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IEEE Standard Performance Requirements for Communications and Control Cables for Application in High Voltage Environments

Sponsor

Power Systems Communications Committee of the IEEE Power Engineering Society

Approved June 9, 1988

IEEE Standards Board

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Foreword

(This Foreword is not a part of IEEE Std 789-1988, IEEE Standard Requirements for Communications and Control Cables for Application in High Voltage Environments.)

Wire line communications and control cables either entering electric power stations or passing through their zone of influence are subjected to extraneous voltages that include the longitudinally induced voltage as well as the GPR voltage. The interfering voltages are frequently higher than the insulation withstand capability of ordinary outside-type telephone cables often used for such purposes. For more background information on these subjects the reader should refer to ANSI/IEEE Std 487-1980 [6], particularly Section 5.3 and Annex A14, which deal with these dedicated cables.

The problems of dielectric withstand become more acute where critical noninterruptable channels are involved and where the GPR is over 300 V.

This standard defines the performance requirements for communications and control cables suitable for these classes of service.

This standard was prepared and approved by a Working Group of the Wire Line Subcommittee of the Power Systems Communications Committee, IEEE Power Engineering Society, which had the following membership at the time of approval:

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IEEE Standard Performance Requirements for Communications and Control Cables for Application in High Voltage Environments

1. General

1.1 Scope. This standard applies to wires and cables, used principally for power system communications and control purposes, which are located within electric power stations or are installed within the zone of influence of the power station ground potential rise (GPR), or which may be buried adjacent to electric power transmission and distribution lines. They may be subjected to high voltages either by conduction or induction coupling, or both. Such voltages are often higher than the insulation withstand capability of ordinary telephone-type cables, which are frequently used for such purposes. This standard covers the appropriate design requirements, electrical and mechanical parameters, the testing requirements, and the handling procedures for cables that are to be installed and operated in high voltage environments. Coaxial and fiber optic cables are specifically excluded from this standard.

The objective of this standard is to specify a cable that may be used to ensure the overall reliability of communications and control cables in high voltage environments. There should be a very high probability that these cables will perform their intended function for specified periods of time under high voltage interference conditions.

In addition to the requirements of this standard, all communications cables shall meet the requirements of ANSI / ICEA S-56-534-1983 [1][1], and all cables shall meet the requirements of ANSI / IEEE Std 532-1982 [8]. All cables shall meet any specific requirements from any of the referenced standards in 1.2.3 as required by the user.

[1] The numbers in brackets refer to those of the references listed in 1.2.3.

1.2 General Information

1.2.1 Electric Power Station Environment. Electric power stations subject communications and control cables to a high voltage environment since these cables run from the control room or other locations to remote station locations and to remote locations off the station ground grid via trays, trenches, conduits, direct burial, etc. To limit potential differences in the station during cable and equipment faults or lightning strokes, ground grids are installed within the station area with station equipment, building frames, and structures connected to this grid. During a local or power station ground fault or fault on a power line at a location remote from the power station, some of the fault current flows through the ground grid and produces a potential difference, ground potential rise (GPR), along the ground grid and between the ground grid and remote earth. Communications and control circuits serving power stations are usually within the influence of this ground potential rise. This standard principally applies to communications and control cables that serve the power station, but may also apply to all such cables that are exposed to the effects of hostile electrical environments because they are entering the GPR zone to serve telephone subscribers within the zone of influence, or because they merely pass through the zone of influence.

In addition, these cables may be subject to moisture, contaminated water, temperature extremes, vibrations, pulling stresses, physical contact with other cables, etc.

The basic requirement for acceptable cable performance is that the cable should have a serviceable life equal to the design life of the electric power station, while operating at the design voltage and current ratings, and while being subjected to the environmental conditions prevalent to the power station site. When cables are used that are not suitable for all applications, for example, ionizing radiation, they shall preferably be restricted to areas where detrimental conditions do not exist.

1.2.2 Communications Versus Control Cable Requirements. Present supplier industry standards for telephone-type cables do not adequately provide for a sufficiently high cable dielectric withstand strength for their jackets and adequate testing procedures for their use within the influence of an electric power station where the GPR is high, for example, over 1 kV. By the same token, present supplier industry standards for control-type cables do not adequately address communications transmission requirements.

1.2.3 References. The following publications shall be used in conjunction with this standard:

[1] ANSI/ICEA S-56-534-1983, Polyolefin Insulated Communications Cables for Outdoor Use.[2]

[2] ANSI/IEEE Std 80-1986, IEEE Guide for Safety in AC Substation Grounding.[3]

[3] ANSI/IEEE Std 82-1963 (R1971), IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors.

