NEUTRALIZING TRANSFORMERS

CONTENTS

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. It is written to provide information on the application of neutralizing transformers as a means of reducing excessive induced fundamental frequency longitudinal voltage and current (60 Hertz). Under proper conditions they can also provide reduction of higher frequency longitudinal voltages such as power system harmonics of the fundamental frequency.

1.2 The particular type neutralizing transformer described in this section is designed for reducing excessive 60 Hertz induced longitudinal voltage on subscriber loop and trunk telephone cables. This type of neutralizing transformer is not designed for and should not be used for power station telephone protection. They do not have sufficient dielectric strength to withstand the large ground potential rise or inductive voltage environment that can occur during a power line fault.

1.3 Application of neutralizing transformers might be considered when the power influence on the cable pair exceeds 90 to 95 dBrnc (126 dB 3kHz Flat or 50 volts RMS). Low frequency longitudinal voltage reduction of 10 to 20 dB (32 to 90 percent) can be achieved at the station and terminal ends of exposed cable pairs as a result of the transformer installation.

2. THEORY OF OPERATION

2.1 The neutralizing transformer is constructed with a number of twisted pairs of telephone cable wound around a ferromagnetic core. The number of pair windings on the transformer are identical to the number of pairs in the telephone cable on which it will be installed. The largest transformer manufactured is 100 pairs so for cables containing more that 100 pairs additional transformers are required. The primary winding may be one or more pairs of the transformer connected to one or more of the cable pairs. The extreme ends of each primary cable pair are connected to a low resistance ground. Secondary windings are all of the pairs of the transformer not utilized as primary windings. These pairs are spliced to the pairs of the cable being treated.

2.11 When a neutralizing transformer is installed on a cable that is subjected to power line induction, a longitudinal current will flow in the primary winding. This current produces a voltage drop across the transformer at the terminals of the primary winding. Since the secondary windings are longitudinally coupled to each other and to the primary winding, by the high mutual inductance, a longitudinal voltage will be induced into the secondary windings. Due to transformer action, this induced longitudinal voltage on the secondary windings will be opposite in polarity to the voltage induced in the cable pairs by the power line. Thus, this induced voltage in the secondary winding opposes and effectively neutralizes the voltage that otherwise would exist on the telephone circuit.

2.12 Complete neutralization cannot be achieved due to a difference between the voltage drops across the impedance of the primary winding and the primary circuit, and the induced voltage on the cable pairs in the secondary winding. This voltage difference is referred to as the "remnant voltage".

3. APPLICATION GUIDELINES

3.1 Neutralizing transformers should be considered as a noise mitigation measure when the conditions in Paragraph 1.3 above are found. Application of neutralizing transformers should usually not be considered until other methods of achieving mitigation have proven impractical.

3.2 Following a determination that a neutralizing transformer will be used for noise mitigation, a decision must be made as to the best location for installation. The open circuit voltage to the central office ground or voltage to ground at the subscriber location should be measured to determine the induction voltage to be neutralized. This should be the highest value of voltage to ground that will have to be neutralized. It is desirable, where possible, that measurements of voltage to ground be made each half hour or recorded with a recording voltmeter over a 24-hour period to find the "worst case" voltage to ground. Measurements should be made with a high impedance FET-type VOM or VTVM.

3.21 The next step is to determine the electrical mid-point of the cable. Voltage to ground should be measured at various points along the cable route. The electrical mid-point will be the location where the voltage to ground is one-half the open circuit voltage to ground. Measurements should ideally be made during the same time of day the highest open circuit voltage to ground was found. All measurements should be made with a high impedance FET-type VOM or VTVM. While this electrical mid-point is the desirable location the transformer can be placed at other locations.

3.22 This location can be adjusted two or three kilofeet so the loading should be studied to determine if the section in which the electrical mid-point appears is best. If an adjacent section is shorter than average, the location of the unit might better be chosen in that short section. The cable wound into the transformer will help build-out the short section.

3.23 The next step is to determine the total current that could be drawn by the existing pair for the open circuit voltage to ground at the subscriber location. For example, assume a subscriber loop made up of 40,500 feet of 22 gauge cable having nine loading points with a voltage to ground of 54 volts. Assuming a nominal loop resistance of 32.4 ohms/kilofoot the parallel resistance of the pair will be (32.4/4) x 40.5 = 328 ohms. The loading coils will add (6/4) x 9 = 13.5 ohms so the total resistance of the two cable conductors in parallel is 328 + 13.5 = 342 ohms. The ac impedance will be only slightly more than this figure. To find the total ac current that could be drawn we use the formula:

$$I = \frac{E}{R}$$

$$I = \frac{54\ \text{Volts}}{342\ \text{Ohms}}$$

$$I = 0.158\ \text{Amperes, } 158\ \text{Milliamperes}$$

3.24 If a 50 pair transformer is being installed, 14 to 16 mA is all the current required to excite the transformer to 54 volts. (See Figure 1). It is quite obvious only about 1/10 of the total current the circuit could deliver will be used for excitation.

