PROBE WIRE AND EXPLORING COIL MEASUREMENTS

CONTENTS PAGE

1. GENERAL

1.01 This practice discusses the indirect measurement of power system inductive influence at voice frequencies. Although these tests provide an initial characterization of the power system environment, they are only a part of the overall study of coupling. The degree of completeness or accuracy necessary in the measurements will depend upon the severity and complexity of each particular case. Analysis of data obtained by these methods is discussed in Section 873-600-100.

1.02 The techniques described in this section for measuring the extent of magnetic induction are the probe wire (sometimes referred to as the exploring wire or search wire) and the exploring coil (sometimes referred to as the loop antenna or the bicycle rim loop). The probe wire measurement provides the most accurate characterization of an inductive environment as it is likely to affect telephone plant, since most aspects of coupling are taken into account. The probe wire technique may be used for measuring the induced longitudinal voltage that exists on telephone plant located near the probe wire.

1.03 The measurements discussed in this practice do not include two concepts which have been used in the past for analyzing inductive interference problems. These concepts, the application of the Telephone Influence Factor (TIF) and the determination of ground-return current, are omitted from the measurements because they are not applicable to the inductive coordination investigations discussed in this practice. The use of TIF as a weighting to be applied to harmonic measurements in order to indicate the possible interfering effect of power system waveshapes on telephone facilities is no longer valid with today's plant. The TIF objectives were formulated based on the following assumptions:

(1) Coupling between power and telephone systems is directly proportional to frequency.

(2) Balance (susceptibility) of the telephone circuit is independent of frequency.

With the advent of shielded cables and carrier frequencies, however, the effective coupling may be significantly less than that assumed in the TIF objective and may even be independent of frequency. Also, the balance assumption was developed back when the primary transmission facility was open wire; but with the widespread use of cable plant today, the balance is dominated by the capacitance-to-ground and, hence, is dependent upon frequency.

1.04 The function of a probe wire has often been erroneously stated as the measurement of power system ground-return current. Actually, the longitudinal voltage induced in a probe wire is a result of the magnetic effect of the net current on the power phase and neutral conductors. That this current returns to its source through the earth is incidental. (For an MGN system, this net current is about 60% of the net current on the phase conductors alone; the remaining 40% of the net phase current returns via the neutral and does not cause induced interference.)

1.05 A power system is usually engineered for an ***overall*** average load balance. This may mean that certain loads along each conductor create an unbalance in one particular section, which is corrected by the next load section. The net result of several sectional unbalances in the distribution network may be an overall average power load balance at the generating source. Therefore, these unbalanced sections may not be detectable at the source by power load indicators, and the power company may be unaware that they are causing a problem. Since power companies do not routinely check each section for balance, it may be difficult to convince them that they might be causing induction problems without some form of evidence. A probe wire or exploring coil can be used for isolating or locating such a section and measuring its associated interference. The amount of interference will be proportional to the length of power exposure only if power loads are similarly distributed along each of the phase conductors and if the loads remain similarly balanced among the three phase conductors. Such ideal conditions, however, rarely occur in practice. Power loads are usually distributed at random and may vary by the hour depending upon the requirements or habits of the user. If the power lines suspected of causing a problem are located parallel to a road, the inductive coordination engineer can merely drive down the road with an exploring coil test set-up. This method is much quicker than the probe wire method, and since power loads do change frequently, this added speed may reduce errors resulting from power conditions changing during a test.

1.06 Even in a power system with good load balance, noise induction can result from odd-triple harmonic zero-sequence components, from nonlinear loads (such as rectifier installations), or from power system resonances involving power factor correction capacitors. Probe wire and/or exploring coil measurements can be used to help isolate the areas of high influence.

2. PROBE WIRE MEASUREMENTS

2.01 The probe wire measurement is the best method for obtaining a quantitative determination of the degree of coupling between power and telephone conductors. However, several measurements may be required to cover the length of the disturbing exposure and provide an accurate characterization of the environment. The tests should at least be made at both ends of the exposure and in the middle to give a representative measurement. If for some reason only one test can be made at a single location, it is suggested that a point near the middle of the exposure be measured to give an approximate average value. The accuracy of the measurement will depend on the possible shielding effects of other conductors in the vicinity of the probe wire. Underground metallic pipes, grounded cable, and wire fences on metal posts are examples of the types of conductors to avoid when considering a possible test location. These conductors may cause secondary induction into the probe wire which would lead to errors. An analysis of the secondary induction may be desired if it is suspected of causing inaccuracies. Also, probe wires should not be placed near a ground on the disturbing power circuit. If this were to be done, the ground potential rise at that location would have to be subtracted (vectorially) from the induced voltages measured by the probe wire. For power substations, a distance of at least 2000 feet should be maintained between the ground terminals and the location of the probe wire to avoid any ground potential rise effects. Smaller separations can be used for smaller power grounding systems. In general, the separation from a power ground should be chosen so that V_{GPR} at the probe wire will be small relative to the probe wire voltage (which is generally of the order of tenths of a volt). V_{GPR} can be estimated by use of the equation:

$$V_{GPR} \cong \frac{I_G \rho}{2 \pi r^2}$$

where I_G = current to ground through electrode

ρ = earth resistivity

r = distance from electrode.

