

IEEE Guide for the Implementation of Inductive Coordination Mitigation Techniques and Application

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of the
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Abstract: IEEE Std 1137-1991 provides guidance for controlling or modifying the inductive environment and the susceptibility of affected wire line telecommunications facilities in order to operate within the acceptable levels of steady-state of surge induced voltages of the environmental interface (probe wire) defined by IEEE Std 776-1987. Procedures for determining the source of the problem are given. Mitigation theory and philosophy are discussed, and mitigation devices are described. The application of typical mitigation apparatus are addressed. Advice for determining the best engineering solution is offered, and general safety considerations are discussed.

Keywords: coordination, coupling, harmonic, ICEP, impedance, inductive, influence, mitigation, mutual, noise, power, susceptibility

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Foreword

(This Foreword is not part of IEEE Std 1137-1991, IEEE Guide for the Implementation of Inductive Coordination Mitigation Techniques and Applications.)

This document was suggested during the preparation of IEEE Std 776-1987 as a companion in the area of implementing mitigating techniques. The following individuals made a significant contribution to the effort.

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IEEE Guide for the Implementation of Inductive Coordination Mitigation Techniques and Application

1. Scope

This Guide offers users assistance in controlling or modifying the inductive environment and the susceptibility of affected wire-line telecommunications facilities in order to operate within the acceptable levels of steady-state or surge-induced voltages of the environmental interface (probe wire) defined by IEEE Std 776-1987 [4]¹. The methodology, application, and evaluation of results for mitigative techniques or devices in general are addressed for all Specific Type A and Specific Type B coordination methods also defined by IEEE Std 776-1987 [4].

2. Introduction

In IEEE Std 776-1987 [4], the recommended procedures for determining the source and type of inductive interference are explained. Detailed methods are provided to determine the cause and effect relationship by calculation or direct measurement on the probe wire interface. Tables are given to set the environmental thresholds for the initiation of inductive coordination.

This guide examines the implementation of general and specific mitigation techniques. Note that long accepted practice suggests that both power and communications companies design, construct, operate and maintain their respective systems utilizing general coordination methods, as defined in IEEE Std 776-1987 [4]. Some of the mitigation devices and procedures that are defined as specific mitigation measures have been used by companies as economic trade offs against more expensive general coordination methods. This guide neither recommends nor condemns this practice. IEEE Std 776-1987 [4] suggests that specific mitigation methods should not be employed as the best engineering solution until each company is employing general coordination methods. However, users of this guide should note that implementation of any method or device should include the consideration of timeliness and economics irrespective of the system to which it is to be applied in order to meet each utility company's obligations to their mutual customers and regulatory bodies, as applicable.

¹The numbers in brackets correspond to those of the References in Section 4.. The numbers in brackets, when preceded by the letter "B," correspond to the Bibliography in Section 12.

3. Definitions

coupling: The means by which electric power may be transferred from one conductor to another.

influence: The capability of a power circuit to couple voltage and/or current into nearby communication circuits.

loop current: The dc current flowing in the communications metallic circuit at the customer interface during the talk and signaling states.

power influence: The power of a longitudinal signal induced in a communication circuit by an electromagnetic field emanating from a conductor or conductors of a power system. The unit of measurement is dBrnC.

susceptiveness: The characteristics of a communications circuit including its connected apparatus that determine the extent to which it is adversely affected by inductive fields.

voltage-to-ground: The unweighted longitudinal voltage induced in a communication circuit by an electromagnetic field emanating from a conductor or conductors of a power system. The unit of measurement is volts rms or dBrnF.

4. References

This guide may be used in conjunction with the following documents:

[1] IEEE Std 367-1987, IEEE Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault.²

[2] IEEE Std 455-1985, IEEE Standard Test Procedure for Measuring Longitudinal Balance of Communication Equipment Operating in the Voice Band.

[3] IEEE Std 487-1980, IEEE Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations.

[4] IEEE Std 776-1987, IEEE Guide for Inductive Coordination of Electric Supply and Communication Lines.

