Engineering Standard

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Telecommunications - Inductive Coordination

Document Responsibility: Communications Standards Committee

Saudi Aramco DeskTop Standards

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Primary contacts: Ghamdi, Khalid Sulaiman on +966-13-8801354 and
Nufaii, Abdullah Sufran on +966-13-8801359

1 Scope

This standard prescribes minimum mandatory requirements governing the technical objective related to inductive coordination between power lines and telecommunication lines.

2 Conflicts and Deviations

Any deviations, providing less than the mandatory requirements of this standard require written waiver approval as per Saudi Aramco Engineering Procedure SAEP-302.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall apply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302 *Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-B-008 *Restrictions to Use of Cellars, Pits and Trenches*

SAES-B-068 *Electrical Area Classification*

SAES-P-107 *Overhead Distribution Systems*

SAES-T-634 *Communications - Cable Testing and Identification*

SAES-T-887 *Telecommunications: Electrical Coordination - Protection at Power Plants and Radio Stations*

SAES-T-903 *Telecommunications Outside Plant Electrical Protection & Grounding*

3.2 Industry Codes and Standards

NFPA 70 *National Electrical Code (NEC)*

IEEE C2 *National Electrical Safety Code (NESC)*

IEEE 776 *IEEE Recommended Practice for Inductive Coordination of Electric Supply and Communication Lines*

IEEE 1137	*IEEE Guide for the Implementation of Inductive Coordination Mitigation Techniques and Application*
IEEE 487	*IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations*

4 Definitions and Terms

Decibel: The decibel (dB) is used to compare voltages, currents or power levels. The advantages of the dB are that large differences in levels can be expressed by a simple number, and losses or gains can be added algebraically.

$dB = 10 \log P_1/P_2$ or

$dB = 20 \log V_1/V_2 = 20 \log I_1/I_2$

The dB is also used to express absolute values when followed by a suffix, by comparing a magnitude to a reference value.

The power ratio doubles for every +3 dB, and halves for every -3 dB

dBrn: dBrn is dB above the reference noise level of 1 Pico Watt. Noise measurement sets use a termination of 600 Ohms; therefore, voltage at reference noise is 24.5 Micro Volt.

C Message Weighting Factor - C_f: The amount of interference a noise signal causes depends on frequency as well as magnitude. C Message weighting was designed to take this frequency effect into account. It is the combined response of the human ear, the 500-type telephone set, and telephone circuits to different frequencies. It is most responsive to frequencies in the 800 to 2000 Hz ranges. Noise measuring sets have C Message filters so they can measure the true effect of various frequency components of noise. The C Message weighting factor is designated C_f.

dBrnC: dBrnC is dB above reference noise with C Message weighting.

Noise Metallic (Nm-dBrnC): Noise Metallic (Nm) in dBrnC is the C Message weighted voltage measured between the conductors of a telephone circuit, usually measured at the subscriber end. With a quiet termination at the central office side, it is the noise that the user actually hears. Recommended design value for Nm is less than or equal to 20 dBrnC

Noise-to-Ground (Ng-dBrnC): Noise to Ground (Ng) in dBrnC is the C Message weighted voltage measured between the conductors of a telephone circuit and ground, with the far end of the line grounded. A user does not hear noise to ground.

Balance (B-dB): Telephone circuit balance (B) is an indication of the quality of a telephone circuit, and it is a measure of how closely the two conductors are equal in impedance to ground. Recommended design value for B is less than or equal to 60.

Power Line Influence (PI-dB): Magnetic induction occurs on aerial, underground and buried telecommunication cables. Current in power line causes an alternating magnetic field around the power conductors. A telecommunications cable adjacent to the power line will experience an induced voltage on the cable pairs and the metallic shield.

Coupling: Coupling is the mechanism whereby voltages on an adjacent telecommunications line, and is present whenever a power line route parallels a telecommunications line route. Coupling increases with frequency and earth resistivity. Coupling generally decreases when separation between the two facilities is increased. Separation is the only factor we can control at the design stage.

