LESSON 5:
CROSS BAR SYSTEMS

Objective:

The objective here is to learn types switching systems like crossbar system.

Introduction:

Strowger switching system has been used for telephone switching for almost 70 years since its introduction in 1889. The major disadvantages of the Strowger switching system is its dependence on moving parts and contacts that are subject to wear and tear. A two-motion selector moves, on an average, 4 cm vertically. It makes a complete rotation horizontally in establishing and terminating a connection. These mechanical systems need regular maintenance and adjustment. As we know that telephone networks spread to remote areas therefore it becomes necessary to devise switching systems that would require less maintenance and little readjustment after installation.

The solution of above type of maintenance and adjustment in switching system is obtained by using another type of switching system. This switching system is known as crossbar switching system. The crossbar switching systems was introduced in the field in 1938 by AT & T laboratories in the USA. The first design was christened No.1 crossbar system. Since then the crossbar systems have been progressively replacing Strowger systems. Apart from the desirable and efficient switch characteristics, crossbar switching system differ from Strowger switching systems in one fundamental respect: they are designed using the common control concept.

Crossobar Switching System

Principle of Common Control

Common control systems were first introduced in crossbar telephone exchanges. The genesis of Common Control Concept can be traced to the Director System used with Strowger switching system or exchanges. A Director System facilitates uniform numbering of subscribers in a multi exchange area (like a big city) and routing of calls from one exchange to another via some intermediate exchanges. Uniform numbering means that to call a particular subscriber, the same number is dialled, no matter from which exchange the call originates a fact to which we are so accustomed, these days. We cannot implement common control scheme in a direct control switching system without the help of a Director.

Now we have following type of multiexchange network. It is shown in Fig.5.1

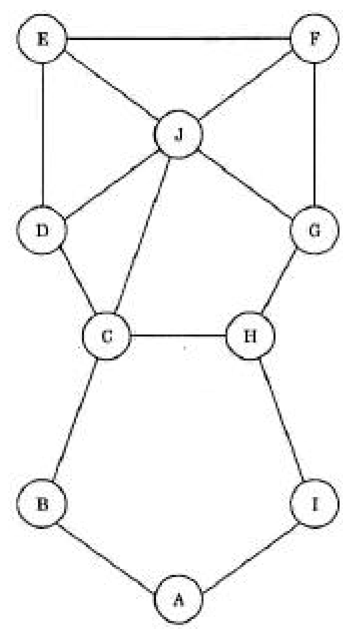

Fig.5.1 Illustration of a multi-exchange network

It is not a fully connected network because of considerations of economy. If a subscriber in a telephone exchange A wants to call a subscriber in telephone exchange F, the call has to be routed via at least three telephone exchanges. Two routes are possible. These routes are: A-B-C-J-F and A-I-H-G-F. In Strowger switching system, a call can be sent out of an exchange by reserving a level in the first group selector for out side calls. The 10 outlets at the reserved level can be connected to 10 different telephone exchanges. Let us assume that the reserved level is zero. Therefore, the outlets are assigned as in the following for the sake of discussions shown in Table 5.1 :

From Telephone Exchange	Outlet	To Telephone Exchange
A	01	B
A	02	I
B	03	C
C	04	J
I	05	H
H	01	G
G	02	F
J	01	F

Let 1457 be the subscriber to be called in telephone exchange F. From exchange A, the called subscriber can be reached by dialling either of the following number sequence:

For route A-B-C-J-F 01-04-03-01-1457

For route A-I-H-G-F 02-05-01-02-1457

Following difficulties are now obviously faced.

- Identification number of a subscriber is route dependent.
- A user must have knowledge of the topology of the network and outlet assignments in each telephone exchange.
- Depending on from which telephone exchange the call originates, the number and its size vary for the same called subscriber.

Above difficulties can be overcome if the routing is done by the telephone exchange and a uniform numbering scheme is presented as far as the user concerned.

A number may now consist of two parts. These parts are:

1. An exchange identifier and
2. A subscriber line identifier within the exchange.

An exchange must have the capability of receiving and storing the digits dialled, translating the exchange identifier into routing digits, and transmitting the routing and the subscriber line identifier digits to the switching network. This function is performed by the director subsystem in Strowger telephone exchange.