[5] IEEE Std 820-1984, IEEE Standard Telephone Loop Performance Characteristics.³

5. Determining the Source of the Problem

5.1 Introduction

Power interference in a communication system results from a three-fold interaction between the power and communication circuits, as depicted in Fig 1.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers Service Center, 445 Hoes Lane, Piscataway, NJ 08854, USA.

³IEEE Std 820-1984 has been withdrawn; however, copies can be obtained from the Institute of Electrical and Electronics Engineers, Standards Department, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

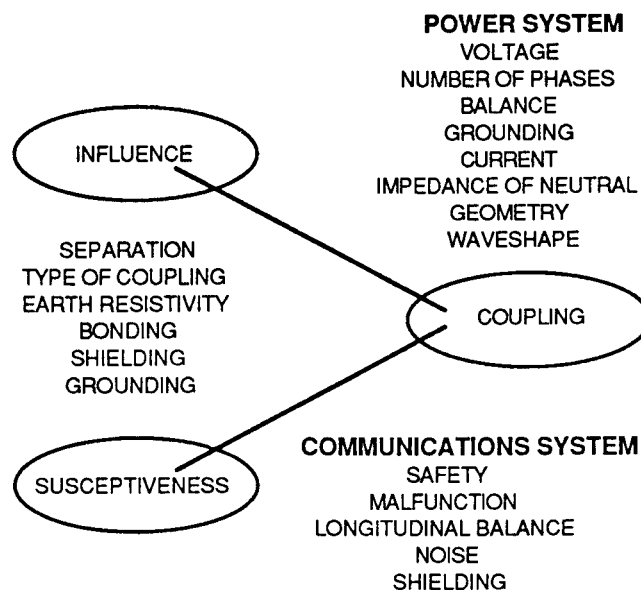


Figure 1 — Interaction: Influence-Coupling-Susceptiveness

5.1.1 Influence

Influence refers to the capability of a power circuit to cause interference in a nearby communication circuit. Unbalanced phase currents, excessive earth return currents and distorted voltage or current wave shapes contribute to high influence. The power utility and its users jointly control or affect influence. A measure of the influence of a power line may be obtained by either utility, through measurements on a probe wire interface placed near and parallel to the power line. Refer to IEEE Std 776-1987 [4].

NOTE — The term power influence introduced in 5.2.1 has a completely different meaning from this traditional concept of the influence of a power system.

5.1.2 Coupling

Coupling refers to the mutual impedance between the power and communication lines [B1], [B2]. Magnetic (inductive) coupling and electric (capacitive) coupling depend upon length of exposure, earth resistivity, frequency, separation and shielding. Mutual impedance may be computed by using equations as found in IEEE 367-1987 [1].

Conductive (resistive) coupling depends upon the size and proximity of ground electrodes of the two systems, as well as on earth resistivity, frequency, and upon the presence or absence of metallic connections between grounded parts of the two systems (and upon the resistance or impedance of such bonds, if present).

Coupling may be affected by either utility, through route planning and facility design/construction.

5.1.3 Susceptiveness

Susceptiveness (or susceptibility) refers to those characteristics that determine the extent to which the service rendered by a communications circuit can be adversely affected by a given longitudinal voltage or current. Susceptiveness can be expressed in terms of relationships between the longitudinal voltage or current and the resulting metallic voltage or current (balance). Alternatively, susceptiveness can be expressed as the limiting voltage or current that a device or system can withstand without malfunction or damage. The communication utility and its users jointly control the susceptiveness of the communication circuit: Refer to IEEE Std 776-1987 [4]. It should be noted that susceptiveness is frequency dependent.