Susceptibility: A cable, which has an effective shield and well-balanced pairs, is less susceptible to induction. Almost no shielding is provided at 60 Hz, but a shield that is electrically continuous and effectively grounded at each end will provide shielding of about 10 db overall at noise frequencies.

Longitudinal Voltage: Longitudinal voltage is the induction caused by coupling between the power line and the telephone line. It results in a voltage along the telephone conductors with return through earth. The induced voltage in each conductor is in the same direction and approximately equal in magnitude.

Metallic Voltage: Metallic voltage is the induction, which occurs between the two conductors of the telephone pair. This occurs because of a difference in the longitudinal voltages of the two wires of a pair, caused by a telephone circuit's unbalance to ground.

Mitigation: Mitigation is the application of devices or methods to lessen or moderate the effects of induction.

Telephone Influence Factor (T or TIF-dimensionless): A measure of the interference of power-line harmonics with telephone lines, which is derived by weighting the terms in the mathematical expression for the total harmonic distortion of the power-line voltage. IT is an index of the interfering effect - of different harmonic frequencies of the power line currents and voltages on nearby telephone circuits.

I*T: The I*T of a power line is the product of the RMS value of the current waveform (I) and the TIF of the current waveform (T). The “Balanced I*T” is the I*T *value* of the phase currents. The “Residual I*T” is the I*T value of the neutral (ground return) current.

W_f (dimensionless): W_f is the TIF weighting factor for each harmonic.

Shielding Factor (S): Most telephone cables have a metallic shield, which is a low-resistance metal tape surrounding the cable core. The shield is grounded at both ends of the cable route, and tends to cancel induction voltages on cable pairs. Without proper grounding, the shield has virtually no effect. Shielding factor is the ratio of voltage induced with shield being grounded at both ends to voltage induced without shield being grounded. A shielding factor of 1.0 indicates no shielding, and a shielding factor of 0.5 indicated that the shield reduces the induced voltage to one-half of the unshielded voltage. For design purposes, typical value of 0.3 could be used.

Uniform Exposure: When the power line is continues with uniform separation from the telecommunications cable.

Slanting Exposure: When the power line is continues with varying separations, or telecommunications cable is exposed to induction from more than one power line.

5 Design

IEEE 776 Recommended Practice for Inductive Coordination of Electric Supply and Communication Lines, IEEE 1137 Guide for the Implementation of Inductive Coordination Mitigation Techniques and Application are hereby adopted as the reference standards for design and mitigation of telecommunications inductive coordination. Copper OSP serving electrical substations shall also comply to IEEE 487 Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations.

5.1 Noise Objectives

5.1.1 Noise Metallic: Noise metallic at the telephone set shall be 20 dBrnC.

5.1.2 Telephone Circuit Balance: The objective shall be 60 dB or more.

5.1.3 Noise-to-Ground: A design value of 80 dBrnC shall be used since the objective for noise metallic is 20 dBrnC and a circuit balance of 60 dB.

Noise-to-Ground interpretations, reviews, calculations and mitigation equipment shall be included with the design package.

5.1.4 Shielding Factor (S): For design purposes, typical value of 0.3 should be used.

5.2 Mathematical Basis for Design of Horizontal Separations

5.2.1 Relationship between I*T and Noise to Ground

The relationship between I*T and Noise-to-Ground on telephone cable pairs shall be defined by the following formula:

Ng = 20 log 0.0513 m L I*T S in dBrnC (1)

where m = mutual inductance between the power line and the telephone cable, in μH per km

L = length of parallel in km,

I*T = residual power line current times TIF (weighted A)

And S = shielding factor of the telephone cable.