[4] ANSI/IEEE Std 383-1974 (R1980), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

[5] ANSI/IEEE Std 455-1985, IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band.

[6] ANSI/IEEE Std 487-1980, IEEE Guide for the Protection of Wire Line Communications Facilities Serving Electric Power Stations.

[7] ANSI/IEEE Std 525-1987, IEEE Guide for the Design and Installation of Cable Systems in Substations.

[8] ANSI/IEEE Std 532-1982, IEEE Guide for Selecting and Testing Jackets for Cables.

[9] ASTM D257-1978 (R1983), E1 Test Method for D-C Resistance or Conductance of Insulating Materials.[4]

[10] ASTM D746-1979 (R1987), Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.

[11] ASTM D1248-1984, Specification for Polyurethane Plastic Molding and Extrusion Materials.

[12] EIA 359-A-1985, EIA Standard Colors for Color Identification and Coding.[5]

[13] ICEA S-19-81 (Sixth Edition)/NEMA WC3-1980, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.[6]

[14] ICEA S-61-402 (Third Edition)/NEMA WC5-1973 (R1979), Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

[15] ICEA S-68-516/NEMA WC8-1976 (R1982), Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

1.3 Definitions (Applicable to This Standard)

aerial cable. A cable for installation on a pole line or similar overhead structure that may be self-supporting or installed on a supporting messenger (cable) and is designed to resist solar radiation and precipitation.

A self-supported aerial cable is one that includes a messenger cable that has an outer

[2] ANSI/ICEA publications may be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Insulated Cable Engineers Association, PO Box 411, South Yarmouth, MA 02664.

[3] ANSI/IEEE publications may be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Institute of Electrical and Electronics Engineers, Service Center, Piscataway, NJ 08854-1331.

[4] ASTM publications may be obtained from the Sales Department, American Society of Testing and Materials, 1916 Race St, Philadelphia, PA 19103.

[5] EIA publications may be obtained from Electronic Industries Association, 1722 Eye St NW, Suite 300, Washington, DC 20006.

[6] ICEA/NEMA publications may be obtained from ICEA or from the National Electrical Manufacturers Association, 2101 L St NW, Washington, DC 20037.

jacket that covers the messenger and the shield. The messenger is available for support, gripping, pulling, and tensioning.

attenuation. A general term used to denote a decrease in magnitude in transmission from one point to another.

α = attenuation, nepers per unit length (dB per unit length = 8.686 nepers per unit length) can be derived as follows from the electrical characteristics of a balanced cable pair that are given by the following relations:

$$\gamma = \alpha + j\beta = \sqrt{Z/Y} \text{ (propagation coefficient)}$$

$$Z_o = \sqrt{Z/Y} = \sqrt{\frac{R + jwL}{C + jwC}}$$

= characteristic impedance, see 1.3.13

$$Z_o\gamma = Z = R + jwL$$

$$\gamma / Z_o = Y = G + jwC$$

where

- β = phase shift, radians per unit length
- $Z = R + jwL$ = series impedance, ohms per unit length
- $Y = G + jwC$ = parallel admittance, ohms per unit length
- R = series resistance, ohms per loop unit length
- L = series inductance, henrys per loop unit length
- G = parallel conductance, ohms per unit length
- C = mutual capacitance, farads per unit length
- $w = 2\pi f'$, where F' is the frequency in hertz

In the equation $\gamma = \alpha + j\beta$ it may be shown that in terms of the distributed parameters *R*, *L*, *G*, and *C*:

$$\alpha = \sqrt[4]{(RG - w^2LC)^2 + (GwL + RwC)^2} \times \cos\left[\frac{1}{2} \tan -1 \frac{GwL + RwC}{RG = 2^2LC}\right] \text{ nepers per mile}$$

At high frequencies this equation may be expressed as

$$\alpha \cong \tfrac{1}{2}\, G \sqrt{L/C} + \tfrac{1}{2}\, R \sqrt{C/L} \text{ nepers per unit length}$$

At low frequencies this equation may be expressed as

$$\alpha \cong \sqrt{wRC/2} \text{ nepers per unit length}$$

buried cable (direct buried). A cable for installation under the surface of the earth in such a manner that it cannot be removed without disturbing the soil. It is designed for direct burial in the earth to withstand submersion in ground water, the pressure of back fill material, and in special applications, to withstand the gnawing of burrowing rodents.

cable. An insulated conductor or combination of electric conductors that are insulated from each other. A shield is usually provided.

cable armor. A metallic element or envelope inserted in or around a cable sheath to provide mechanical protection against rodents, severe installation conditions, etc.

cable core. The core of a cable is the cylindrical center consisting of insulated conductors usually twisted together in pairs and pairs arranged together in groups that lie under the sheath.

cable filler. The material used in multiple-pair cables to occupy the interstices formed by the assembly of the insulated conductors, and to form a cable core of the desired shape (usually circular). A material may be used that resists the entrance of water (nonhydroscopic) and ionizes at a higher voltage than air.

cable jacket. A thermoplastic or thermosetting covering that is extruded over a cable to provide physical protection and electrical insulation.

