GROUNDING FOR REDUCTION OF POWER INFLUENCE

CONTENTS

1. GENERAL
2. THEORY
3. SYSTEM DESIGN CONSIDERATIONS
4. INSTALLATION
5. POWER COMPANY COORDINATION

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers telephone systems. Discussion is presented of a technique for reduction of C-Message weighted power influence by grounding via the power system multi-grounded neutral (MGN) conductor.

1.2 The best shielding at the harmonic frequencies of 60 Hertz occurs when the highest current is flowing in the cable shield loop or circuit to nearly cancel the induced current in the cable pairs. The cable shield loop is made up of the cable shield, ground connections and a return path through a conductive medium. This conductive medium can be the earth, power system MGN or a combination of both.

1.2.1 Provision of high shielding current along the entire cable length cannot be obtained by providing a low resistance path to earth only at the ends of the cable shield and optimum shield performance will not occur. There are other factors that affect the shielding current which must be considered. Among these are length of the exposure in relation to the total cable length and location of the exposure.

1.2.2 Effective shielding current is developed through ground connections to the main shield. Along buried cable routes the high buried drop or service wire shield resistance reduces the resulting current from the MGN connection at the premises. There are no shields on aerial drops to provide a connection to the MGN.

1.3 The average cable in service will usually have a low resistance ground connection at the central office. There may or may not be a low resistance ground at the far end of the cable and there may be some random grounds along the cable. Some of the random grounds may be connections directly to the MGN. In buried cable there should be connections to the MGN through the buried drop shields. These do not provide sufficient current along the main cable route for satisfactory shielding.

1.3.1 It is probable that the majority of the cable shield ground connections along existing cable have been installed primarily because of requirements in the National Electrical Code, National Electrical Safety Code and local ordinances. This means the ground systems are the result of safety considerations with minimum attention to noise and protection. While these random unplanned ground connections do provide some measure of equipment protection and noise immunity there is a question relative to their overall effectiveness in noise reduction.

1.3.2 There is a need to provide a grounding system based on planned connections which will provide for both good protection and noise performance in a telephone system. This system should conform with the requirements of the electrical codes mentioned in paragraph 1.3.1.

1.4 There are two factors, noise and protection, which may provide the basis for the design of a cable shield grounding system. Regardless of the primary basis for the design (noise or protection) there will be some benefit to the other. In general, the more stringent grounding requirements for good shielding will provide adequate electrical protection while the reverse may not be true.

1.4.1 Where there is a record of excessive damage to electronic and other equipment a design technique which will improve the cable protection performance is in order. A technique developed for this purpose is presented in TE&CM Section 817, Electrical Protection Through Effective Grounding of Cable Shields.

1.4.2 When there is high power influence a design technique which will reduce the magnitude of the power influence should be considered. A technique for accomplishing this goal is discussed in the practice. The design steps are quite simple and do not involve any mathematical calculations. This factor makes it especially valuable to smaller companies that do not maintain an engineer on their staff.

