carrier: indicates the identity and permission for entering or leaving a data center. For example, the key to a mechanical lock and an access card.
  - Reading device: A device that exchanges information with a feature carrier. It reads information about identities and permissions from the feature carrier appropriately. For example, the lock insert of a mechanical lock and a card reader.
  - Locking device: The access control system is practical only when it is equipped with a proper locking device. After confirming the identity and permission of the holder, a reading device allows the authorized person to enter and exit and rejects a request of the unauthorized person. For example, the magnetic lock at the access of a data center.
  - Controller: refers to the core control device of the access control system. It is used for communication connection and function implementation of system components.

Access Control System Monitoring Requirements

- The access control system ensures the physical security of a data center and implements effective management and recording of personnel entrance and exit. Common authentication modes are password, card, fingerprint, facial recognition, and hybrid authentication.



- The intrusion alarm system generally consists of front-end equipment, transmission equipment, operation control equipment, and display and record equipment.
  - Front-end equipment: The front-end detection part consists of various detectors. It is the tactile part of the intrusion alarm system. It senses the changes of physical parameters such as temperature, humidity, smell, and energy, and converts them into electrical signals that are suitable for transmission based on certain rules. For example, infrared sensors and alarm buttons.
  - Transmission equipment: includes electrical cables and/or optical cables, and possibly wired/wireless signal modulation and demodulation equipment.
  - Operation control equipment: generally refers to the alarm controller.
  - Display and record equipment: generally refers to a device that transmits alarm information after an alarm is generated. For example, alarm beacons and monitors.

Intrusion Alarm System Monitoring Requirements

- The intrusion alarm system is the tactile system of a data center or an equipment room. It can detect abnormal intrusions as early as possible and report alarms in real time.

Contents

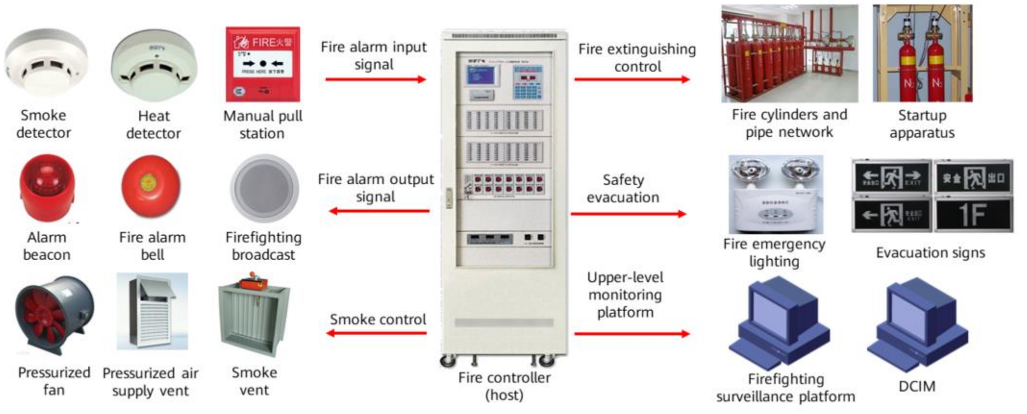
Firefighting System

- The Firefighting system of a data center is the core for monitoring and responding to fires, ensuring the safety of data center O&M personnel, and protecting equipment and property.
- The system is also called the fire linkage control system. Generally, a complete firefighting system includes the fire alarm system, fire extinguishing system, smoke control system, and safety evacuation system.
  - The automatic fire alarm system can implement linkage control of the fire extinguishing system, smoke control system, and safety evacuation system.
  - Fire extinguishing systems are classified into gas fire extinguishing system and liquid (water) fire extinguishing system.
  - The smoke control system exhausts a large amount of smoke produced by fire and prevents the smoke diffusing out of the protected zone. In this way, it ensures the smooth evacuation and safety of people in the building and create favorable conditions for firefighters to put out the fire.
  - The safety evacuation system consists of fire emergency lighting and evacuation guidance lighting. When a fire occurs and the normal power supply is cut off, the safety evacuation system maintains a certain degree of lighting in important rooms or main passages of buildings. In this way, it ensures personnel can evacuate quickly so that firefighters can handle the accident timely.