For instance, if an electrode is carrying 0.75 amperes (a typical value for power-pole vertical ground rods) and ρ = 1000 m—Ω, the V_{GPR} at 30 meters would be:

$$V_{GPR} = \frac{(0.75)(1000)}{2 \cdot \pi \cdot 30^2}$$
$$= 0.13 \text{ volts}$$

For this rod, 100 meters or 300 feet would probably be the minimum acceptable separation between the probe wire and the ground rod. Greater separation would be desirable.

2.02 The standard procedure for performing a probe wire measurement involves the use of a 100-foot insulated wire laid parallel to the power system. A closely twisted pair of wires may be used if a single conductor is unavailable, as long as the ends are twisted together. It is important that this length of wire be kept on the ground as a precaution against possible high electrostatic induction levels. The position of the probe wire should be symetrically located beneath the power lines as shown in Fig. 1 in order to

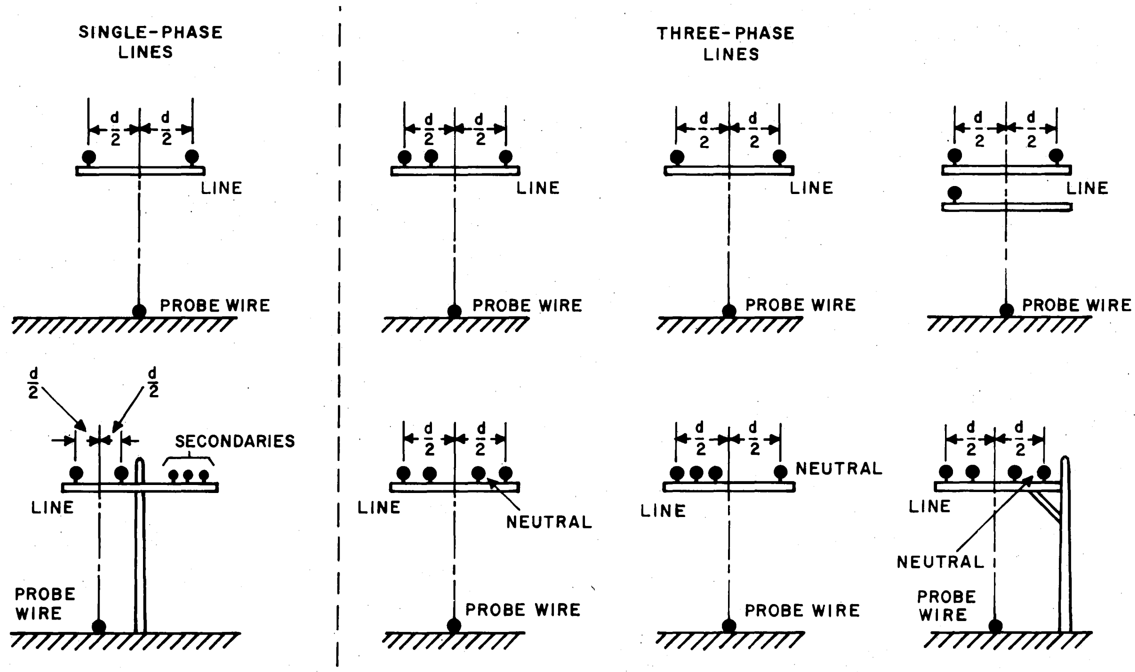

Fig. 1—Probe Wire Locations Under Various Power Lines

minimize the induction from balanced currents. One end of the probe wire should be grounded, and the other end connected to either a frequency analyzer or a noise measuring set (NMS) as illustrated in Fig. 2. The other input to the test set or its external ground terminal should also be connected to ground. The test lead wires from the test set to the probe wire and ground rod should be twisted to prevent any extraneous signals from interfering with the test results. It may be convenient in some field tests to make the readings with the measuring equipment at some distance from the probe wire terminals; for instance, in a truck alongside a highway. In this situation, a twisted insulated pair of wires up to 50-feet long should be laid on the ground and used as the interconnecting leads between the test set and probe wire. It is preferable that the lead wire be laid at right angles to the probe wire and power system in order to avoid additional induced voltages.

2.03 Making probe wire measurements involves the use of a high impedance frequency-selective voltmeter (analyzer) and a noise measuring set. The significant advantage of the high impedance test set technique is the elimination of the need for measuring the resistance of the probe wire grounds, since only a negligible current is flowing during the measurement. In fact, screwdrivers stuck in the ground and connected to the ends of the probe wire provide an effective ground.