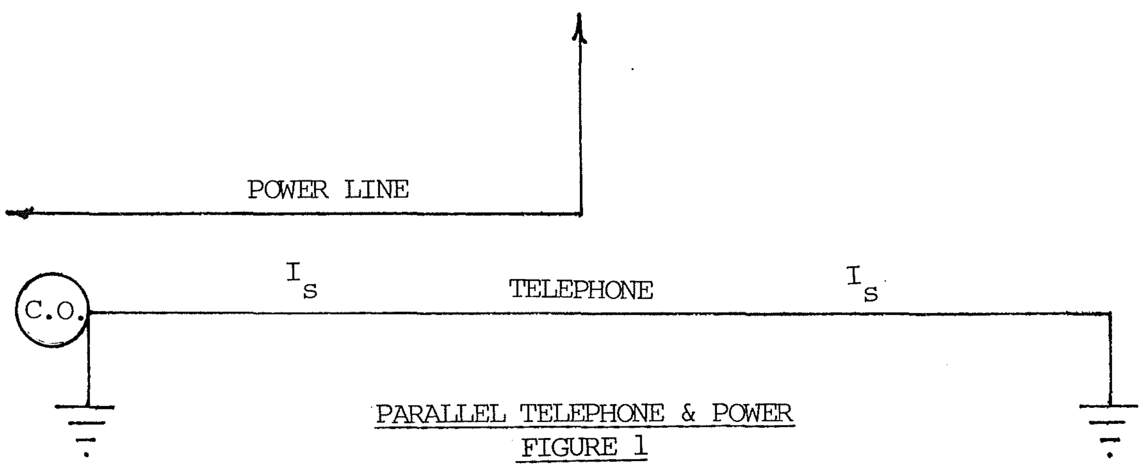
1.5 Application of this grounding technique is not recommended when the power influence exceeds 95.0 dBrnc after the continuity of the cable shield has been verified from end to end. The technique for checking shield continuity through shield current measurements as discussed in TE&CM Section 451.2, Paragraph 5, is recommended for this purpose. Power influence of this magnitude suggests the problem may be due to some abnormal condition in the power system.

1.6 This grounding technique is not presented as a solution to every noise problem. It is a proven tool to be used where it appears to be the best option among those considered. Where it has been applied reductions in power influence from 3 to 15 dBrnc have been achieved.

2. THEORY

2.1 The basic theory for this grounding technique is that maximum shielding of C-Message weighted power influence occurs only in that length of cable where the induction takes place. Any unshielded residual power influence will not be further reduced elsewhere along the cable. The maximum shielding effficiency occurs when the highest possible induced current is flowing in the cable shield circuit in that length of cable where the induction is present. The lowest resistance shield loop which will produce the current is provided when the power system multigrounded neutral conductor is used to complete the circuit.

2.2 A simplified illustration of a parallel power and telephone system will aid in understanding the theory of grounding for noise reduction. In Figure 1 a telephone cable is shown extending from a central office to its end in the field. The cable shield is grounded at each end. There is a power line parallel to the telephone cable extending from the central office end to a point one half way toward the end of the cable.

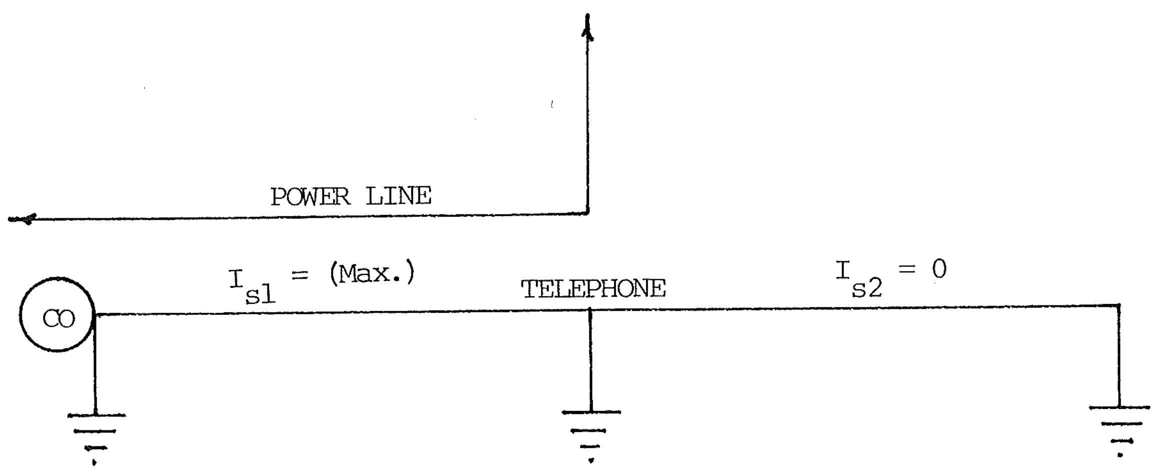


PARALLEL TELEPHONE & POWER
FIGURE 1

2.2.1 Induction will occur only along the portion of the cable which is parallel to the power system. With the shield grounded only at the ends a current (I_S) will flow along the entire length of the cable shield. The maximum harmonic frequency shielding resulting from this current flow will occur within the limits of the parallel between the two systems. It is only in this area that voltage is being induced in the cable pair and the near 180° phase difference will exist between the induction from the power system and that from the shield circuit.