- The automatic fire alarm system can implement linkage control of the fire extinguishing system, smoke control system, and safety evacuation system.
- Fire extinguishing systems are classified into gas fire extinguishing system and liquid (water) fire extinguishing system.
- The smoke control system exhausts a large amount of smoke produced by fire and prevents the smoke diffusing out of the protected zone. In this way, it ensures the smooth evacuation and safety of people in the building and create favorable conditions for firefighters to put out the fire.
- The safety evacuation system consists of fire emergency lighting and evacuation guidance lighting. When a fire occurs and the normal power supply is cut off, the safety evacuation system maintains a certain degree of lighting in important rooms or main passages of buildings. In this way, it ensures personnel can evacuate quickly so that firefighters can handle the accident timely.

Firefighting System Network Architecture

- Common networking architecture of the firefighting system:



Firefighting System Monitoring Requirements

- Generally, the DCIM monitors the firefighting system to obtain the running status and alarm information of the main system. The DCIM does not directly control the firefighting system and therefore does not affect the normal running of the system.

Contents

Other Monitoring Requirements

- With the popularization of the modular concept, more data centers choose the modular deployment mode. In addition to the basic power supply and distribution, cooling, security, and firefighting systems, the data center deployed in modular mode also provides the following functions to implement intelligent management:
  - IT asset information: The data center uses network data such as electronic labels to implement real-time online management of IT assets and simplify stocktaking.
  - Capacity information: The data center uses the U space detection device to comprehensively manage the U space of cabinets in the data center and implement capacity management based on asset information.
  - Linkage control: In addition to the default linkage control logic in the data center, a user can customize linkage rules and manage them in a unified manner based on the actual project situation or special requirements.

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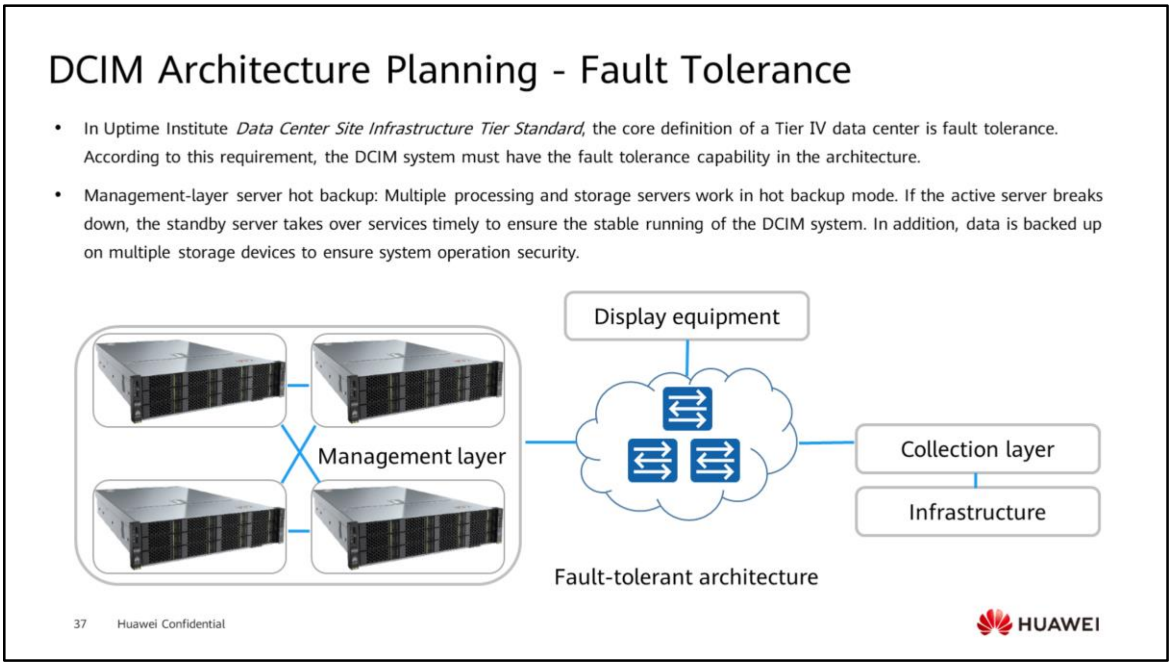
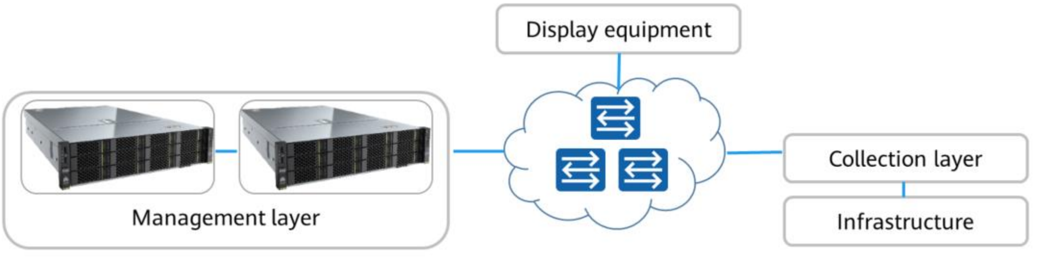