5.2 Communication Noise Investigation

5.2.1 Preliminary Measurements

Communication lines are, in general, reasonably quiet and free from audible interference. Noise investigations usually only take place upon receipt of a customer complaint. A technician would be dispatched to investigate the complaint. Standard equipment is commercially available for the technician to make the following tests from the Network Interface (NI):

- 1) Loop current. The tester should measure and record the milliamperes of direct current flowing through the loop and a 430 Ω resistor with the customer equipment in the on-hook condition. This should be 20 mA or more. Refer to IEEE Std 820-1984 [5].
- 2) Circuit loss. The tester should use a test handset to dial up the office milliwatt. This results in a transmission of a 1004 Hz tone from a 0 dBm supply (1 milliwatt) from the central office. The measuring set in the “circuit loss” setting measures the received level as a negative dBm value. This value should be recorded by the tester. The reading should not be less (more negative) than -10 dBm. This would represent a circuit loss of 10 dB, which should not be exceeded for good communication transmission. Refer to IEEE Std 820-1984 [5].
- 3) Circuit noise. Many test milliwatts automatically switch to a quiet line termination after a short period of time. If this does not happen, the tester should dial a separate Quiet Line number to obtain a grounded balanced termination at the central office. The test set, with the circuit noise setting, would read C Message Weighted Metallic Noise in dBmC. The tester should record this reading.
- 4) Power influence or PI, also called C Message Weighted Longitudinal Noise or C Message Weighted Noise-to-Ground. (Note that some noise measuring sets need a 40 dB correction to be added to the reading to obtain power influence. But the test sets generally available to the technician usually measure PI directly in dBmC.) This reading should be recorded.
- 5) The tester should calculate and record the longitudinal balance from the measured PI and Circuit noise by taking the difference (in dB) between the PI reading and the Circuit Noise reading.
- 6) For the purpose of comparing unweighted to weighted values, measure the rms ac voltage across a 100 000 Ω resistor from the circuit to ground. Convert the voltage reading to an unweighted dBm reading and compare to the C message noise to ground reading in dBmC. Refer to IEEE Std 776-1987 [4].

$$PI_{dBm} = 20 \times \log \left[\frac{V_1}{V_2} \right]$$

where

V_1 = measured rms voltage
 V_2 = [Resistance $\times$ 1 pico watt (10^{-12})]^{1/2}
 Resistance= usually 600 Ω or 900 Ω (test set input resistance)

5.2.2 Noise Performance Thresholds

Information on Noise Performance Thresholds for C message weighted metallic noise, C message weighted longitudinal noise and balance, is given in Tables 1, 2 and 3, respectively (see also [5]). With respect to the performance categories, the ‘Recommended’ levels should be considered as the basic design levels, as well as the objective maintenance levels. The ‘Acceptable’ category, should be considered as a temporary situation only, with full expectation that the performance will be improved to ‘Recommended’ in a short period of time, or, when required, for general or specific coordination.

For example, traditional wisdom indicates that Noise metallic C message weighted less than 20 dBmC will not result in a customer complaint for a noisy line but Noise metallic C message weighted greater than 30 dBmC will, with some possibility of a complaint between these two levels. Based on this, some jurisdictions impose an upper limit of 5% of their lines greater than 20 dBmC with an immediate action limit at 30 dBmC, recognizing of course that the root of the noise problem could be “influence,” “coupling” or “susceptiveness.”

Similarly, “acceptable,” or even “not recommended,” longitudinal noise or balance performance categories could be tolerated if there was no impact on the metallic noise performance of a pair or route.

**Telephone Loop Stand from
(IEEE Std 820-1984)**

Table 1—C-Message Weighted Metallic Noise Performance Thresholds

Noise Level (dBrnC)	Performance Category
≤ 20	Recommended
> 20 and ≤ 30	Acceptable
> 30	Not recommended

Table 2—C-Message Weighted Longitudinal Noise Performance Thresholds

Noise Level (dBrnC)	Performance Category
≤ 80	Recommended
> 80 and ≤ 90	Acceptable
> 90	Not recommended

Table 3—Longitudinal Balance Performance Thresholds

Balance (dB) (C-Message)	Performance Category
≤ 60	Recommended
50–60	Acceptable
< 50	Not recommended

5.2.3 Analysis of Measurement Results

The Circuit Noise/Power Influence/Balance relationship has the following implications:

- 1) A high PI reading indicates one or more of the following: high influence of a nearby power line, insufficient separation between the power line and the communication cable, or poor shielding of the communication cable. Poor shielding may be due to defective bonding and/or grounding of the communication cable.
- 2) A low longitudinal balance may indicate cable trouble (i.e., defective splices or wet cable), left-in service wire, grounded ringers, or operated protectors. Note that the balance may be degraded by either a series unbalance, where the impedance of the two communication conductors is not equal, or by a shunt unbalance, where the impedance to ground of both communication conductors is not the same.