2.2.2 Current will flow in the cable shield circuit at the same magnitude along both cable segments, paralleled and nonparalleled. There is no induction from the power system along the section where there is no parallel. The voltage induced in the cable pair due to the current flowing in the cable shield will result in a longitudinal noise voltage or power influence since there is no induced voltage on the pair from the power system in this section. This will produce a higher net power influence on the circuit and a corresponding increase in circuit noise.

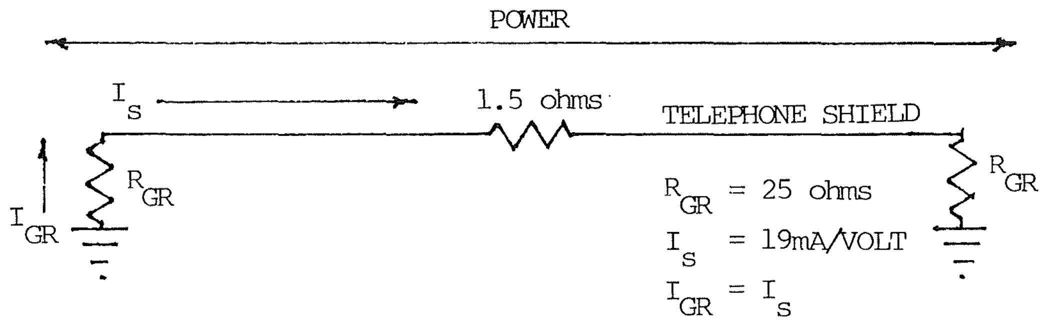
2.2.3 This undesirable voltage induction can be eliminated by placing a ground connection at the end of the parallel between the power and telephone systems as shown in Figure 2. There will now be negligible current flowing in the shield along the nonparalleled section of cable. This effectively eliminates this portion of the shield as a source of inductive interference. The shielding current along the length of parallel exposure will be increased resulting in improved harmonic frequency shielding. This is due to the reduction of shield resistance between the two ground points.