(1) **inner jacket.** A jacket that is extruded over the cable core covering to provide additional dielectric strength when it is needed between the conductors and the shield. An inner jacket may be used in cables that are used for direct burial and also where high ground potential rise is to be withstood.

(2) **outer jacket.** A jacket that is extruded over the cable shield. It also may be extruded over both the shield and a supporting messenger cable.

cable sheath. The outer covering over the insulated conductors to provide mechanical and electrical protection for the conductors. In telephone-type cables the sheath usually includes a shield and may include armor.

cable shield. A conducting envelope, composed of metal strands, ribbon or sheet metal that encloses a wire, group of wires, or cable, so constructed that substantially every point on the surface of the underlying insulation or core wrap is at ground potential or at some predetermined potential with respect to ground.

capacitance unbalance, pair to ground—$C_{UB,\ PG}$. The unbalance that exists between the capacitance of each conductor of pair *ab* to the grounded shield with all the other conductors connected to the shield. This is: $C_{UB,\ PG} = (Cag + Cap) - (Cbg + Cbp)$, where *Cag* and *Cbg* are capacitances between each conductor (*a* and *b*) to ground and *Cap* and *Cbp* are capacitances between each conductor (*a* and *b*) and all other pairs connected together and grounded.

capacitance unbalance, pair to pair—$C_{UB,\ PP}$. The unbalance in capacitance that exists between each conductor in a pair (*ab*) to each conductor in another pair (*cd*). This is: $C_{UB,\ PP} = (Cad + Cbc) - (Cac + Cbd)$, where *Cac, Cad, Cbc,* and *Cbd* are direct capacitances between conductors.

characteristic impedance. The ratio of the complex value of voltage between the conductors to the complex value of current on the conductors in the same transverse plane with the sign so chosen that the real part is positive.

The characteristic impedance can be calculated using the following equation:

$$Z_o = \frac{1}{Y_o} = \sqrt{\frac{R + \mathrm{j}\omega L}{G + \mathrm{j}\omega C}} \text{ (ohm)}$$

where

Y_o = characteristic admittance of line in *S*
R = resistance of line in ohms/loop unit length
G = conductance of line in *S*/unit length
L = inductance of line in *H*/loop unit length
C = capacitance of line in *F*/unit length
W = frequency in radians per second

color code. A system of standard colors used for identification of conductors. Colors identify the tip and ring conductors in pairs of a communications cable. Combinations of colors identify the pair numbers. Pair groups are bound with threads or tapes that are identified with color bands or with unit numbers and the names of the colors.

communications cable. A cable that carries a low level of electric energy used for the transmission of communication frequencies. A telephone-type cable consists of two or more, solid, insulated, twisted, paired and/or quadded, shielded or unshielded conductors ranging from No 19 to No 26 AWG, with either a shielded or unshielded sheath.

control cable. A cable that usually carries relatively low current levels used for indication purposes to change the operating status of a utilization device of a plant auxiliary system. A control cable usually consists of two or more insulated, unpaired, shielded or unshielded conductors. Sizes may be No 22, 20, 19, 18, or 16 AWG solid and No 14, 12, 10, or 9 AWG stranded or solid conductor. Control cable conductor insulation usually has voltage ratings of 300, 600, or 1000 V rms, 50–60 Hz.

dedicated cable. A cable containing only pairs servicing an electric power station. It is installed at any station with ground potential rise (GPR) above a given level, for example, 300 V rms, and will have a core and jacket dielectric capability suitable to withstand worst fault-produced voltage stress.

inside communications cables. A telephone-type cable intended for indoor use that is not designed to withstand solar radiation or precipitation and may or may not be shielded.

instrumentation cable. A cable that carries low level electric energy from a transducer to a measuring or controlling device. It may be used in environments such as high temperature, high radiation levels, and high electromagnetic fields. An instrument cable may consist of a group of two or more paired or unpaired, shielded or unshielded, solid or stranded insulated conductors.

longitudinal balance. The ratio of the disturbing longitudinal rms voltage (V_s) to ground and the resulting metallic rms voltage (*Vm*) of the network under test, expressed in decibels as follows: longitudinal balance $= 20 \log_{10} Vs/Vm$ (in dB), where *Vs* and *Vm* are at the same frequency.

mutual capacitance. The capacitance between two conductors in a pair when the rate of change of the charges on the two are equal in magnitude but opposite in sign, and the potentials of the remaining conductors in the cable are held constant.

tip and ring wires. The pair of conductors associated with the transmission portions of telephone cables, circuits, and apparatus.

underground cable (in ducts). A cable for installation below the surface of the earth in ducts or conduits so it can readily be removed without disturbing the surrounding earth and designed to withstand submersion in ground waters.