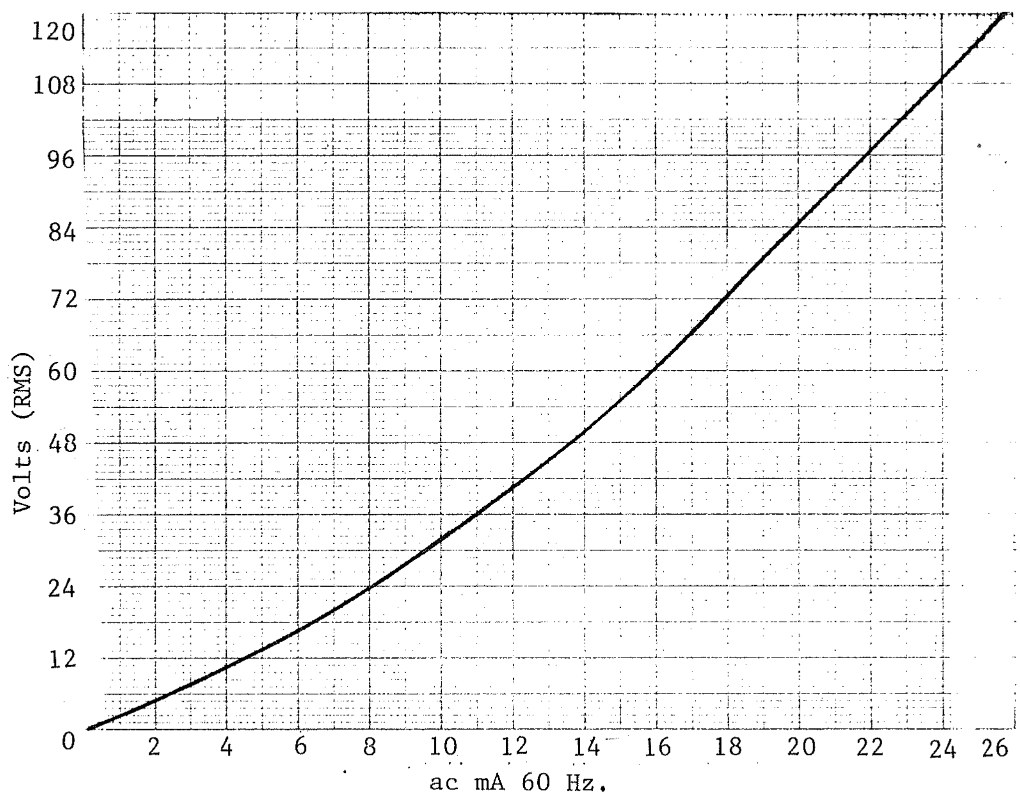

FIGURE 1: NEUTRALIZING TRANSFORMER (EXCITING CURVE)

Courtesy of SNC Manufacturing Co., Inc.

3.25 The remnant voltage (See Paragraph 2.12, above) when the transformer is neutralizing 100 volts can be determined by substituting values in the following formula:

$$V_{REM} = I(R_{PRI} + R_{EXT})$$

Where: V_{REM} = Remnant Voltage

I = Primary winding exciting current required to produce the desired neutralizing voltages.

R_{PRI} = Series resistance of primary winding.

R_{EXT} = Resistance of external primary circuit (Exciting current resistance in cable plus total resistance of grounds at each end)

3.251 Then for 100 volts:

V_{REM} = (Exciting current for 100 volts from Figure 1) X (Resistance of primary windings plus resistance of external primary circuit.)

$$V_{REM} = 0.023 \times (25 + 342 + 10) = 8.67 \text{ volts}$$

3.252 From this the remnant voltage to neutralize 100 volts is 8.67 volts out of a total of 108.67. At this 8.0 percent voltage remnant rate (8.67/108.67) the voltage remnant would be V_{REM} = .08 x 54 or 4.3 volts.

3.6 Installation of a neutralizing transformer in loaded cable can result in one section being longer than the average. The possibility that the loading may have to be respaced beyond the point of installation should be considered. In many cases the small return loss degradation will not be serious enough to require any action.

3.7 Resistance of grounds at each end of the exciting pair should be as low as possible. At the central office, the office ground will usually be sufficient. If possible, the ground connection at the subscriber end of the cable should be to the MGN of the power company.