ADDED GROUND FOR SHIELDING

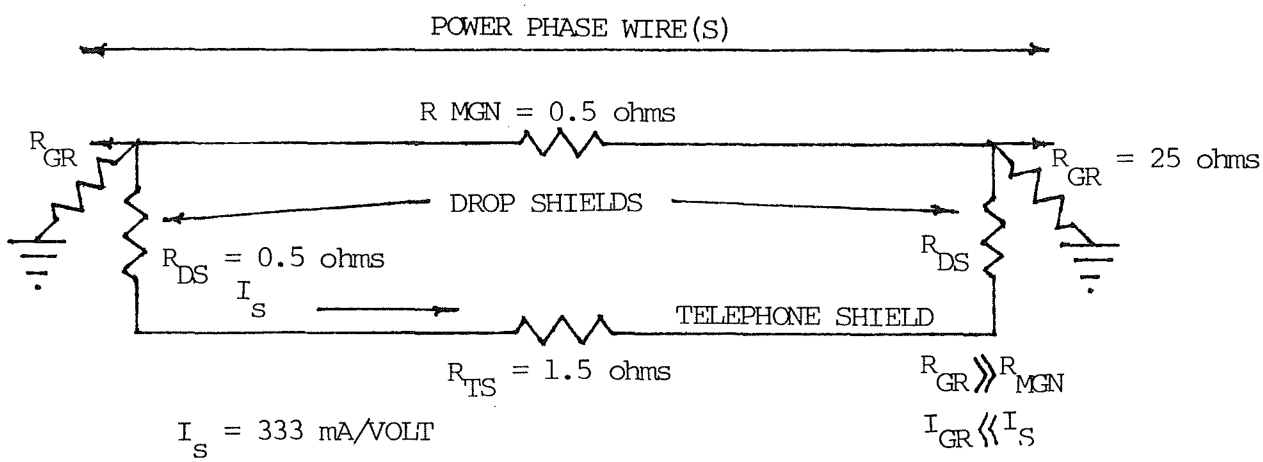
FIGURE 2

2.3 Maximum shield current will flow when there is a very low resistance shield circuit. This occurs when there are direct connections between the main cable shield and the MGN. Figure 3 shows a single exposure length with a ground at each end. These grounds are established with a ground rod, each having a resistance to earth of 25 ohms, with a shield resistance between electrodes of 1.5 ohms. For each volt of induced voltage on the shield there will be a shield current of 19 mA.



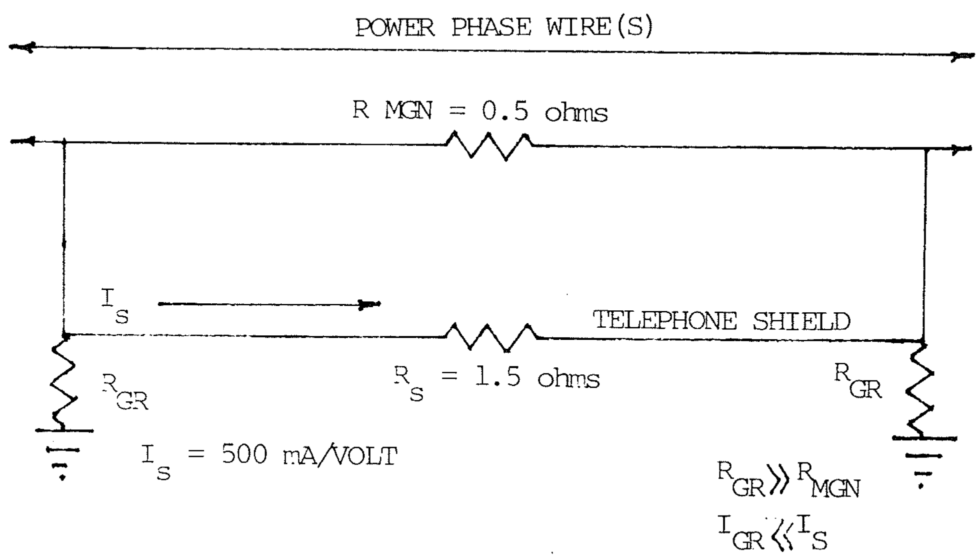
SHIELD CURRENT WITH GROUND RODS
FIGURE 3

2.3.1 Figure 4 illustrates a buried drop located at both ends of the exposure each of which has a shield resistance of 0.5 ohms. These drop shields are connected to the power service neutral at the subscriber end with a neutral conductor resistance between the two connections of 0.5 ohms. The main cable shield resistance is 1.5 ohms as in Figure 3. In this example there will be a current of 333 mA for each volt of induced voltage.