1.4 Information To Be Supplied By User. The user should consider the following characteristics of the power system control or communications system on which the particular cable is to be used and indicate any specific requirements to the supplier.

1.4.1 Operating Voltage. The general range of system voltages for communications and control cables has been found to be up to 250 Vdc and up to 120 Vac.

1.4.2 Operating Current. The general range of operating currents for communications and control cables ranges from less than a milliampere for instrumentation and communications applications to about 20 A for high voltage circuit breaker tripping applications.

1.4.3 Operating Frequency Range. The frequency ranges for various applications are generally as follows:

(1) dc for control, alarms, remote tripping, circuit monitoring for pilot wire protective relaying, telephone signaling, etc

(2) 17 to 60 Hz—ac for control, metering, protective relay systems, including pilot wire and telephone ringing

(3) 300 Hz to 3400 Hz—audio-tone transfer trip, data, supervisory control, telemetering, and voice communications

(4) 5 kHz to 3 MHz—analog and digital carrier systems

1.4.4 Installation Methods. Communications and control cables are routed throughout the potentially hostile electrical environment by various methods such as the following:

(1) *Aerial lines:* Aerial cable is usually supported by a messenger that is generally a noninsulated member whose primary purpose is to support the communications or control cable. This messenger is supported at dead ends and at intermediate locations to eliminate tension on the cable conductors.

(2) *Nonmetallic conduit:* Precast concrete, transite, fiber, PE or PVC, or fiberglass conduits are used in many cases where the conduits run underground. These conduits can be encased in concrete envelopes that may also contain several other conduits in a duct bank.

In the case of the dedicated communications cable leaving the station, it is recommended that this cable be installed in a continuous PVC conduit within the station and for at least 3 m (10 ft) beyond the ground grid or the power station perimeter fence. To prevent moisture accumulation in this conduit, consideration must be given to have the outside open end of the conduit at a lower elevation than the other (station's) end (usually sealed) to ensure proper conduit slope for continuous drainage.

(3) *Metallic conduit:* Galvanized steel conduits may also be used to protect cables within the station and on the station side of the high voltage protective interface. The above ground terminations of these metallic conduits are normally accomplished with galvanized steel conduit bends, using nonmetallic to galvanized steel adapters. In a number of cases, a direct buried cable is brought to the ground surface in a galvanized steel conduit bend, using an insulated bushing. Like the nonmetallic conduits, the metallic conduits may be encased in concrete envelopes if required as a single conduit or as a duct bank with other conduits. For above ground applications, aluminium or galvanized steel conduit may be utilized. Flexible conduit may be used between rigid conduit and equipment junction boxes where vibration is anticipated.

(4) *Design considerations for cable support:* Certain design considerations should be given when using either metallic or nonmetallic conduits. For mechanical protection, aluminium, steel, or thick walled PVC conduits are adequate, subject, however, to some limitations. For example, there are minimum bending radii for various sizes of conduits, ranging from 114 mm (4.5 in) for the smallest recommended conduit size to 1640 mm (64.5 in) for 152 mm (6 in) conduit. In addition, a run of conduit between two pull boxes should not contain more than the equivalent for four quarter bends (360 degrees total), including the bends located immediately at the pull box. Another important consideration is the maximum acceptable cable fill. This is in the order of 35% to 40% of the conduit area where there are more than two conductors in the duct. For electrostatic shielding, aluminium conduits are the best. For electromagnetic shielding, steel conduit is the most suitable.

NOTE: It is important that metallic conduits should not be used or extended outside the station grid.

(5) *Direct buried:* Communications and control cables are often directly buried. Sometimes,

these cables would be double jacketed and filled and, generally, would be buried a minimum of 610 mm (24 in) below grade with 150 mm (6 in) minimum of sand above and below the cables. At a road crossing within the power station, where vehicular passage can be expected, appropriate mechanical protection such as wooden planking or modular 50 mm (2 in) thick concrete slabs may be placed at grade level above the direct buried cable.

2. Environmental Considerations

2.1 General. Communications and control cables used in the high voltage environment of an electric power station or that are exposed to the influences of such stations or high voltage power lines are subject to widely varying physical, electrical, and mechanical conditions. Often these environmental conditions are in the extreme and, therefore, such cables must be capable of withstanding all of the following conditions.