Commentary Note 5.2:

For TIF (weighted A) of 700, shielding factor (S) of 0.3; equation 1 may be simplified as:

*Ng = 20.65 + 20 log m*L in BrnC (1-A)*

5.2.2 Noise to Ground versus Voltage

When measuring noise-to-ground C Message weighting shall be used. (Various frequencies are attenuated in accordance with the C Message curve, and there is no simple relationship between voltage and dBrnC). When using a flat weighting such as 3 kHz, Noise to ground in dBrn shall be:

$$Ng = 20 \log V/24.5 * 10^{-6} \quad (2)$$

5.2.3 Weighted Amperes and dBA

Power line I*T shall be measured in dBA, which is dB above 1 Ampere. The relationship between I*T in weighted Amperes and dBA shall be as follows:

I*T in dBA = 20 log I*T in weighted Amperes, or (3)

I*T in weighted A = 10dBA/20 (4)

The following table shall be used to convert I*T in weighted Amperes to dBA:

Wtd A	300	500	700	1000	2000
dBA	49.50	54	56.90	60	66

5.2.4 Noise Design Charts

The mathematical relationships in Section 5.2 shall be used to draw up a family of curves for a simple method of determining horizontal separations required for various lengths of parallels and power line I*T values. For copper telecommunications cable a noise to ground design value of 80 dBrnC is used.

5.3 Power Line I*T Measurements

5.3.1 The I*T of a power line shall be measured using a probe wire or an exploring coil such as HP3582A, and a wave analyzer such as Wilcom T132Z or T136.

5.3.2 Measurement shall be made without direct connections to the power line.

Commentary Note 5.3.2:

A 30 m probe wire provides more accurate results than the exploring coil. Exploring coil measurements are quicker, and are satisfactory. The exploring coil also has the advantage that it can be used in rocky areas where it is not possible to drive ground rods for probe wire measurements.

5.4 Design Procedures – Noise Design Charts

Exhibit (1) shall be used for a quick way to design the required separation for a uniform exposure. Power line I*T value of a 46 dB (200 wtd A) shall be used. Knowing the length of the parallel, the required separation shall be determined.

5.5 Uneven Separations

When the power line is continues with varying separations, or telecommunications cable is exposed to induction from more than one power line, it shall be necessary to calculate the separation requirement in more detailed.

Commentary Note 5.5:

When there is one power line with varying separations, we can assume that induction voltages from each section add in phase that is they combine on a current basis. When there are several power lines contributing to induction on one telephone cable, we consider that induction voltages from different sections add on a random or power basis because the frequencies and phase relationships of harmonic currents on different power lines are unrelated. A simple method of adding two dB values such as noise is to find the difference between the two noise levels, and add the appropriate combining term from table to the larger number. Similar methods can be used to combine more than 2 dB quantities.

Table 1

Difference in dB	Combining Term	
	Voltage/Current	Power
0.0	6.0	3.0
0.6 to 1.6	5.5	2.5
1.7 to 3.0	5.0	2.0
3.1 to 3.9	4.5	1.6
4.0 to 5.3	4.0	1.3
5.4 to 6.8	3.5	1.0
7.2 to 8.5	3.0	0.7
8.6 to 10.5	2.5	0.5
10.6 to 13.0	2.0	0.3
13.1 to 16.2	1.5	0.2
16.3 to 20.9	1.0	0.1
21.0 to 30.6	0.5	0.0
30.7 and up	0	0.0

Example of Combining Noise on a Voltage Basis (in phase)

*Assume a cable exposed to a power line with an I*T of 700. Separation is 100 m for 4 km and 200 m for 4 km.*

From Exhibit 2, m=95 for a separation of 100 m and m=42 for separation of 200 m.

For the first section:

Using Eq. 1-A with m=95 and L=4 km, Ng is 72 dBrnC.

For the second section:

Using Eq 1-A with m= 42 and L = 4 km, Ng is 65 dBrnC.

Combine the induction voltages from the 2 sections on a voltage basis:

The differences is 7 dB, the combining term is 3.0 dB

Example of Combining Noise on a Power or Random Basis

*Assume that a cable is exposed to 3 different power lines. One power line has an I*T of 500 and extends for 3 km at a separation for 100 m. The second power line has an I*T of 750 and has a separation of 150 m for 10 km. The third line has an I*T of 560 and runs for 4 km at a separation of 200 m.*

From Exhibit (2), m=95 m for 100 m separation, m=60 for 150 m separation and m=42 for 200 m separation. Assume a shield factor of 0.3:

For the 1st section:

*Using Eq. 1 with m = 95, I*T = 500, L = 3 km, and S = 0.3; Ng is 66.8 dBrnC*

For the 2nd section:

*Using Eq 1 with m = 60, I*T = 750, L = 10 km, and S = 0.3; Ng is 76.8 dBrnC*

For the 3rd section:

*Using Eq 1 with m= 42, I*T = 560, L = 4 km, and S = 0.3; Ng is 63.2 dBrnC*

Combining the first two sections:

The difference is 76.8 - 66.8=10 dB,

From Table-1 the combining term for power summation is 0.5 dB.