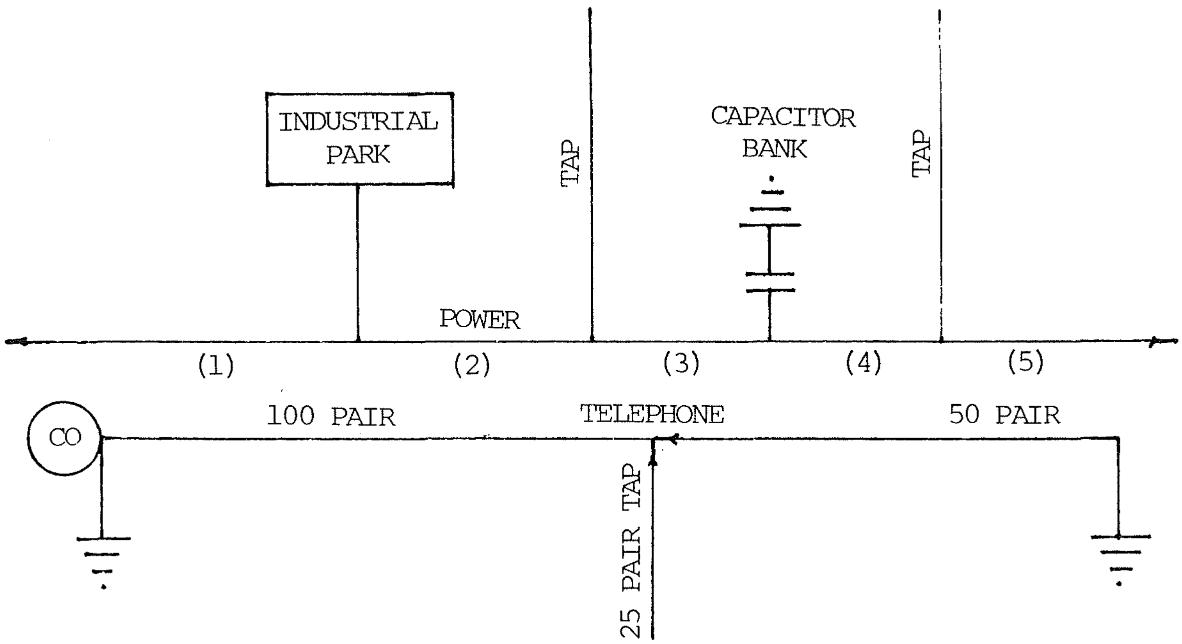
SHIELD CURRENT WITH DROPS & MGN
FIGURE 4

2.3.2 The best condition is where a direct connection is established to the MGN from the main cable shield at each end of the exposure. This is shown in Figure 5. The resistance between the ends of the shield is 1.5 ohms and of the MGN conductor is 0.5 ohms. For each volt induced on the shield a current of 500 mA will result. This grounding configuration will provide the best harmonic frequency shielding for the cable pairs.



SHIELD CURRENT WITH MGN
FIGURE 5

2.4 Figure 6 shows a telephone cable which has a single tap. There is a power line parallel to the telephone cable along its entire length. There is an industrial center located along the power line with two taps located beyond the center and a capacitor bank located between the two taps. Study of this can provide further insight into the theory of grounding for noise reduction.