5.2.4 Communication Technician's Follow-up

Communication utilities have standard practices regarding repair and maintenance of their network facilities. The follow-up for any case of trouble usually includes:

- 1) Checking and replacing (if necessary) the network interface or communication protector.
- 2) In the case of low balance, progressively sectionalizing the circuit into smaller and smaller sections, testing in each direction from the point of sectionalization, to seek and correct the source of unbalance.

- 3) If the power influence is still excessive, the trouble is referred to an expert in noise mitigation measurements and techniques, or to a specialist versed in Inductive Coordination and Electrical Protection. To simplify further discussion, such specialist will hereinafter be referred to as the “ICEP Engineer.”

5.3 Coordination Between Power and Communication Utilities

5.3.1 ICEP Engineer's Follow-up

Having received a complaint of high power influence in a particular communication cable, the ICEP engineer could employ any of a number of trouble-shooting techniques to determine the worst exposure and to analyze the nature of the interference.

Many power utilities have inductive coordination engineers, protection engineers or communications engineers who are experts in not only their own system operation, but in noise measurement and mitigation as well. For future discussion, such a person will be referred to as the power engineer. The ICEP engineer should be acquainted with the power engineer. Ideally, both of them would have a day-to-day working arrangement for the investigation and mitigation of power interference.

A common denominator in the search for the interference is the use of some type of spectrum analyzer, as a substitute for, or in addition to, the simpler test set used by the technician. Spectrum analyzers range from a hand-tuned analog variety with a “nixie tube” digital display to the Fast Fourier Transform (FFT) device with a visual display of the whole spectrum.

Some communication utilities also utilize personal computers to control, via an IEEE Std 488 Interface, the measurements by the Spectrum Analyzer. A few utilities have specially designed and equipped mobile laboratories housed in vans, to identify and initiate the best engineering solution in a timely manner. Following are some measurement techniques:

- 1) Exploring Coil. The ICEP Engineer may use a hand-held or vehicle-mounted exploring coil to follow the suspect power line, while observing the reading of a noise measuring set (NMS) or Spectrum Analyzer (SA) connected to the exploring coil. The exploring coil consists of a number of turns of insulated fine gauge wire formed into a circular or rectangular air core coil. For safety reasons, two persons would customarily participate in any vehicular reconnaissance.
- 2) Probe Wire. As described in IEEE Std 776-1987 [4], a 100-foot (30 m) long insulated wire may be placed on the ground parallel to the power line and terminated on a ground rod or probe at each end. The measuring set input circuit is connected in series with the probe wire and ground electrodes. The standard radial separation of the probe wire from the power line is 50 feet (15 m) for a distribution line and 75 feet (23 m) for a transmission line. (See IEEE Std 776-1987 [4].)
- 3) Power Station Current Transformers (CT's) and Potential Transformers (PT's). Most electric substations contain control circuitry that depends upon measurements of phase current and voltage to ground for relaying, telemetering or supervisory control.

With the concurrence of the Power Engineer, and with the assistance of the power utility relay technician(s), access may be gained to the secondaries of the CT's and PT's for input to the spectrum analyzer or noise measuring set.

CAUTION — Extreme care is necessary to avoid causing relay misoperations and to avoid open-circuiting the secondary of a CT. Connections to CT's and PT's should only be done by a competent power relay technician or relay engineer.

5.3.2 Determining the Source of Power Interference

Having determined the nature and severity of the influence from the power system, the ICEP Engineer's next task would be to seek an explanation for the high influence, and to request help from the Power Engineer.