So, Ng for bothe sections will be 76.8 + 0.5= 77.3 dBrnC.

Combining this value with the third section:

The difference is 76.8-63.2=14.1 dB.

The combining term (using Table 1) is 0.2 dB.

Therefore the total expected noise-to-ground is 77.3+0.2 = 77.5 dBrnC, this value is within the acceptable range.

5.6 E1 Carrier cable

5.6.1 Cable pairs carrying E1 carrier signals shall not be affected by noise induction from power lines. However, faults locate and order wire pairs operate at voice frequency shall require the same separation from power lines as user lines.

5.6.2 In case of severe 60 Hz longitudinal induction the line repeaters shall experience powering problems. These problems shall usually overcome by using line repeaters with high immunity to 60 Hz induction.

5.7 Fiber Optic Cables

Optical fibers shall not be affected by electrical voltages and currents. However, if the cables contain metallic components such as copper pairs, steel strength member and aluminum shield, grounding shall be in accordance with the requirements of SAES-T-903. Refer to SAES-T-887 for appropriate protection requirements if the cable is subjected to severe exposure due to fault current or ground potential rise (GPR).

5.8 Joint Use

5.8.1 Joint-use shall be avoided where possible, because of noise and protection problems that may result. If joint-use is the only feasible method of construction, both telecommunications and power facilities shall be grounded as described in Sections SAES-T-903 and SAES-P-107. However, ensure that no point on the cable is more than 150 m (500 ft.) from a bond to the power ground.

5.8.2 To avoid noise problems, maximum telecommunications cable length for joint use with power line shall be 1.5 km.

5.9 Mitigation

IEEE 1137 proposes techniques for controlling and mitigating of inductive coordination.

5.9.1 Shield Continuity

This is actually belongs to normal maintenance, however, it is easier to check this electrically than visually. The ground at each end shall be 5 Ohms or less.

5.9.2 Cable Pairs transposing to improve Balance

If exposed cable pair balance is less than 60 dB and there is a noise on the cable pairs, transposing the cable pairs may help. At several locations, splice tip to ring and ring to tip. It is necessary to flag these splices so they are not restored to their original state by splicers who are not informed of why the reversal was made.

5.9.3 Noise Chokes

Noise chokes shall be inserted in series with exposed cable pairs at the switching center to reduce the longitudinal current flow and thus reduce the effect of pair unbalance.

5.9.4 Induction Neutralizing Transformers

Induction neutralizing transformers shall be placed in series with exposed cable pairs to reduce 60 Hz induced voltage. For induction neutralizing transformer designed for use with PCM carrier systems, the transformer shall be located in the center of the span.

5.9.5 Carrier

Subscriber Carriers shall be used in place of exposed voice frequency operation. Subscriber carrier is immune to normal noise frequency induction from power lines.

5.9.6 Relocation

As a last resort, telecommunications cables shall be relocated to increase the separation from power lines, thus reducing coupling.

5.10 Coordination

Power Distribution Department and the Engineering Department of IT provide essential services to the same users. There shall be mutual responsibility to cooperate in preventing and mitigating interference in the services provided.

6 Installation

The installation of all telecommunications cables shall comply with this standard, NFPA 70, IEEE C2, general requirements related to land use, clearances, road or pipeline crossings, etc. Construction in or near Hazardous or Classified areas shall comply with SAES-B-008, SAES-B-068, IEEE C2 (NESC), NFPA 70 (NEC), and other applicable codes and standards.

7 Testing and Inspection

The testing and acceptance of all telecommunications cables shall be done in accordance with SAES-T-634. Quality assurance inspections shall be performed during all phases of construction by a Saudi Aramco Telecommunications Inspection Department Inspector.