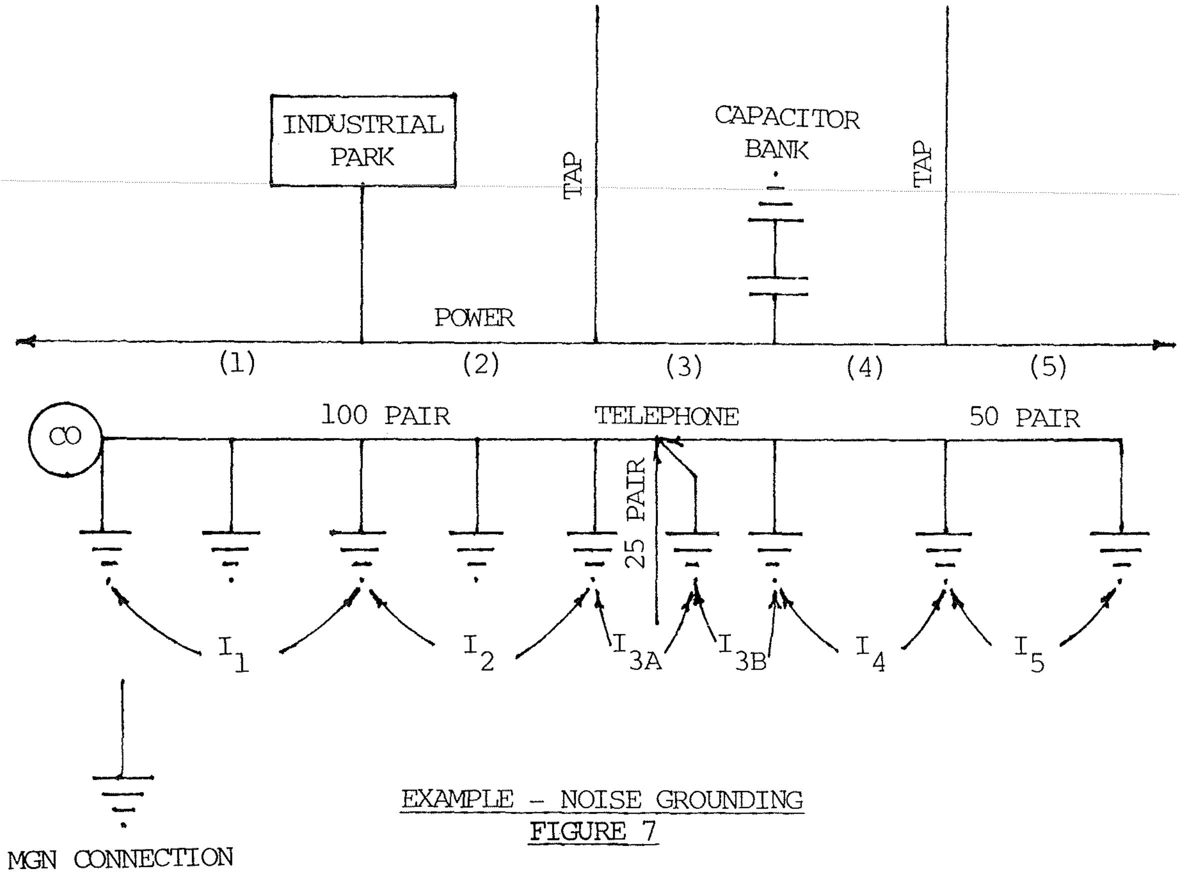


EXAMPLE - PARALLEL POWER & TELEPHONE
FIGURE 6

2.4.1 The telephone cable is made up of a 100 pair from the office to a point in the field between the first power line tap and capacitor bank location. At this point it diminishes to a 50 pair cable with a 25 pair tap. There is a ground shown at the central office and at the end of the 50 pair cable. While no ground is shown on the tap cable there would be one or more for protection purposes.

2.4.2 Between the telephone office and the end of the cable there are five identifiable sections of power line. Each of these sections can have a different phase balance and associated magnetic field intensity. There can be different voltage levels induced in the telephone cable parallel to each of these five power line segments. The objective of grounding for noise reduction is to provide the maximum shielding current along each length of cable where the induced voltage from the power line will be essentially the same magnitude.

2.4.3 The objective can be accomplished by establishing an MGN connection at the ends of the five power line segments. A connection at the central office and at the point service is provided to the industrial center as shown in Figure 7 will provide maximum shielding for the first exposure section. Additional connections to the MGN at the location of the first power system tap, capacitor bank, second power system tap and the end of the telephone cable will provide the minimum grounding system. Intermediate connections are advisable where there is a long distance between MGN connections. (See Paragraph 2.4.6).



EXAMPLE - NOISE GROUNDING
FIGURE 7

2.4.4 An additional connection should be made to the MGN at the point where the cable changes size and the tap is connected. The two shield resistances will produce different shield currents and for maximum effectiveness should be separated by a MGN connection to provide two shield circuits. It is also desirable to keep current from flowing to the tap shield where it might become a source of inductive interference.

2.4.5 After all of the connections to the MGN are established each of the five power line segments will be matched with a corresponding cable shield segment by MGN connections. Each shield segment will have maximum shield current for reduction of the power system induced noise in that section. They are shown in Figure 7, as I_1, I_2, I_{3A}, I_{3B}, I_4 and I_5.