Some important observations regarding the director system:

- As soon as the translated digits are transmitted, the Director is free to process another call. The director is not involved in maintaining the circuit for the conversation.
- Call processing takes place independent of the switching network.
- A user is assigned a logical number. This logical number is independent of the physical line number used to establish a connection to him. The logical address is translated to actual physical address for connection establishment by an address translation mechanism.

All the above are fundamental features of a common control system. Fig.5.2 shows a functional block diagram of a Common Control Switching System. Following control functions are performed in a switching system.

4. Event Monitoring
5. Call Processing
6. Charging
7. Operation and Maintenance.

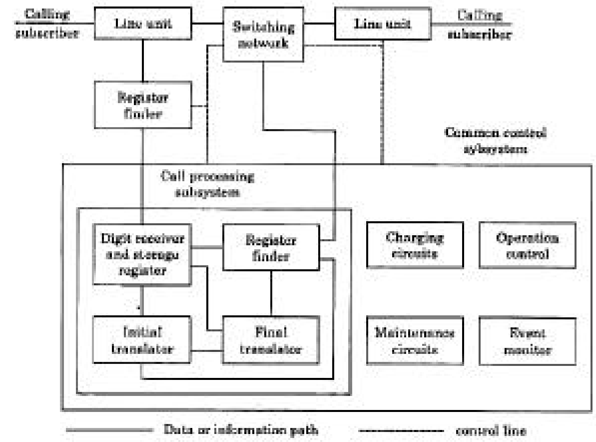

Fig.5.2 Block Diagram of the common control switching system

Events occurring outside the telephone exchange at the line units, trunk junctors and inter exchange signalling receiver/ sender units are all monitored by the control subsystem.

Typical events include all requests and call release signals at the line units. The occurrences of the events are signalled by operating relays, which initiate control action. Relays in the junctors, receivers senders and the line units may be operated by control subsystem. Thus it commands these units to perform certain functions. Event monitoring may be distributed. For example, the line units themselves may initiate control actions on the occurrence of certain line events.

When a subscriber goes off-hook, the event is sensed, the calling location is determined and marked for dial tone. Therefore, the register finder is activated to seize a free register. Identity of the calling line is used to determine the line category and class of service to which the subscriber belongs. We already know that a subscriber telephone may use either pulse dialling or multifrequency dialling. Therefore, the line is categorized on the basis of type of dialling used. A register appropriate to the line category is chosen, which then sends out the dial tone to the subscriber, in readiness to receive the dialling information.

Usually initial digits are 2 to 5. As soon as the initial digits which identify the exchange are received in the register, they are passed on to the initial translator for processing. Simultaneously, the register continues to receive the remaining digits.

The initial translator finds the route for the call through the network. Therefore it decides whether a call should be put through or not. It also determines the charging method and the rates applicable to the subscriber. Such decisions depend on the class of service information of the subscriber which specifies details such as the following:

1. Call Barring: A subscriber can be barred from making certain calls, e.g. STD or ISD Barring.
2. Call Priority: When the telephone exchange or network is overloaded, only calls from subscribers identified as priority call subscribers, may be put through.

3. Call Charging: It is possible to define different charging rules for different subscribers in the same telephone exchange.
4. Origin-Based Routing: Routing is also called destination. Routing of certain calls may depend on the geographical location of the calling subscriber. For example, calls to emergency services are routed to the nearest emergency call centre.
5. No Dialling Calls: These calls are routed to predetermined numbers without the calling party having to dial, e.g., hot line connections.

Initial translation may also take into account instructions from the operating personnel and information regarding the status of the network. For example, if a trunk group is affected by a fault, a proportion of the calls may be rerouted via other trunk groups. The initial translator is sometimes referred to as Office code translator or Decoder marker. The term “marker” was first used by Betulander. Betulander was the Swedish pioneer of Crossbar technology. The term came into use because the terminals to be interconnected were ‘marked’ by applying electrical signals.

If a call is routed or destined to a number in an exchange other than present on processing the digits, the initial translator generates the required routing digits and passes them on to the register sender.

