Engineering Standard

SAES-T-887 21 May 2012

Telecommunications: Electrical Coordination
- Protection at Power Plants and Radio Stations

Document Responsibility: Communications Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This Standard prescribes mandatory requirements for electrical protection of telecommunications plant serving or in proximity of power facilities and communications radio stations.

2 Conflicts and Deviations

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

3 References

All referenced Specifications, Standards and Codes, Forms, Drawings and similar material shall be of the latest issue (including all revisions, addenda and supplements) unless stated otherwise. Applicable references are listed below.

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-P-111	*Grounding*
SAES-T-435	*Telecommunications Station Protection*
SAES-T-634	*Telecommunications Cable Testing & Acceptance*
SAES-T-795	*Communication Facility Grounding Systems*
SAES-T-903	*Communications Electrical Protection - Outside Plant*

Saudi Aramco Standard Drawings

AA-036361	*VHF/UHF Antenna, and Installation on Self Supporting Towers*
AA-036765	*Grounding for Remote Communications Sites*

3.2 Industry Codes and Standards

National Fire Protection Association

NFPA 70	*National Electrical Code (NEC)*

NFPA 78	*National Fire Protection Association*

Institute of Electrical and Electronics Engineers

IEEE 81	*Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System*
IEEE 487	*Guide for the Protection of Wire Line Communication Facilities Serving Electric Power Stations*

Underwriters Laboratories, Inc.

UL 497	*Protectors for Paired Conductor Communication Circuits*
UL 497A	*Secondary Protectors for Communication Circuits*
UL 497B	*Protectors for Data Communication and Fire Alarm Circuits*

4 Design

Mandatory requirements are listed herein.

4.1 Electrical Protection Engineering Fundamentals

This section describes the engineering fundamentals involved in attaining the goals of electrical protection. These goals include safeguarding:

- Life.
- Property.
- Communication services.

4.1.1 Telecommunication outside plant facilities shall be protected from foreign voltages such as:

a) Lightning,

b) Accidental contact with light or power lines of 300 volts or more,

c) Voltages electromagnetically induced into communication lines by fault currents in paralleling power lines,

d) Voltages electrostatically induced into the communication lines by normal currents in paralleling power lines,

e) Ground potential rises due to the flow of lightning or power fault currents.

4.1.2 Ground Potential Rise (GPR)

When communications facility with metallic member is within 1.0 km of power facility, a GPR analysis shall be done. Based on the calculated GPR voltages, appropriate protection devices and grounding shall be incorporated in the design of the communications facility. The cable design or location shall be such that the GPR exposure does not exceed 50% of the cable core-to-sheath dielectric rating. GPR calculations, grounding and recommended protection equipment shall be provided as part of the project design package. Only if there is uncertainty regarding provided design, interpretations shall be provided through the Saudi Aramco Communications Standard Committee Chairman. A copy of the GPR analysis shall be included with the design package.

4.2 Protection design of communication facilities serving electric power stations shall be as follows:

4.2.1 Minimum Protection Requirements at Power Stations are indicated in Table 1.

4.2.2 Required Pair Identification and Physical Safeguards

Safeguards shall be provided, during installation, for Class "A" or Class "B" services circuits, wherever they appear in wires, cables, pedestals, microwave locations, radio sites, building terminals, distributing frames (CDF, MDF, and IDF), and anywhere else the circuits are physically accessible. From the point of origin to the point of termination or destination, these services shall be clearly identified and safeguarded as follows:

a) Provide physical protection and identification at every point in the cable distribution system where the conductors appear outside the cable sheath.

b) Materials and supplies to be used in safeguarding these services shall be red in color and shall include cable warning tags, labels, stenciling in red ink or red paint, binding post caps, plastic separators on connector blocks, etc.