2.4.6 Extra connections are shown to the MGN along the first and second exposure lengths. These connections are not essential to the basic design of the grounding system. They are placed when there is a long distance between the two ends of the exposure. If the intermediate MGN connection were not used, a severe noise problem could occur in the event of an open shield circuit due to the resulting unshielded length. The intermediate grounds insure that in the event of an open shield circuit only a short section of unshielded cable will result.

3. SYSTEM DESIGN CONSIDERATIONS

3.1 The design of a grounding system for the reduction of C-Message weighted power influence is simple and requires no mathematical calculations. It should require little time to develop the information to implement the design procedure.

3.2 Initial steps should not be undertaken without determining that the telephone cable shield is continuous from end to end. Travel along the length of the parallel between the telephone and power system. Observe the power system and note any significant changes which could change the magnetic field intensity surrounding the power conductors. These changes could include large transformer banks, capacitor banks, taps, customer service taps with high load demand, and changes in the distance between the systems. Normal residential service taps may be ignored since the loads are small. The location(s) of any change in the number of phases should also be noted such a reduction from three-to two-or one- and from two-to one-phase.

3.3 At each point of change in the power system the telephone system should be studied. This is necessary to determine what is required to make a connection between the MGN and the cable shield. There are three different types of telephone cable construction each of which requires different considerations.

3.4 Aerial telephone cable in joint construction with the power system will provide the least problems. At each of the points of change in the power line, with few exceptions, there will be a power system ground connection on the same pole. This provides a convenient connection to the neutral which should already be in place due to electrical code requirements. There will be a problem, common to all three types of telephone system construction, at points where there is a change in the power system with no existing power system ground connection. This will be discussed in Paragraph 5.2.

3.5 Where the aerial telephone cable is not in joint construction such as with road separation there are definite problems. The power system ground connections are not readily available for establishing a connection to the MGN conductor. It is still usually possible to provide an acceptable connection between the two systems.

3.5.1 When a power system tap is involved the tap may extend in either direction from the power line. When the direction is opposite to the telephone cable location there is possibly a telephone tap extending in the same direction. Often there will be a single joint use pole at the point of crossing when the road separation is continued along the tap route. A connection to the MGN can be established at this pole.

3.5.2 There will sometimes be a power service crossing the cable near the tap location with a joint use pole at the point it crosses the telephone cable. Such a pole will provide a location for connection to the power neutral. Since connections at locations other than where the change in the power system occurs will result in degradation of noise grounding system efficiency they should be limited to a maximum distance of 150 meters about (500 feet).

3.5.3 At other locations where power system changes occur there is little possibility of an MGN connection right at the point of change. These would include large transformer banks, capacitor banks, and locations where significant changes in separation occur. As discussed in Paragraph 3.5.2 a nearby power service crossing of the telephone cable may provide the best opportunity to establish a connection to the MGN. The distance between the change in the power system and the shield connection to the MGN should be the shortest length possible.

3.5.4 If the distance between the power line changes identified in Paragraph 3.5.2 and 3.5.3 and the location of connections between the cable shield and MGN along a cable route will average 150 meters (about 500 feet) or over, other forms of mitigation should be considered.

3.6 Buried cable plant can be located directly below the parallel power system or with road separation in most situations. Each presents a different set of problems. Where the telephone cable is buried directly below the power line there will be some existing contacts with the MGN. These occur when a pole with a power system and is located near a pedestal and the connection is required by the electrical codes for safety purposes. Unfortunately these connections are not often at the points necessary for implementation of a noise grounding system.

3.6.1 As each point for connection to the MGN is identified the first consideration is to determine if the power pole is located close enough to a pedestal that the connecting wire could be buried between them. The maximum distance for these connections should be determined by each company. Condition of the soil and costs are among the factors which must enter in these decisions. It seems that distances up to 45 meters (150 feet) could readily be justified. The pole may not have a neutral ground connection. This will be discussed in Paragraph 5.