2.2 Temperature. Usual ambient temperature range is minus 20°C to plus 55°C. Unusual conditions of temperature must be specified by the user.

2.3 Humidity. Humidity range is from 0% to 100% and/or immersion in water to a depth of 1 m (3 ft).

2.4 Mechanical Shock. At minus 40°C, the cable should not be damaged from mechanical shock equal to a 4 J impact test.

2.5 Altitude. The cable should be capable of operating at altitudes between minus 200 m (650 ft) and plus 4000 (13 120 ft) relative to sea level.

2.6 Ultraviolet. The cable, if located outdoors, shall have a minimum 25 year life under maximum solar radiation conditions.

2.7 Chemical Environment. Cable shall not sustain damage in an environment as defined in ASTM D1248-1984 [11] for low or medium density polyethylene and PVC.

2.8 Fungus. The outer cable jacket shall have fungus-resistent properties equal to or better than that of medium or low density polyethylene.

2.9 Insects or Rodents. In areas where insect or rodent damage is possible, special mechanical protective precautions, that is, armor or special insulating compounds shall be indicated by the user if required.

2.10 Lightning. Lightning environment is described in ANSI/IEEE Std 487-1980 [6].

Cable shall not be damaged by ten applications of a standard impulse 1.2×50 μs test wave at 2 s intervals. This test wave shall be applied as described in Sections 5 and 6.

3. Operating Service Conditions

3.1 Ambient Environment Conditions. Refer to Section 2. Unusual conditions and other environmental conditions (eg, radiation) outside the specified limits shall be reported to the manufacturer so that appropriate changes in ratings may be considered.

3.2 Electrical Environment Conditions. Communications and control-type cables are directly exposed to interfering voltages, transients, and harmonics when they are in proximity to power conductors or power stations.

Three forms of coupling must be considered: magnetic (inductive) coupling, electric (capacitive) coupling, and conductive (resistive) coupling.

The magnitude of interference will be determined by the influence of the power lines, the susceptibility of the cables, and the coupling mechanisms.

3.2.1 *E*-Field (Electric Field Intensity). Cable insulating materials should withstand 10 kV/m (*E*-field) continuously without damage.

4. Installation Practices

4.1 General Types of Cable Plant

4.1.1 Outdoor. Installation of communications or control cables, located entirely outside of power station buildings, can be one of the following types.

4.1.1.1 Overhead (Aerial) Joint Use. Joint use means the supporting of power lines and communications or control cables on the same structure (each installation may be owned by separate utilities).

4.1.1.2 Overhead (Aerial) Nonjoint Use. Nonjoint use means communications or control cables supported by their own separate structures.

4.1.1.3 Underground Joint Use. In underground cable plants, joint use means the sharing of common pedestals, trenches, rights of way, duct systems, etc, between power cables and communications or control cables. Furthermore, they could have the following:

(1) *Planned separation:* power cables and communications or control cables are maintained at a fixed or minimum horizontal and vertical separation

(2) *Random separation:* the variable separation that results when power cables and communications or control cables are installed in a common trench at approximately the same depth with no effort to maintain a fixed or minimum separation, which means there may be zero separation between the cables at some points in the run

4.1.1.4 Underground Nonjoint Use. Communications or control cables in separate underground structures or facilities.

4.1.2 Indoor. Communications or control cables located inside the power station buildings are generally installed in cable trays and vertical risers, segregated and separated from power cables, and, where necessary, to provide an additional isolation or mechanical protection, in separate conduits.

4.2 Interference Mitigations. Communications and control-type cables, especially those with low signal levels, may require shielding and segregation from power cables and the use of balanced twisted pairs to preserve the integrity of the transmitted signal.

4.2.1 Coupling to Power Cables

4.2.1.1 Capacitive Coupling

(1) *Capacitive shielding:* Capacitive coupling of communications and control cables to high voltage cables is reduced by electrostatic shielding provided by a grounded conductor(s) placed between or enclosing power and / or communications cables.

(2) *Capacitive balance:* To minimize capacitive coupling of energy into communications and control circuits, both conductors of a pair should have equal or balanced capacitance to the metallic shield and to other conductors in the cable.

4.2.1.2 Inductive Coupling. Electromagnetic flux caused by power current or rapidly changing transient currents in power circuits couples energy into conductors of a communications or control cable by electromagnetic induction. This is reduced by shielding, bonding, and separation.

(1) *Electromagnetic shielding:* Electromagnetic shielding, for example, is provided by conductor(s) near communications and control conductors, by the current induced into them and the cable shield and / or messenger, the spinning or lashing wire(s) if they are adequately grounded. This current causes a counteracting electromagnetic flux that reduces the effect of the source flux. The shielding characteristic of a shield conductor(s), for example, is increased if its longitudinal and terminal reactances and resistances are made low so as to minimize the ground loop impedance.