Here, the digits corresponding to subscriber identification are concatenated and the combined digit pattern in transmitted over the trunks to the external telephone exchange. Register sender uses appropriate signalling technique. This signalling technique depends on the requirements of the destination telephone exchange. If the call is routed to a subscriber within the same telephone exchange, the digits are processed by the final translator. The translation of directory number to equipment number takes place at this stage. The final translator finds the line unit to which a call must be connected and the category of the called line. The category information influences charging and connection establishment. For example, there will be no charge for emergency lines or fault repair service lines.

Some commercial services may offer charge-free or toll-free connection to their numbers. In some practical implementations, both initial and final code translator functions are performed by a single translator.

Controlling the operation of the switching network is an important function of the common control subsystem. Controlling of the switching network is done by making the switching elements at different stages in accordance with a set of binary data. This binary data defines the path and then commands the actual connection of the path.

Path finding can be carried out at the level of the common control unit or the switching network. In the case of common control unit, the technique is known as map-in-memory. But in the case of switching network, the technique is called Map-in-Network.

In the map-in-memory technique, the control unit supplies the complete data which defines the path.

But, in the map-in-network technique, the control unit merely marks the inlet and outlet to be connected. In this case, the actual path is determined by the switching network.

The map-in-memory technique is usually present in Stored Program Control (SPC) subsystems.

But, the map-in network technique is more commonly used in crossbar telephone exchanges using markers for control.

Administration of a telephone exchange involves activities such as putting new subscriber lines and trunks into service, modifying subscriber service entitlements and charging routing plans based on the network status.

Above mentioned administrative functions are facilitated by control subsystems. Maintenance activities include supervision of the proper functioning of the telephone exchange equipment, subscriber lines and trunks. Maintenance personnel can access any line or trunk for performing tests and making measurements of different line parameters. The control subsystem should also aid fault tracing without the maintenance personnel having to perform elaborate tests.

Principle of Crossbar Switching

The basic idea of crossbar switching is to provide a matrix of n x m sets of contacts with only n + m activators or less to select one of the n x m sets of contacts.

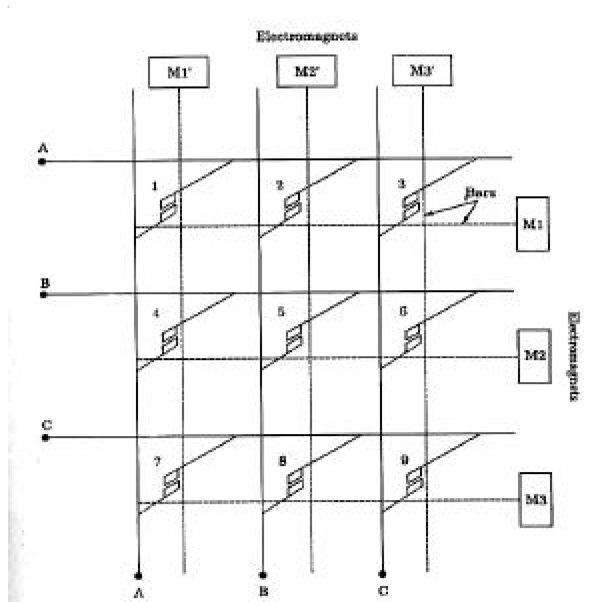

Fig.5.3 3 x 3 matrix crossbar switching.

This form of switching is referred to as coordinate switching because switching contacts in this switching are arranged in X- Y plane Fig. 5.3 show a diagrammatic representation of a crosspoint switching matrix. There is an array of horizontal and vertical wires. These wires are shown by solid lines in the figure. A set of vertical and horizontal contact points are connected to these wires. The contact points form pairs. Each pair consists of a bank of three or four horizontal and a corresponding bank or vertical contact points. A contact point pair acts as a crosspoint switch and remains seperated or open when not in use. The contact points are mechanically mounted (and electrically insulated) on a set of horizontal and vertical bars shown as dotted lines. These bars are attached to a set of electromagnets.