Table 1 – Minimum Protection Requirements at Power Stations

SPO (Service Performance Objective)	GPR (Ground Potential Rise) + Induced Voltage Level in Volts GPR<300	300<GPR<1000	GPR>1000
Class A (Critical Circuits, non-interruptible type service; must work during power fault)	No special protection is required	Special high voltage protection is required (Optical Isolators such as Teleline Isolators(1), Tucon(2) Fiber links, or ABB Fiber Optic System(3), Neutralizing Transformers, dedicated cable with isolated shield)	Special high voltage protection is required [Optical Isolators such as Teleline Isolators(1), Tucon(2) Fiber links, or ABB Fiber Optic System(3), Neutralizing Transformers, dedicated cable with isolated shield]
Class B (Emergency circuits that may be interrupted for not longer than duration of power fault. Service restored without human intervention)	No special protection is required	Solid state protection is required, dedicated cable with isolated shield may be required.	Special high voltage protection is required (Optical Isolators such as Teleline Isolators(1), Tucon(2) Fiber links, or ABB Fiber Optic System(3), Neutralizing Transformers, dedicated cable with isolated shield)
Class C (Circuits that can be interrupted until a station visit is made to restore service)	No special protection is required	Solid state protection is required.	Special high voltage protection is required. (same as for Class A & B)

Notes: (1) The Teleline Isolator is a trademark product of Positron Indus. Inc.
(2) The Tucon Optical Link is a trademark product of Ericsson
(3) The ABB Fiber Optic System is a trade mark of Asea Brown Boveri

Commentary Note:

Refer to 1985 AT&T Manual on "Telecommunications Electrical Protection" for more detailed information.

4.2.3 If GPR exceeds 1000 V, the Cable shield must be:

a) Isolated from ground at all locations on the power station premises and at pedestals within the zone of influence. Pedestals shall not be placed in a zone of influence, where the GPR level is 300 volts or greater.

b) Isolate the shield from ground but maintain shield continuity within the zone of influence.

4.2.4 Safety Precautions

When working in power substations and other high voltage areas, personnel must:

a) Use insulating gloves.

b) Check the grounds with a high voltage detector (General Machine Products, B Voltage Tester or equivalent high voltage tester). Volt-Ohm meters shall not be used to test grounds and other points of probable high voltages (Volt-Ohm meter will be required to perform continuity and polarity test as part of SAES-T-634, Cable Testing and Acceptance standards).

c) If isolated cable shields are accessible to touch during any work operation, cable shields shall be bonded to the power station ground to ensure safe working conditions for communication employees while they are working on these cables. The bond must be removed after the work has been completed.

d) Put on high voltage insulating gloves and wear them when making connections to ground terminals or working on cable shields at power stations.

e) Avoid contact with other metal objects within the power station grid area when installing communication equipment and doing cable work.

4.3 Power Station Protection, Remote Ground Arrangement

4.3.1 The Remote Drainage Location (refer to IEEE 487) must be placed outside the effective range of influence (GPR is 300 volts or less) of the power station GPR at a location where it is possible to establish a low resistance (25 ohms or less) 'man made' ground.

4.3.2 Cable pairs and cable shields or armors, when present between the high-voltage interface location and the Remote Drainage Location, must not be connected to or contact the ground structure at the power station. The cable must be routed through insulating conduit (PVC) in the station grid area if the GPR level is greater than 1000 volts.

4.3.3 The Remote Drainage Ground must be no closer than 6 m (20 feet) to the Dedicated Cable shield ground (refer to IEEE 487). The 6 m (20 feet) spacing is the minimum distance required to prevent coupling through the earth between grounds if the dedicated cable shield should inadvertently contact the power station grounding structure.

4.3.4 Solid state protectors must be provided on all cable pairs at the Remote Drainage Location to limit voltages on cable pairs to a safe level before entering the General Use Cable (refer to IEEE 487). Protectors shall be UL 497, UL 497A, or UL 497B listed.

4.4 Engineering Fundamentals of Electrode Ground Design

4.4.1 All electrode designs and installations must comply with:

- Saudi Aramco Standards (refer to paragraph 3.1 above)
- National Electrical Code
- National Electrical Safety Code
- Sound engineering judgment.
- SAES-P-111 when connections are made to power electrodes.

4.4.2 All corrosion measures shall be coordinated with the Corrosion Control Division of the Consulting Services Department.

4.5 Fundamentals of Ground Measurements

Ground resistance and soil resistivity shall be measured in accordance with IEEE 81.

4.6 Fundamentals of Inductive Coordination for Communication Circuits

4.6.1 Approved Equipment for Noise Harmonics Measurements are:

a) Northwest Electronics Model TTS-37B Noise Measuring Set or equivalent.

b) HP Model 3551 A or equivalent.

c) Wilcom Model T 136 or equivalent.

d) Wilcom Model T 132 B or equivalent

4.6.2 Mandatory Noise Requirements

Table 2 shows the acceptable noise measurement values.