- The Uptime Date Center Site Infrastructure Tier Standard requires that a Tier IV data center have multiple independent redundant devices and lines that are physically separated.
- The fault tolerance and redundancy of the DCIM system are mainly reflected by the configuration of servers at the management layer.

DCIM Architecture Planning - Redundancy

- In *Uptime Institute Data Center Site Infrastructure Tier Standard*, the core definition of a Tier Ⅱ data center is redundancy. According to the requirement, the DCIM system must have the redundancy capability in the architecture.
- Management-layer server redundancy: Processing and storage servers work in two-node cluster hot backup mode, and core data is backed up in redundancy mode, ensuring system architecture stability and data redundancy.



Redundant architecture

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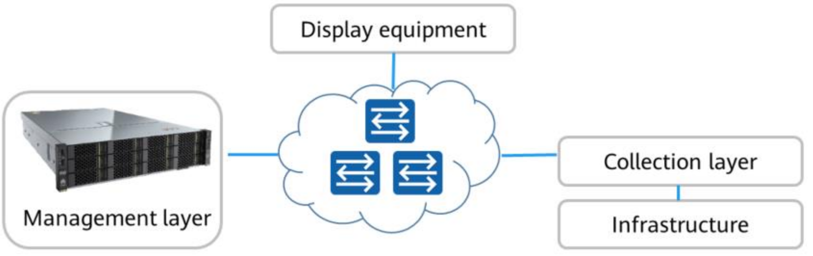
DCIM Architecture Planning - Basic

- In Uptime Institute *Data Center Site Infrastructure Tier Standard*, the core definition of a Tier Ⅰ data center is to meet basic requirements. Therefore, the system only needs to meet the basic management requirements.



Basic architecture

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DCIM Function Selection - Basic Functions

- The DCIM system functions are the basis of data center O&M. Specific system functions can be selected based on the data center level and type.
- The DCIM is recommended to provide the following basic functions regardless of the level and type of the data center.

Function	Remarks	Function	Remarks
Data collection	The system collects data of various monitored objects and adapts to various mainstream communication protocols and communication interfaces.	Configuration	The system provides multiple built-in device configuration (device template), page configuration (page template), and policy configuration to facilitate system deployment.
Data transmission	As for data transmission mode, the system supports query and automatic reporting. It also supports standard southbound and northbound interfaces.	Alarm	The system supports real-time alarm reporting, alarm analysis, and alarm notification for devices in the system.
Data processing	The system is able to process, analyze, and process various device data uploaded by the data collection layer.	Log	The system allows users to view and export its operation and operational logs.
Data storage	The system supports long-term data storage, export, and compression.	Rights management	The system supports setting multi-level rights, roles, and groups for user management.
Report	The system is able to export multiple reports in various modes.	System maintenance	The system supports system software functions, such as license check and software version.

DCIM Function Selection - Specific Functions

- In addition to basic functions, different levels, types, and service requirements of data centers affect function selection. Take the data center level as an example. Generally, the higher the level is, the higher the requirements for the DCIM system function configuration are.
- The following table provides suggestions on selecting DCIM functions for data centers of different levels.