When an electromagnet (say in the horizontal direction) is energised, the bar attached to it slightly rotates in such a way that the contact points attached to the bar move closer to facing contact points, though they do not actually make any contact. Now, if an electromagnet in the vertical direction is energized, the corresponding bar rotates causing the contact points at the intersection of the two bars to close. This happens because the contact points move towards each other. For example, if electromagnets M1 and M_1' are energized, a contact is established at the crosspoint 1 such that the subscriber A is connected to the subscriber A. If electromagnets M_2 and M_3' are energised, a contact is established at the crosspoint 6 such that the subscriber B is connected to the subscriber C. In order to fully understand the working of the crossbar switching, we consider a 6 x 6 crossbar schematic diagram shown in Fig 5.4. The schematic diagram shows 6 subscribers with the horizontal bars representing the inlets and vertical bars the outlets.

Now consider the establishment of the following connections in sequence:

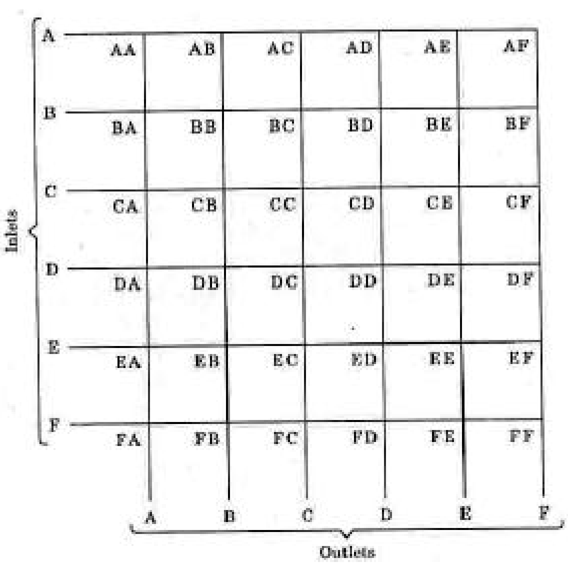

Fig.5.4 Illustration of 6 x 6 crossbar matrix.

Connection A to C and Connection B to C

First of all the horizontal bar A is energised. Then the vertical bar C is energised. The crosspoint AC is latched and the conversation between A and C can now proceed. Suppose we now energise the horizontal bar of B to establish the connection B-E, the crosspoint BC may latch and B will be brought into the circuit of A-C. This is prevented by introducing an energising sequence for latching the crosspoints. A crosspoint latches only if the horizontal bar is energized first and then the vertical bar. The sequence may well be that the vertical bar is energised first and then the horizontal bar. Hence the cross point BC will not latch even though the vertical bar C is energised as the proper sequence is not maintained. In order to establish the connection B-E, the vertical bar E needs to be energised after the horizontal bar energised.

In this case, the cross point AE may latch because the horizontal bar A has already been energised for establishing the connection A-C. Latching of crosspoint AE can also be avoided and is done by de-energising the horizontal bar A after the crosspoint is latched and making a suitable arrangement such that the latch is maintained even though the energisation in the horizontal direction is with-drawn. The crosspoint remains latched as long as the vertical bar E remains energised. As the horizontal bar A is de-energised immediately after the crosspoint AC is latched, the crosspoint AE does not latch when the vertical bar E is energised.

Crossbar Switch Configurations

In a nonblocking crossbar configuration, there are N^2_S switching, elements for N_S subscribers. We require actually only N_S / 2 switches for establishing connections when all the subscribers are engaged. The values of different design parameters for 4 nonblocking switches are given in Table 5.2. Here we have assumed the unit cost for each crosspoint switching element. N^2_S crosspoints (even for moderate number of users) leads to impractical complex circuitry. A 1000- subscriber line telephone exchange would require 1 million crosspoint switches. Therefore, we found various ways and means to reduce the number of switch contacts for a given number of subscribers.

Table 5.2 Various Design Parameters for Nonblocking Crosspoint Switch Systems

No. of Subscribers (N_S)	No. of switching elements (N_E)	Switching Capacity (SC)	Equipment Utilization Factor (f_{EU})	Total Cost (C)	Cost Capacity Index (I_{CC})
4	16	2	12.50	16	0.5
16	256	8	3.13	256	0.5
64	4096	32	0.78	4096	0.5
128	16384	64	0.39	16384	0.5

We observed in the switch matrix of Fig.5.4 that different switch points are used to establish a connection between two given subscribers, depending upon who initiates the call. For example, when the subscriber C wishes to call subscriber B, crosspoint CB is energised. If the subscriber B wishes to call subscriber C, then crosspoint BC is energised. In other words, we can say that when subscriber B initiates the call to contact subscriber C, the switch BC is used.