Table 2 – Noise Measurement Values

Noise Metallic	Not to exceed 20 dBrnC
Noise-to-ground	Not to exceed 80 dBrnC
Balance	Not less than 60 dB

4.7 Determination of Minimum Separation between Digital Sites and Electric Power Facilities

Telecommunication digital facilities shall not be located where the maximum Ground Potential Rise (GPR) exceeds 300 volts peak, or where

the Electromagnetic field originated by a fault in the power system would impose more than 3.33 Joules within the digital communication facility when calculated as followed:

$$\text{The amount of energy (in Joules)} = (Vi^2/Rd) * t$$

Where:

Vi is the peak value of the induced voltage = 1.414 * Imf * Zm * Ls

Imf is the maximum fault current

Zm is the mutual impedance of the site

Ls is the length of the exposed facility

Rd is the resistance of the most susceptible electronics component

t is the maximum clearing time of the power system (in seconds)

4.8 Engineering Considerations Radio Station Protection

4.8.1 Construction and Design Considerations

4.8.1.1 Grounding System Design Requirements

Microwave station ground resistance shall not be greater than 2 ohms.

4.8.1.2 Bonding Connection Requirements

a) Ground connections shall be made according to the following:

- Buried ground accepted method of connecting is brazing by either powdered metal method (exothermic weld), or acetylene-oxygen method.
- Use UL listed pressure clamps method for bond connections to elements under tension.

b) Bonding connections shall be made according to the following:

- When clamping to a structural member, use UL listed clamp that does not require drilling a hole in the structural member.
- Structural members of towers (down guys and anchor rods) shall not be welded to the grounding conductors.
- Bonds made to the power ground system shall comply with SAES-P-111.

4.8.1.3 Grounding Conductors Grounding Requirements

a) Grounded structures (water pipes, metal conduit, manholes, gas pipes, etc.) shall be bonded to grounding conductors when they are located within 2 m (6 feet) of each other.

b) The unavoidable bends shall have a large radius. The minimum acceptable bending radius shall be:

- 15 cm (6 in) for sizes up to No. 6 AWG (16 mm^2).
- 30 cm (12 in) for sizes more than No. 6 AWG (16 mm^2) and up to No. 4/0 AWG (120 mm^2).
- 60 cm (24 in) for sizes greater than No. 4/0 AWG (120 mm^2).

c) Use a minimum of #2 AWG (35 mm^2) tinned solid copper wire when burying grounding or bonding conductors.

4.8.1.4 Ground Rods Specifications

Ground rods shall be:

a) 10-feet (3.0 m) long by 5/8-inch diameter

b) Connected to the ground ring

c) Spaced at a minimum of 3 m (10 feet)

d) Driven to a depth of at least 3 m (10 feet)

4.8.1.5 When installing fuel tanks:

a) Do not locate a fuel tank between towers and radio station buildings.

b) Avoid burying a tank close to a tower ground if the tank is not metallic or not bonded to the grounding systems in the site.

c) The distance between the tank and the tower grounding electrode shall be a minimum of 5.0 m (15 feet) where soil resistivity is less than 100 ohm-meter and a minimum of 8.0 m (25 feet) in areas where soil resistivity is above 100 ohm-meter.

d) Ground fuel tanks by clamping the ground wire to the filler pipe or other external hardware. Do not weld or drill on the tank itself.

e) Bond buried metallic structures (fuel pipes, water pipes, ground rings, etc.) together where they pass within 2 m (6 feet) of each other.

4.8.2 Grounding Considerations

4.8.2.1 Grounding Arrangements

a) Fixed radio stations shall be grounded using inner (inside building) and outer (outside building) ground ring concept.

b) Grounding connections outside the building shall be made to the outer ground ring.

c) The outer ground ring shall be composed a minimum of #2 AWG (35 mm²) solid tinned copper wire and shall be buried not less than 0.8 m (2.5 feet) below grade level and at least 0.6 m (2 feet) outside foundation and tower footings.

4.8.2.2 Towers on Top of Multilevel Buildings

a) Combine the tower grounding with the lightning protection system.

b) Bond the tower grounding to other grounding systems at a point outside building according to SAES-P-111 and NFPA 78 guidelines.

c) Provide multiple paths of discharge (minimum of one down conductor for each corner) around the building perimeter.