Revision Summary

17 September 2013	Revised the “Next Planned Update”. Reaffirmed the contents of the document, and reissued with minor revision.

Exhibit (1) – Noise Design Chart

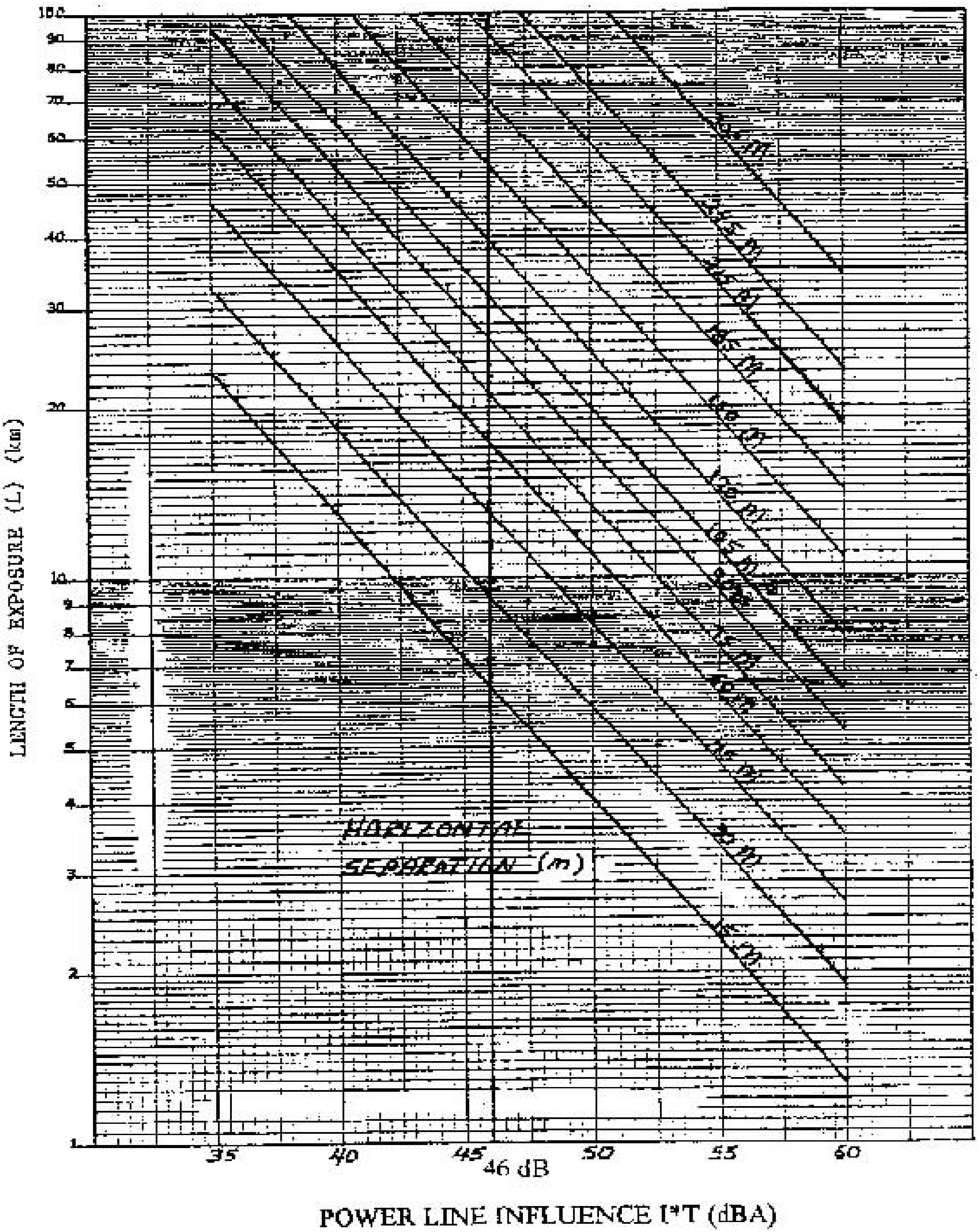

Exhibit (2) – Mutual Inductance - Horizontal Separation Chart