(2) *Longitudinal balance:* The interfering effects of inductive coupling into a cable are minimized, as may be required by the user, if the conductors of the circuit in the cable have equal reactance, and resistance to ground. Conversion of the longitudinally induced voltage (common mode voltage) into transverse or metallic voltage (differential mode voltage) will be minimized if conductors in a pair have balanced electrical characteristics.

4.2.1.3 Resistive Coupling. Resistive coupling occurs between power circuits and communication or control circuits due to resistive coupling of each to ground. Connections to ground are made by Y-grounded connected three-phase power circuits at supply or load terminals. Under fault conditions or where an extreme unbalance exists on the power system, connections can be made to ground from surge arresters and protectors applied to both power and communications or control circuits, or by direct contact or an arc.

Resistive coupling between power and communications or control circuits is minimized when the earth is not used deliberately as a communications circuit return path. Resistive coupling is increased due to the reduction in insulation resistance to ground with aging of power, communications and control cable insulation, and because of the reduction or failure in the insulation resistance to ground in surge arresters and protectors.

(1) *Protection against resistive coupling:* Resistive coupling is reduced by providing protection for communications and control cable insulation to ground. This is done by limiting voltage to ground and voltage between conductors with surge protector gaps. Optimum protection is provided by a high ratio of insulation voltage withstand level to the protective gap voltage limit level.

(2) *Insulation resistance unbalance:* The resistive coupling of energy into communications and control circuits is increased if the resistance of each conductor of a circuit to the grounded shield or sheath through conductor insulation is not equal. Defective protectors having unequal voltage limiting characteristics will increase resistive coupling to power circuits.

4.2.2 Grounding. In hazardous locations and depending on the protection schemes, standard grounding practices may not apply and reference should be made to ANSI/IEEE Std 80-1986 [2] and to ANSI/IEEE Std 487-1980 [6].

4.2.2.1 Ground Isolation Within the Zone of Influence of a Power Station. To minimize coupling between power cables and communications or control cables entering the zone of influence of a GPR from a remote point, cables including their messengers and shields shall be effectively isolated and/or insulated from ground throughout the zone of influence. Such cables are usually terminated at a high voltage protective interface cabinet and their shields are not to be grounded at that point except through surge protective devices. The internal or station-side supplementary protective devices are to be connected to station ground.

4.2.2.2 Grounding Outside the Zone of Influence. To minimize coupling between power cables and communications or control cables outside the zone of influence, shielding shall be effectively grounded at intervals of no greater than 300 m (1000 ft).

Effective grounding outside the zone of influence of a power station should have resistance (impedance) to earth of less than 20 Ω.

4.2.2.3 Bonding Inside the Power Station. The effective ground of the power station should have resistance to the earth of less than 0.5 Ω if at all possible.

4.2.2.4 Isolation and Insulation Between Shields of Cables Inside and Outside the Zone of Influence. If the option of remote drainage protection is deemed desirable (ANSI/IEEE Std 487-1980 [6]), isolation and insulation are provided between the cable shields located inside and outside the zone of influence of a power station.

5. Cable Design Requirements

5.1 General

5.1.1 This standard covers the requirements for multipair, No 19, 22, 24, and 26 AWG polyolefin insulated, PVC or polyolefin jacketed, shielded telephone or communications-type cable, as well as paired or nonpaired, shielded or nonshielded, control-type cables, solid or stranded, No 9 to 19 AWG, for use in high ground potential rise (GPR) zone of influence areas, for example, over 300 V.

5.1.2 The preferred pair count in any communications-type cable manufactured to this specification should be one of the following: 3, 6, 11, 12, 16, 18, 25, 37, 50, 75, and 100 pairs.

5.1.3 Other pair complements, paired or nonpaired, shielded or nonshielded, and other wire gauges, particularly for control-type cables, should be available as specified. Performance requirements and testing will vary in accordance with any specific user requirements.

5.1.4 These cables are intended for use within the zone of influence of an electric power station or other high voltage environments where the GPR does not exceed 10 kV rms symmetrical. Where the GPR is above 10 kV, specially designed cables are required.

5.1.5 The quality of the materials used and the methods of manufacture, handling, and shipment shall be such as to ensure, for the complete cable, all the properties called for in this standard.

5.2 Conductors.

Each conductor shall be solid, round wire (or equivalent stranded) of commercially pure annealed copper and shall meet the requirements of ANSI/ICEA S-56-534-1983 [1].

5.2.1 Factory joints shall be avoided as much as possible.

5.2.2 Joints in the conductor prior to insulating shall be made by butt welding or by butting together the two ends of the conductor and brazing with silver alloy solder. If a flux is used it must be nonacidic.