By designing a suitable control mechanism, only one switch may be used to establish a connection between two subscribers, irrespective of which one of them initiates the call. By doing so, the crosspoint matrix reduces to a diagonal matrix with N_S / 2 switches. We have shown a diagonal connection matrix for 4 subscribers in Fig.5.5

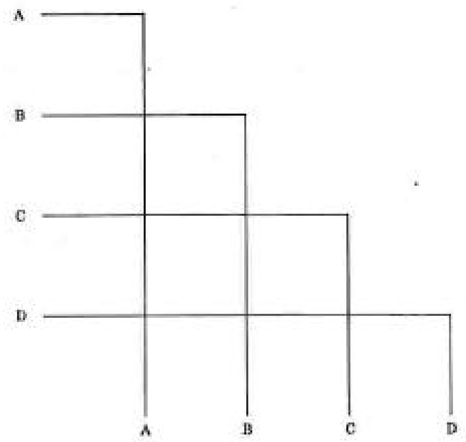

Fig. 5.5 Illustration of diagonal crosspoint matrix for 4 subscribers A, B, C and D.

The crosspoints in the diagonal connect the inlets and the outlets of the same subscriber. This is not relevant. Hence, these are eliminated. In this case, the number of cross points reduces to $[N_S (N_S -1)] / 2$. This quantity represents the number of links in a fully connected network. So also, the diagonal crosspoint matrix is fully connected. The call establishment procedure here is dependent on the source and destination subscribers. When subscriber D initiates a call, his horizontal bar is energised first and then the appropriate vertical bar. If subscriber A initiates a call, the horizontal bar of the called party is activated first and then the vertical bar of A.

A diagonal crosspoint matrix is a non-blocking configuration. Even it is difficult to handle a very large number of crosspoint switches such as $[N_S (N_S -1)] / 2$. The number of crosspoint switches can be reduced significantly by designing blocking configurations. These configurations may be single stage or multistage switching networks. The crossbar hardware may be reduced by connecting two subscribers to a single bar and letting the bar turn both in the clockwise and the anticlockwise directions. Therefore, it closes two different crosspoint contacts. With such an arrangement the number of crossbars reduces, but the number of crosspoint switches remains the same.

In blocking crossbar switches, the number of vertical bars is less than the number of subscribers and determines the number of simultaneous calls that can be put through the switch.

Now we consider the 8 x 3 crosspoint switch shown in Fig.5.6

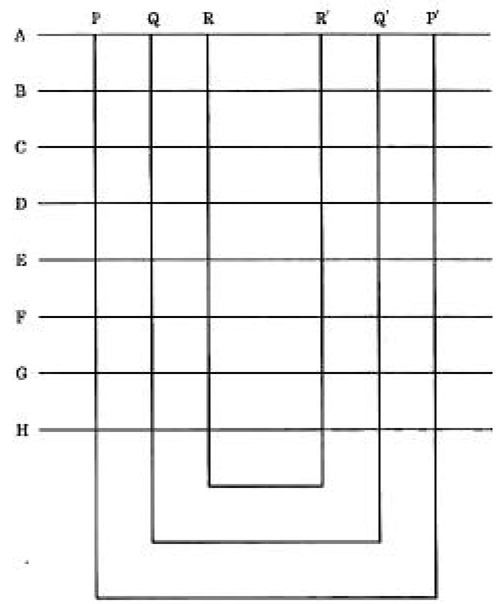

Fig.5.6 Illustration of blocking crossbar switch.

[8 x 3 crossbar switch]

Here, number of subscribers are 8 and number of free vertical bars are 3.Let a connection be required to be established between the subscribers A and B. First of all the horizontal bar A is energised. Then one of the free vertical bars [say P] is energised. The crosspoint AP latches. Now if we energise the horizontal bar B, the cross point BP will not be latched, as the P vertical is energised before B was energised. For connecting A to B, we need another vertical crossbar which should electrically correspond to the vertical bar P. In this case, the bar P' is associated with the same electrical wire as bar P when P' is energised after B, the crosspoint BP' is latched and a connection between A and B is established.