3.6.2 Where the buried telephone cable and the power system have been placed with road separation, there are additional problems. The power system ground connections are not readily available for establishing a connection between the telephone system and the MGN conductor. It is still usually possible to establish an acceptable connection between the two systems.

3.6.3 When the change in the power system is a tap, it may extend in either direction from the power line. Where the direction is opposite to the telephone cable location, sometimes there will be a telephone cable tap in same direction as the power tap. A pole and pedestal close together a short distance along the tap can provide a location for the desired connection.

3.6.4 There will sometimes be a power service crossing the buried cable near the tap location with a pole located near the telephone cable pedestal. This can provide a location for connection to the power system neutral conductor. Since connections at locations other than where the power system change occurs will result in some degradation of noise grounding system efficiency they should be limited to a maximum distance of 150 meters (about 500 feet).

3.6.5 At other locations where power system changes occur there is slight chance of establishing a connection to the MGN right at the point of change. These would include large transformer banks, capacitor banks and locations where significant changes in separation occur. As discussed in Paragraph 3.6.4 a nearby power service crossing of the cable may provide the best opportunity to establish a connection to the MGN. The distance between the change in the power system and the shield connection to the MGN should be the shortest length possible.

3.6.6 If the distance between the power line changes identified in Paragraph 3.6.4 and 3.6.5 and the location of connections between the cable shield and MGN along a cable route will average 150 meters (about 500 feet) or over other forms of mitigation should be considered.

3.7 The last step is to determine the distance separating the various connections between the cable shield and the MGN. Where the distance is greater than 610 meters (2000 feet) a connection should be established near the midpoint. This will reduce the noise which will result if the cable shield is accidently opened.

4. INSTALLATION

4.1 There are no special techniques required during the installation of connections to the power sytem MGN conductor for reduction of power influence. The work could start at any point along the route. There are some suggested steps which can provide information that can lead to monetary savings.

WARNING: Potential differences between the shield and power neutral can be hazardous. They should be treated as high voltage conductors at all times.

4.2 At locations where it is necessary to bury the connecting wire a long distance 45 meters (150 feet), or more it is suggested a temporary connection be established by laying the wire on the ground surface. Measure the power influence at the far end of the cable to determine the effect of the connection. If the power influence is reduced by 2-3 dB or more the wire should be buried and a permanent connection established. Should the reduction by less than 2 dB look for a point nearby where the connection can be made without the expense of a long burial.

4.3 It is recommended that the installation be started at the far end of the cable from the office. As each connection to the MGN is completed measure the power influence and circuit noise at the far end of the cable. When the connection has been made to the MGN which produces a power influence value below 80 dBrnc additional connections are not essential. While there are advantages related to accidental shield openings and increases in power system unbalance to be derived from completing the connections along the entire cable they can be deferred where economic considerations are predominant.

5. POWER COMPANY COORDINATION

5.1 It is always essential to coordinate with the power company when performing work which involves connection to the power system multi-grounded neutral. Since there may be a need for connections to the MGN on poles which do not have an existing power system ground wire some negotiating with the power company is in order.

5.2 In some areas agreements have been successfully reached on procedures for establishing connections to the multigrounded neutral conductors on poles without an existing power system ground wire. The basic procedure is recommended as a guide for negotiations on this subject between power and telephone companies. When the telephone company desires a connection to the MGN on a pole without a ground wire they provide a ground rod near the pole and extend the wire up the pole. If the cable is aerial and in joint construction a coil of wire long enough to reach the MGN conductor is left just above the cable. Where the cable is buried the wire is extended about 12 feet up the pole and a coil of wire is left which is long enough to reach the MGN conductor. The telephone company personnel next establish a connection between the ground wire and the cable shield. The power company is then notified and provided the pole number(s) where connection to the MGN is desired. Their crews visit the location and establish the connection after extending the wire up the pole. Any compensation for making the attachment should be determined by negotiation between the parties involved.