5.2.3 The finished joint shall be free of lumps and sharp projections.

5.2.4 The resistance of any 150 mm (6 in) section of a conductor, including a factory joint, shall not be more than 105% of the resistance of an adjacent 150 mm (6 in) section of a solid conductor without a joint.

5.3 Insulation of Conductors

5.3.1 Each conductor shall be insulated with colored polyolefin to meet the electrical requirements of ANSI/ICEA S-56-534-1983 [1].

5.3.2 The polyolefin and PVC shall meet the requirements of ANSI/ICEA S-56-534-1983 [1].

Pigments used to color the polyolefin shall be compatible with the insulation and the antioxidant.

5.4 Color Scheme of Conductors

5.4.1 The color scheme used in this cable corresponds to that used in "even PIC" telephone cable (that is, in the color scheme used in EIA 359-A-1985 [12] and ANSI/ICEA S-56-534-1983 [1]).

5.4.2 The colors used shall be readily distinguishable under normal installation conditions.

5.5 Forming of Pairs

5.5.1 The insulated conductors shall be twisted into pairs.

5.5.2 The lengths of twist for the individual pairs shall be such as to provide the required characteristics and to provide a cable meeting the capacitance unbalance requirements.

5.5.3 Defects detected prior to sheathing shall be repaired as in regular plastic-insulated-conductor (PIC)-type cable core.

5.6 Stranding. The pairs shall be stranded together to form the cable core.

5.7 Core Wrap. A core wrap (that is, polyester) shall be used such that (a) is suitable for the application, (b) acts as an adequate heat barrier to the core, and (c) gives, with the PVC or polyolefin sheath or jacket, an adequate dielectric strength to pass the requirements of ANSI/ICEA S-56-534-1983 [1].

5.8 PVC or Polyolefin Insulating Jacket

5.8.1 A PVC or polyolefin jacket shall be applied over the cable core. The compound used shall be of an outdoor grade suitable for aerial or direct buried use. It shall have characteristics such that the electrical requirements of this standard will be met. The polyolefin or PVC material shall meet the requirements of ANSI/ICEA S-56-534-1983 [1]. The choice of either polyolefin or PVC for the jacket shall be at the user's option.

5.8.2 An alternative form of construction could consist of an industry standard type of communications cable, aluminum shielded, coated, or noncoated, to which has been added an additional (separate) jacket or either polyolefin or PVC to achieve the assurance of the dielectric withstand test for the total cable jacket. This outer jacket should then have some continuous identifying feature to differentiate it from standard cable.

5.9 Routine Tests on All Cables

5.9.1 Each and every individual length or reel of cable will be subject to tests prior to shipping as per Section 6 and as per ANSI/ICEA S-56-534-1983 [1].

5.9.2 No cable is acceptable that has an open circuit in any conductor or shield.

5.10 Dielectric Strength of Cables

5.10.1 The minimum dielectric strength between all adjacent conductors in nonfilled cables shall be 4.5 kVdc for 19 AWG, 3.6 kVdc for 22 AWG, 3.0 kVdc for 24 AWG, and 2.4 kVdc for 26 AWG for 3 s.

The minimum dielectric strength between all adjacent conductors in filled cables shall be 7.0 kVdc for 19 AWG, 5.0 kVdc for 22 AWG, 4.0 kVdc for 24 AWG, and 2.8 kVdc for 26 AWG for 3 s.

5.10.2 The minimum dielectric strength between all conductors, connected in parallel to shield, shall be 20 kVdc for 3 s for filled cables and 10 kVdc for 3 s for nonfilled cables.

5.10.3 For both filled and nonfilled cables the dielectric strength between all conductors connected in parallel with the shield and ground shall be 30 kVdc for 3 s. Ground in this case shall be either a salt water bath or a closely fitting ring die through which the cable length shall be passed.

5.10.4 No cable is acceptable that has a dielectric failure.

5.11 Tests on Sample Pairs. The manufacturer of the cable shall be responsible for maintaining control of the following electrical characteristics. Special tests on sample pairs shall be conducted as per Section 6 or modified as per instructions from the purchaser.

Statistical quality control procedures will be used to comply with the intent of this specification. The level of testing specified in Section 6 will be used as an initial guide; however, with additional experience this may be reduced by mutual agreement between the purchaser and the supplier.