2.04 A number of suitable test sets are commercially available for measuring the induced voltages or currents on the probe wire. The Western Electric 3-type NMS and the 4A frequency analyzer (now rated Manufacture Discontinued) are effective instruments for this purpose, but other comparable equipment such as the Wilcom T132B spectrum analyzer and NMS and the Hewlett-Packard 302A

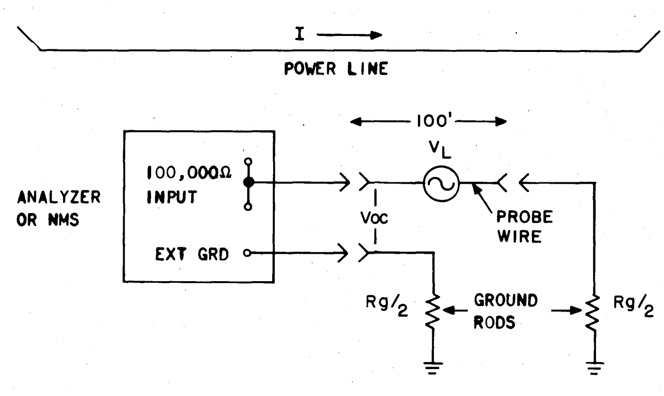

Fig. 2—Probe Wire Measurement Techniques

and 3581C wave analyzers have also given satisfactory service to the operating companies. Any instrument used should be capacitively coupled or insensitive to dc, as dc gradients can exist in the earth (as from dc traction systems, for example), and a meter measuring dc + ac would not indicate true induction levels.

2.05 For making probe wire measurements, the following input functions (or their equivalents) should be used with the following test sets:

3A & 3C NMS—NG (100,000Ω)

4A Analyzer—TEL NOISE-TO-GRD (100,000Ω)

T132B Analyzer—BRDG 600

It should be remembered that 40 dB must be added to the meter readings for the 3A and 3C sets, and 44.1 dB for the 4A, to obtain NG in dBrn. The HP302A and 3581G have 100,000Ω input impedances, but the dBm reading must be corrected to dBrn in order to be comparable with the other test set measurements. This is accomplished as follows:

dBrn = dBm + 90

When the 3A and 3C NMS's are used in the NG input mode, the probe wire should be connected across ***both*** input terminals as shown in Fig. 2. The ground rod should be connected to the test set external ground terminal.

2.06 Methods of analyzing the data obtained from probe wire measurements are detailed in Section 873-600-100. Also discussed there is a method of using probe wire measurements to estimate the presence or absence of an effective shield on a cable. Section 873-200-201 discusses a method of determining effective earth resistivity via probe wire measurements.

3. EXPLORING COIL MEASUREMENTS

3.01 The exploring coil is a quick method for qualitatively measuring disturbing magnetic fields. This measurement technique should be used only as a diagnostic approach, however, since it is not a measure of the coupling between the power and telephone systems. The test is useful primarily for localizing "hot spots" and identifying those sections with large power current unbalances that may cause telephone interference. A current is generated in the coil when it is placed near a disturbing power system; this current varies in proportion to the power unbalance. It may be misleading to assume that the received signal should increase as one approaches a possible source of interference. Power lines offer little loss to harmonics at voice frequencies and the differences in levels may be undetectable over the relatively short lengths of power lines that are of the main concern. Also, the harmonic levels are seldom constant, even at a stationary location, because of the constantly changing power loads.

3.02 Several good exploring coils are listed in Section 870-205-500 for use with an NMS or analyzer. The 1940- or 1570-ohm hold magnet coil of a 325AE, AF, AG, AH, or similar crossbar switch, makes a fairly sensitive exploring coil when used with the NMS in the ***BRDG*** input mode (10,000 ohms). The voltage output of these coils will not depend on the position of the coil in the magnetic field to the same degree as it does with other coils, making positioning less critical. A 47B inductor has proven to be an effective exploring coil, but some very good coils can also be easily constructed. This can be accomplished by wrapping approximately 300 turns of single conductor 26 gauge insulated copper wire around a nonmetallic 30-inch diameter frame. This design is sometimes called the "bicycle rim loop" and is usually assembled on a piece of plywood with a handle. A coil built in this manner should match the 600-ohm input impedance of the NMS or the spectrum analyzer, if used.

3.03 Both of the insulated test leads between the test set and the exploring coil should be kept as short as possible and tightly twisted to minimize extraneous noise that might be picked up and obscure the output of the coil. The exploring coil should be held so that its plane includes the axis of the power line. The coil should then be oriented for the maximum readings. Large, misleading errors could result, however, if the following precautions are not adhered to:

(1) Never locate the coil under a power line span carrying secondary distribution lines.

(2) Discontinuities in the power line, such as bridge taps, corners, or dead-ends should be avoided.

(3) Metal fences that parallel the power line should be avoided.

(4) Joint-use sections with telephone cable should be avoided unless the cable is joint-use throughout the exposure.

(5) Buried cables and metallic pipe lines should be avoided.