3.71 The exciting pair should now be established over the distance of the exposure and grounded at both ends as it will be after the transformer is installed. AC voltage and current readings should now be taken at the proposed transformer location. Measure the ac current in series with the exciting pair and then substitute the ac voltmeter for the ac millimeter for the voltage measurement.

3.72 Figure 2 shows the exciting current for a typical induction neutralizing transformer plotted against its output voltage. If the measured ac current is higher than that shown on the graph for the comparable voltage measured, the proposed transformer will be excited properly and will function to neutralize the induced voltage.

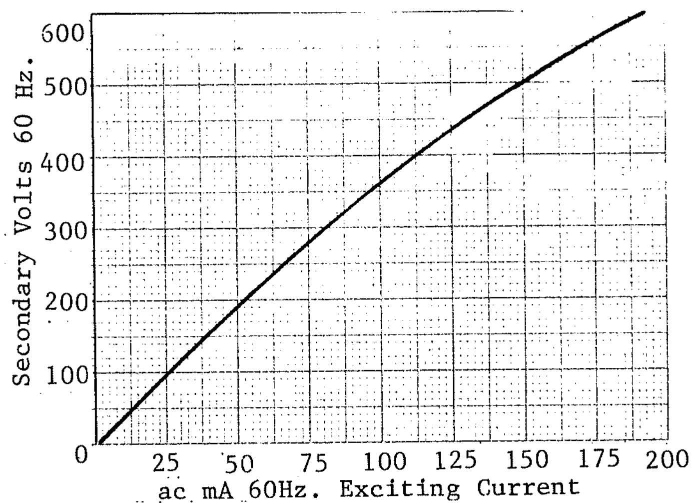

FIGURE 2: NEUTRALIZING TRANSFORMER EXCITING CURVE

Courtesy of SNC Manufacturing Company, Inc.

3.8 The presence of longitudinal direct current flowing through the transformer will result in an increase in the ac current required to excite the transformer to the desired voltage. Certain types of ANI and divided ringing can result in longitudinal dc. Figure 3 shows this relationship.

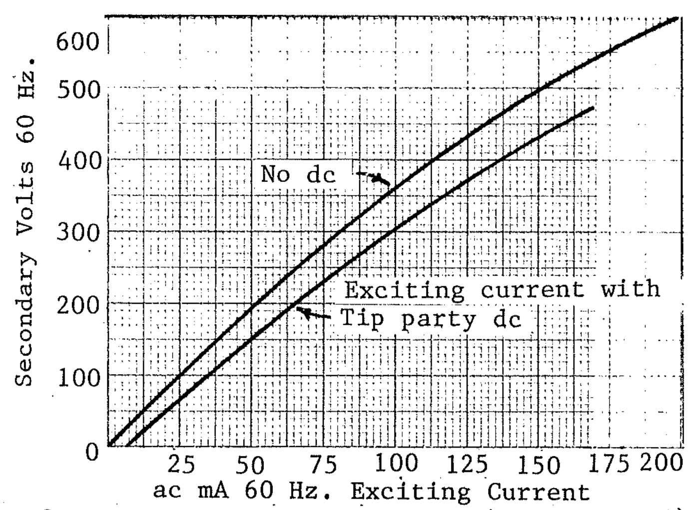

FIGURE 3: NEUTRALIZING TRANSFORMER (EFFECT OF DC)

Courtest of SNC Manufacturing Company, Inc.

3.81 Simplex power feeds for field mounted voice frequency repeaters will also produce excessive longitudinal direct current. Where such power circuits exist they should be modified so that half are positive and half are negative to balance the dc through the transformer.

3.82 Excessive longitudinal dc will cause saturation of the transformer resulting in an increase in the magnitude and frequency composition of the remnant voltage. Noise to ground will also be increased at the location of all stations.

3.83 A short to ground of one of the cable conductors connected through the transformer will also result in longitudinal direct current. Should the magnitude be high enough the transformer could saturate as discussed in Paragraph 3.82 above.

3.9 The transformer should not be connected and operated without a primary winding. While under some conditions the units appear to operate reasonably well without the primary winding the transformer performance may be impaired.

3.10 The same neutralizing transformers that are used on voice frequency cable circuits may be used with analog carrier systems. Design for these systems is the same as for voice frequency pairs except that the placement of the neutralizing transformer can be accomplished most easily just before the pairs enter the repeater location.

3.11 A neutralizing transformer has been designed for use with T-carrier systems. They are similar to the neutralizing transformers used for voice frequency and station carrier applications with the exception that each direction of transmission has its own winding. For most efficient use it is recommended the transformer be located in the center of a span. If the use of a neutralizing transformer is planned for a T-carrier system the manufacturer should be contacted for specific design information.