Function	Tier Ⅳ Data Center	Tier Ⅲ&Ⅱ Data Center	Tier Ⅰ Data Center
Data collection	Mandatory	Mandatory	Mandatory
Data transmission	Mandatory	Mandatory	Mandatory
Data processing	Mandatory	Mandatory	Mandatory
Data storage	Mandatory	Mandatory	Mandatory
Report	Mandatory	Mandatory	Mandatory
Configuration	Mandatory	Mandatory	Mandatory
Alarm	Mandatory	Mandatory	Mandatory
Log	Mandatory	Mandatory	Mandatory
Rights management	Mandatory	Mandatory	Mandatory
System maintenance	Mandatory	Mandatory	Mandatory
Energy consumption analysis	Mandatory	Recommended	Recommended
Trend analysis	Recommended	Recommended	Optional
Asset management	Recommended	Optional	Optional
Capacity management	Recommended	Optional	Optional
O&M management	Recommended	Optional	Optional
Two (multi) -node cluster hot backup	Mandatory	Mandatory	Optional

- Mandatory: indicates that the function must be configured in this scenario.
- Recommended: indicates that the function is applicable to this scenario.
- Optional: indicates that the function can be chosen based on the actual situation.

DCIM Performance Planning

- Based on the performance required for system running, system performance is planned and determined from the following aspects: data collection interval, storage speed, refresh time, capacity, system control response time, and number of accessed clients.
- This slide takes different levels of data centers as an example to describe the detailed performance planning requirements. A user can plan the performance of data centers of different scales or types based on the requirements of different levels.

Performance	Class-A Data Center	Class-B Data Center	Class-C Data Center
Single bus collection interval (s)	< 2	< 2	< 2
Number of refreshed test points per second	≥ 1,0000	≥ 5000	≥ 1000
Number of concurrent events stored per minute	≥ 2000	≥ 1200	≥ 600
Maximum number of concurrent access requests	≥ 100	≥ 100	≥ 50

Contents

DCIM Hardware Device Selection Principles

- To achieve system unification and function integrity, DCIM system hardware is provided by software vendors or recommended partners in most cases. However, hardware must comply with certain principles no matter where the hardware comes from.

01

- Basics
  - The hardware must have high mechanical strength. The installation and fixing mode should have shockproof capabilities.
  - Hardware selection must not affect the running of the system or other subsystems and equipment.
  - Normal operating temperature: –10°C to +50°C; humidity: 0–95% (non-condensing); altitude: ≤ 3000 m.

02

- Reliability
  - The hardware must be highly reliable (with a service life of at least five years).
  - The hardware must have good electromagnetic compatibility (EMC) and the devices do not generate electromagnetic interference that affects the normal operation of the monitoring equipment.

03

- Flexibility
  - Hardware devices must be modularized to adapt to the development of modular data centers.
  - The system capacity can be expanded by adding a few components (such as processors and storage disks) to the system processing and storage devices.
  - The number of system communication interfaces can increase with service changes.

Selection Suggestion - Power Supply and Distribution Monitoring Devices

Device Type	Suggestion	Remarks
Power detection device	Collection devices with intelligent communication interfaces are recommended.	Do not select non-intelligent devices that use analog output.
	Devices with high data collection precision are recommended.	Electrical data is the basis of data center energy consumption analysis. The precision of this type of devices must meet certain requirements.
Switch monitoring device	Digital input collection and monitoring devices are recommended.	The switch has auxiliary contacts.
	Digital input collection devices with high-voltage isolation or digital output devices with high-voltage input are recommended.	The switch does not have auxiliary contacts.
	Monitoring devices with a mainstream communications port are recommended to connect to the upper-level management device.	/
	A single device should be able to monitor the connection and disconnection status of multiway switches at the same time to reduce the number of devices in the entire system.	/
Energy storage system (ESS) collection device	Devices with mainstream communications ports are recommended to collect lead-acid battery or lithium battery parameters.	Do not use non-intelligent DC voltage and current sensors with analog output.
	High-precision collection devices are recommended.	The voltage, current, internal resistance, and ambient temperature of batteries greatly affect the battery lifespan. If the collected data is inaccurate, the battery lifespan will be affected.