4.8.2.3 Radial Grounding Conductors

a) Radial conductors shall be connected to the ground ring using a minimum of #2 AWG (35 mm²) tinned copper wire.

b) Radial conductors shall be buried a minimum of 0.8 m (30 inches) below grade level.

c) Radial conductors shall be a minimum length of 8.0 m (25 feet) and extend as far as required to obtain the desired resistance.

4.8.2.4 Ground Wire around Self-Supporting Tower

a) Ground wires around a self-supporting tower shall be no less than:

- 0.8 m (2.5 feet) below grade level,
- 600 mm (2 feet) from the outside face of the concrete piers.

b) The tower ground ring shall be bonded:

- To the grounding plate twice (if one exists),
- To each tower leg,
- To the ground rods,

- To the building outside ground ring.

c) If conduit is required for physical protection of a ground wire, use non-metallic (PVC) conduit. If metallic conduit must be used, the ground wire shall be bonded to both ends of the metallic conduit.

4.8.3 Antennas and Transmission Lines

This section covers the protection and grounding considerations for:

- Radio station antennas.
- Transmission lines.

4.8.3.1 VHF/UHF Antennas

See Standard Drawing AA-036361, "VHF/UHF Antenna Installation on Self Supporting Towers" for antenna installation and protection.

a) The coaxial type of antenna shall be protected by connecting a star gap arrestor between:

- Inner coaxial conductor (whip), and
- Outer coaxial conductor (skirt) of the antenna.

b) The radiating element of the collinear-array type omnidirectional gain antenna shall be grounded.

4.8.3.2 Coaxial Transmission Lines

a) Bond the coaxial outer conductor to tower structure or down ground lead at the top, and at the bottom of the tower and at 60 m (200 feet) maximum intervals along the length of the coaxial cable.

b) Bond the outer conductor to the ground wire at the top and at the bottom of the pole if coaxial cables are placed on wood poles.

4.8.3.3 RF Surge Suppressors

a) Mount Radio Frequency (RF) surge suppressors at the base of the tower prior to the radial turn toward the building or on the bulkhead.

b) Connect the suppressor's ground lead to the building or tower ground ring.

c) Do not install RF surge suppressors inside the building.

4.8.4 Antenna Supports

a) Antenna Locations

When an antenna support is mounted on the roof of a building, ground leads connections shall follow the rules in the Lightning Protection Code NFPA 78. The following items shall be connected to the grounding system:

- Antenna and antenna supports
- Guy wires
- Guy wire anchors

b) Ground Leads Selection

- Where the height of the antenna plus the roof is less than 23 m (75 feet), use Class I lightning cable, (Copper 187 pounds/1000 feet, 57,400 CM (Circular Mils) with strands no less than #17 AWG (1.29 mm^2).
- Where the height of the antenna plus the roof is more than 23 m (75 feet), use Class II lightning cable (Copper 575 pounds/1000 feet, 115,000 CM with strands no less than #16 AWG (1.31 mm^2).

c) Ground Down Leads

- Ground down leads shall be protected against corrosion when they enter corrosive soil by using corrosion resistant conductors and hardware up to a level no less than one meter (3 feet) above grade and for the entire length of below grade levels.
- Protect ground down leads against physical damage for a minimum of 2.5 m (8 feet) above grade level.

d) Antenna Support Protection

- If the antenna support is mounted on a building with a metal frame and the antenna support is metal, bond the antenna support and the coaxial outer conductor to the metal building frame with Class II secondary conductor cable [14 strands each of no less than #17 AWG (1.29 mm^2) Copper conductor cable].
- Connect down guys to the ground rod as detailed on Standard Drawing AA-036765.
- Provide a system of down leads if the building does not have a metal frame, see paragraph 4.8.2.2.

- Non-live metallic objects 2 m (6 feet) apart or less shall be bonded together using Class II secondary conductor cable [14 strands each of no less than #17 AWG (1.29 mm²) Copper conductor cable].

e) Guyed Anchors Grounding

When soil has a high resistivity (70 ohm-meter or more) or guy wires are anchored in concrete:

- Drive 10 feet by 5/8 inch ground rods in a triangular shape around each anchor.
- Bond the ground rods to each other with a minimum of #2 AWG (35 mm²) tinned solid copper wire.
- Ground the guy wires with a minimum of #2 AWG (35 mm²) tinned solid copper wire. Connection of grounding conductors to guy wires shall be by an approved (i.e., UL Listed) connector. Welding, brazing, and etc., to guy wires are not permitted.