Thus we see that in blocking crosspoint switches we need to operate 4 crossbars to establish a connection. Here the number of switches required is $2N_S K$, where N_S is the number of subscribers and K is the number of simultaneous circuits that can be supplied.

Crosspoint Technology

The hardware of crossbar system consists of crosspoint switches. The cost of the crossbar system increases in direct proportion to the number of crosspoints in the system. Hence, the reduction of size and cost of crosspoint has been the major thrust of crosspoint technology development.

At present two technologies for crosspoint design are prevalent. These are:

1. Electromechanical Crosspoint Technology
2. Electronic Crosspoint Technology.

Classification of crosspoint technology is illustrated in Fig.5.7

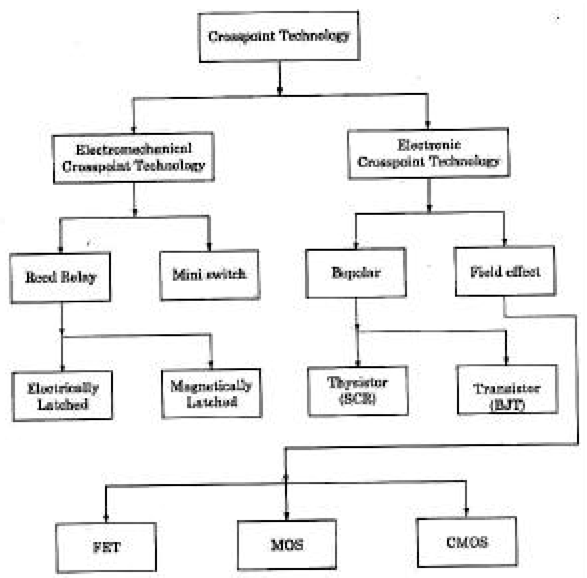

Fig. 5.7 Classification of crosspoint technology.

Electromechanical crosspoints are extensively used even today. They are capable of switching in 1-10 ms time duration and several million times without wear and adjustment. Here switching means that making / breaking contacts. Two principal types of electromechanical crosspoints used are:

- Miniswitches and
- Reed relays.

Miniswitches are made of a precious metal like palladium which permits the design of electrically quieter contacts. The corrosion resistance properties of metals like palladium and a bifurcated contact design have resulted in reliable switching in crossbar systems. Miniswitches are mechanically latched. These generally use 'V' notches for this purpose. Miniswitches are mounted on crossbars. They move horizontally and vertically to establish and release contacts. The switching time of miniswitches is about 8-10 ms.

Reed relay switches were developed to eliminate the mechanical motion of crossbars in a crossbar system. By eliminating mechanical motion, we can increase the operating life of the system. The Reed relay comprises of a pair of contacts made of a magnetic material sealed in a glass tube as shown in Fig.5.8

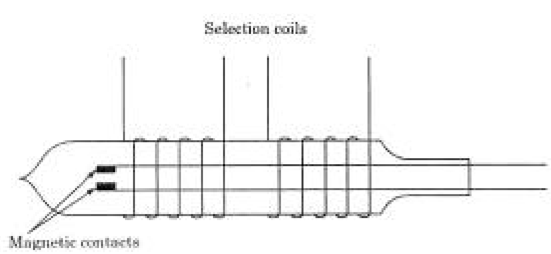

Fig.5.8 Reed Relay electromechanical crosspoint.

The sealing protects the electrical contacts from external contamination. The displacement involved in making contacts is about 0.2 mm. Therefore, this results in fast switching times less than 1 ms. A reed relay may be latched electrically or magnetically. The glass tube is surrounded by a pair of coils. When current is passed through both the coils simultaneously, a field is generated, which causes the reed contacts to move together.

When electrically latched, current is passed continuously through the coil as long as the switched connection is required.

Magnetic latching relies on the hysteresis of the magnetic material. The pole pieces required for this purpose may be placed outside the glass tube, or the contacts themselves may be designed to act as poles by choosing an appropriate ferromagnetic material. In the case of magnetic latching, the reed relay is called remreed. It signifies remnance property of the contact strips. The residual magnetism in the poles keeps the contacts closed even after the currents are withdrawn from the coils. When a demagnetising current is applied to one or the other of the coils, the contacts open.