- The auxiliary switch (contact) is a part of the main switch. It is configured in the power equipment such as the high-voltage or medium-voltage circuit breaker and isolation switch, and functions as the switch-off, switch-on, signal control, and interlock protection of the secondary control loop. It can also be used as the combined switch and changeover switch. The name of an auxiliary switch contains the word "auxiliary" because it is not an independent switch. It is an auxiliary carrier for breaking, connecting, and interlocking functions in the control system.

Selection Suggestion - Cooling and Environment Monitoring Devices

Device Category	Suggestion	Remarks
Temperature and humidity detection device	Temperature and humidity sensors are recommended.	/
	Sensors with liquid crystal displays (LCDs) are recommended.	/
	Sensors with intelligent communications ports are recommended.	Do not use non-intelligent sensors with analog output.
	High-precision sensors are recommended. Generally, the temperature error is within ±0.5°C, and the humidity error is within ±3%.	/
Water leakage detection device	If the pipe of the water system is long, the device with a water detection cable is recommended.	/
	If the detection area is small, the regional water leakage detector (water sensor) is recommended.	/
	Water leakage detection devices with high precision and adjustable sensitivity are recommended to reduce water intrusion risks.	/
Precision air conditioner	Devices with mainstream intelligent communication interfaces are recommended.	/
	In the scenario with multiple devices (with redundancy configuration), devices with the teamwork control function are recommended.	The teamwork control function enables precision air conditioners to be networked and controlled, which is efficient and energy-saving.
	Devices that can work with advanced technologies to implement intelligent management and proactive energy saving are recommended.	Keep data center devices advanced.

Selection Suggestions - Security Monitoring Devices

Device Type	Suggestion	Remarks
Camera	For areas with ceilings inside the data center, semi-dome cameras are recommended.	/
	For areas outside the data center or areas without ceilings inside the data center, bullet cameras are recommended.	/
	For important areas or areas that require all-round surveillance, dome cameras are recommended.	/
Video server (VCN/NVR)	Video servers that comply with the international video compression standard and has multiple mainstream output interfaces are recommended.	/
	Video servers that support functions such as real-time video viewing, historical video playback, and multi-view are recommended.	/
	Video servers whose storage duration is longer than 30 days are recommended.	/
Access management device	Select an appropriate access controller based on the number of doors to be managed.	/
	Access controllers with mainstream communications ports are recommended.	/
	Access controllers and access control devices that support multiple access authentication modes are recommended.	/
Intrusion alarm device	Detectors that support all-round detection and whose detection radius is greater than or equal to three meters are recommended.	/
	Intrusion alarm controllers that provide mainstream communication interfaces and support intrusion events, alarms, and area-based control are recommended.	/
	Intrusion alarm controllers with the anti-sabotage function are recommended.	/

Selection Suggestion - Collector and Server

Device Category	Suggestion	Remarks
Collector	An intelligent collector is recommended.	/
	The collector should have or be able to provide sufficient AI/DI/DO communications ports.	Used to connect to non-intelligent devices for monitoring.
	The collector should have or can be expanded to provide sufficient intelligent communication interfaces.	Used to connect to intelligent devices for monitoring.
	The collector must have storage capacity.	When the collector is disconnected from the server, data can be stored locally. When the system is restored, the data can be used by the DCIM for supplementary collection or invoking.
	The physical parameters of the collector must be properly set to minimize the occupation of U space in the cabinet.	/
Server	Devices from mainstream vendors or mature application vendors are recommended.	/
	Servers that support capacity expansion (processing and storage) are recommended.	/
	Devices with high processing capabilities and low management complexity are recommended.	/

Quiz

1. (Multiple) Which of the following are included in the security protection system of a data center?
   A. Firefighting system
   B. Video surveillance system
   C. Access management system
   D. Intrusion alarm system
2. (Single) Which of the following suggestions on collector selection for the DCIM system is incorrect?
   A. The intelligent collector is recommended.
   B. The collector should have or be able to provide sufficient AI/DI/DO communications ports.
   C. The collector should have or can be expanded to provide sufficient intelligent communication interfaces.
   D. The size of the collector should be the same as that of the standard server.

- Answer: 1. BCD. 2. D.

Summary

- Main management objects of the DCIM system
- Main monitoring parameters and control contents of the DCIM system management objects
- DCIM architecture and function requirements for data centers at different levels
- Principles and precautions for DCIM hardware selection

Thank you.

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