4.8.5 Radio Station Equipment

4.8.5.1 Shielding Information

When shielding of an equipment room is required as determined/approved by the Saudi Aramco Communication Engineering Division Supervisor, provide a shielding that is grounded to the site's grounding system with a minimum of #2 AWG (35 mm²) tinned solid copper.

4.8.5.2 Grounding Radio Equipment

a) Ground the metal parts of radio transmitting and receiving equipment by the rack mounting arrangement using a minimum of #6 AWG (16 mm²) insulated copper conductor.

b) Provide an interior ring bus system as common ground conductor to ground the relay rack uprights, metallic objects and other equipment.

c) If the radio equipment is a part of communication building, connect the equipment bays grounds to a common bus bar, and then connect the ground bus bar to the Master Ground Bar (MGB). Refer to SAES-T-795.

4.8.5.3 Interior Ring Bus System

The interior ring bus system shall be no less than a #2 AWG (35 mm²) bare solid tinned copper cable supported on walls and shall be mounted over racks, trays, framing channels and door frames. Support the ring at a maximum of 600 mm (2 feet) intervals and at turning points.

4.8.5.4 Bonding Connections

a) Bond all non-circuit metal objects in the radio equipment room to the ground bus or ring. This includes items such as, wave guide hatch plates, air ducts, exhausts, hoods, air dryers, metallic door frames, metal cabinets used for spare parts, distribution power panels and master ground bar (if present).

b) The bond path length between metallic objects must not exceed:

- 4.5 m (15 ft) if the objects are within 300 mm (1 foot)
- 9.0 m (30 ft) if the objects are within 1.80 m (6 ft)

c) Provide bonding connections between the external buried ring and the internal ground ring:

- At each corner of the building, with additional bonds separated a maximum of 15 m (50 feet).
- At the location of the entering hatch plate of the wave guides and coaxial cables.

d) Use a minimum of #2 AWG (35 mm^2) tinned bare solid copper wire for these bonding connections.

4.8.5.5 Bend Criteria

a) All unnecessary bends in ground rings (including bonding and grounding wires) shall be kept to a minimum to decrease the inductance of the ground ring.

b) The unavoidable bends shall have the following minimum bending radius:

- 15 cm (6 inches) for sizes up to #6 AWG (16 mm^2).
- 30 cm (12 inches) for sizes more than #6 AWG (16 mm^2) and up to #4/0 AWG (120 mm^2).
- 60 cm (24 inches) for sizes greater than #4/0 AWG (120 mm^2).

4.8.6 Connecting Facilities

4.8.6.1 Cable Sheaths

a) The shields and armors of all cables entering a radio station must be bonded together and grounded to the station ground.

b) Metallic entrance conduits must be bonded together and connected to the station ground using a minimum of #6 AWG (16 mm²) insulated tinned solid copper wire.

c) Bond cable shields and sheaths to the two ends of metallic conduits through which they pass.

d) Outside type polyethylene jacketed entrance cables placed inside buildings (maximum 50 feet, see NFPA 70, NEC Article 800) must be wrapped with approved fire proofing tape.

4.8.6.2 Terminal Ground Requirements

a) Connect the entrance cable protector terminal ground directly to the external ground ring. The grounding conductor length shall not exceed 6 m (20 feet).

b) Bond the cable shield and armor to the ground ring at the points where they cross within 2 m (6 feet) of each other.

5 Installation

The installation and design of all electrical coordination-protection apparatus and procedures in the Saudi Aramco telecommunications network shall be in compliance with this standard, the National Electrical Code, National Electrical Safety Code, and the other applicable Saudi Aramco Engineering Standards (i.e., SAES-T-435 and SAES-T-903). The instructions issued by manufacturers shall be followed to avoid the possibility of violating the warranty conditions of the manufacturer.

6 Testing and Inspection

All apparatus, devices, materials, etc., shall be tested with the cable network in accordance with SAES-T-634. When coordination is required the Saudi Aramco Communications Standards Committee Chairman representative may be involved in tests and inspections.

Revision Summary

27 January 2010	Revised the "Next Planned Update". Remove GTE references. Reaffirmed the contents of the document, and reissued with editorial changes.
12 June 2011	Editorial revision to remove the committee members' list and change the document's Primary Contact Person.
21 May 2012	Editorial revision to change the primary contact.