One reed relay at each crosspoint is placed to construct a crosspoint matrix. Crosspoint selection is achieved by connecting one of the coil winding of each relay in series with its vertical neighbour, and the other winding in series with its horizontal neighbour. The required crosspoint is then selected by pulsing the appropriate vertical and horizontal circuits simultaneously. In practice, each reed relay comprises of a bank of 3 or 4 contacts, as is the case with miniswitches.

Cold cathode diode is the first electronic device that was tried out as crosspoint. This was soon abandoned because of the practical difficulties in implementation and inadequate transmission characteristics. In 1960s, transistorised crosspoints were developed after advances in semiconductor technology. These crosspoints offered better performance than, reed relays at that time but were not economically competitive. With the advent of integrated circuits (ICs), many private automatic branch exchanges (PABX) were designed using IC crosspoints.

But with the arrival of time division switching technology, electronic crosspoints may never find extensive applications, particularly in large public exchanges.

Organisation of Crossbar Exchange

The basic building blocks or elements of a crossbar exchange are link frames, control markers and registers. Link frames consist of a number of crossbar switches arranged in two stages. These stages are known as primary and secondary with links between them as shown in Fig.5.9.

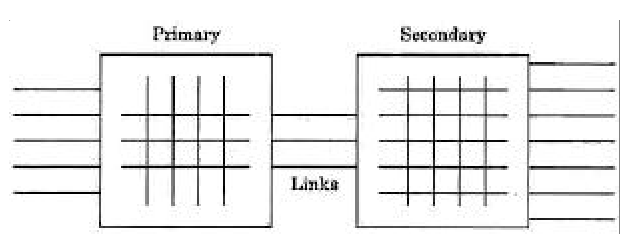

Fig. 5.9 A link frame and its control by a marker.

The two-stage arrangement with links has the effect of increasing the number of outlets for given number of inlets. Therefore, it provides greater selectivity. The switch (in this case) is said to be expanding. .

Markers control the connection between the inlets and the outlets via the primary section, links and secondary section.

Fig.5.10 shows a simplified organization of a crossbar exchange. The line link frames along with the associated markers and registers are known as line unit. The trunk line frame with its associated hardware is called group unit. The trunk link frame may be subdivided into two or three link frames like local office link frame, incoming link frame, etc.

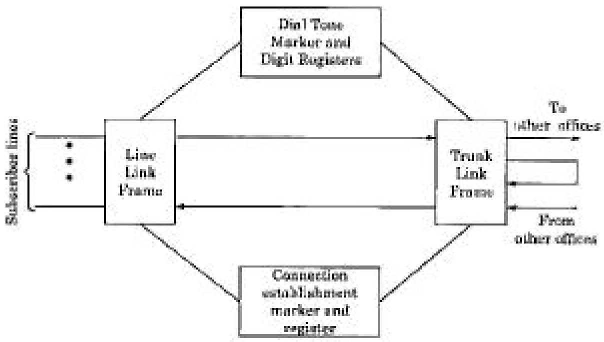

Fig. 5.10 Organisation of Crossbar Telephone exchange.

Line units are two-way units. They can be used for originating as well as terminating calls. Now we can say that this is a significant departure from the Strowger exchange designs. In Strowger exchange designs, the originating and terminating units are seperate and independent. Because of its two-way capability, the secondary section in the line link frame is sometimes referred to as the terminal section. The subscriber lines are terminated on the outlets of the terminal section frames. The group unit is a unidirectional device. It receives the calls from the line unit or from distant telephone exchanges. It is capable of handling local, outgoing, incoming, terminating and transit calls.

In a crossbar telephone exchange, the call processing progresses in three stages. These stages are:

1. Preselection
2. Group selection
3. Line selection.

Preselection is performed by the originating marker. It starts from the moment the subscriber lifts the hand set of the telephone and ends when the dial tone is sent out to him by a register.

In group selection stage, the call is switched through to the desired direction. The direction is decided in accordance with the code given by the translator.

In line selection stage (last stage), the calling subscriber is connected to the called subscriber by the terminating marker the line of the called party is controlled by the terminating marker. The terminating marker also sets up ringing on the line.

Notes