5.11.1 Conductor Resistance

5.11.1.1 The maximum direct-current resistance permitted to all conductors shall be:

27.6 ohms per kilometer (44.4 ohms per mile) for 19 AWG

55.4 ohms per kilometer (89.1 ohms per mile) for 22 AWG
87.6 ohms per kilometer (140.9 ohms per unit) for 24 AWG
141.1 ohms per kilometer (227 ohms per mile) for 26 AWG
[corrected to 20°C (68°F)]

5.11.1.2 The maximum direct-current resistance permitted to any conductor shall be:
28.5 ohms per kilometer (45.8 ohms per mile) for 19 AWG
57.1 ohms per kilometer (91.9 ohms per mile) for 22 AWG
90.2 ohms per kilometer (145.2 ohms per mile) for 24 AWG
144.4 ohms per kilometer (232.3 ohms per mile) for 26 AWG
[corrected to 20°C (68°F)]

5.11.2 Resistance Unbalance. The resistance unbalance of any pair should be as low as possible, consistent with normal manufacturing practices, and shall meet all the requirements of ANSI / ICEA S-56-534-1983 [1].

5.11.3 Mutual Capacitance

5.11.3.1 The average mutual capacitance of any cable at 20°C (68°F) shall be as close as possible to a value of 0.052 μF per kilometer (0.083 μF per mile) and shall meet all the requirements of ANSI / ICEA S-56-534-1983 [1].

5.11.3.2 The maximum average mutual capacitance of any cable shall be 0.059 μF per kilometer (0.095 μF per mile).

5.11.3.3 The tests to determine compliance with the above mutual capacitance requirements will be made as specified in Section 6.

5.11.3.4 If the average mutual capacitance of the tested pairs selected exceeds 0.057 μF per kilometer (0.093 μF per mile), all the remaining pairs shall be tested to determine the cable average.

5.11.4 Capacitance Unbalance

5.11.4.1 The cable shall meet all the requirements of ANSI / ICEA S-56-534-1983 [1]. In every length of cable, capacitance unbalance between any two pairs in a cable shall not exceed 150 pF for a 457 m (1500 ft) length, except as permitted in the standard.

5.11.4.2 High capacitance unbalances permissible as per ANSI / ICEA S-56-534-1983 [1] shall be identified with a sleeve at both ends. A linen tag marked H-PrPr may be substituted for the sleeve.

5.11.5 Crosstalk Loss. The rms output-to-output far-end crosstalk loss between pairs in a completed cable as measured at a frequency of 150 kHz shall be not less than 67.8 dB/km (109 dB/mi). The rms calculation shall be based on the combined total of all adjacent and alternate pair, connections within the same layer and center to first layer pair, combinations. The rms crosstalk loss in dB is the number of dB corresponding to the rms crosstalk voltage ratio. If the crosstalk loss is Kf dB at a frequency f_o for a length L_o, it can be determined for any other length or frequency by the formula

$$\underset{\text{(dB)}}{\text{crosstalk loss}} = Kf - 20 \log_{10} \frac{f}{f_o} - 10 \log_{10} \frac{L}{L_o}$$

Crosstalk shall be measured as per ANSI / ICEA S-56-534-1983 [1].

5.11.6 Longitudinal Balance. Longitudinal balance is a composite of some of the other performance requirements as given in ANSI / ICEA S-56-534-1983 [1], that is, mutual capacitance, capacitance and resistance unbalance, etc. It is intended to aid the cable user by providing a single characteristic by which to check the performance of a cable.

An approximate classification of longitudinal balance is shown below:

POOR	40 dB (less than)
FAIR	40 to 50 dB
GOOD	50 to 60 dB
EXCELLENT	60 dB (greater than)

These values should be obtained as per the standard test procedures and conditions of ANSI / IEEE Std 455-1985 [5].

5.11.7 Characteristic Impedance. Impedance versus frequency characteristics of communication cables for representative wire sizes shall be similar to the typical values shown in Table 1.

5.11.8 Attenuation (Transmission Loss). The anticipated average attenuation of various cable designs when measured at a frequency of 1000 Hz at 20°C shall be as shown below:

Conductor size (AWG):	19	22
Attenuation (dB/kM): at 1 kHz @ 20°C	0.75–0.80	1.10–1.15

Conductor size (AWG):	24	26
Attenuation (dB/kM): at 1 kHz @ 20°C	1.40–1.45	1.80–1.85

Table 1
Nominal Characteristic Impedance at 12.8°C (55°F)

Conductor Size		Frequency	Characteristics Impedance
AWG	(mm)	kHz	Ohm
19	(0.9)	1	402
		10	143
		48	110
22	(0.64)	1	568
		10	187
		48	117
24	(0.5)	1	714
		10	229
		48	128
26	(0.4)	1	903
		10	287
		48	146

5.12 Physical Requirements

5.12.1 Mandrel Test

5.12.1.1 Finished cables shall be capable of being wound onto a mandrel of diameter indicated below, so that the minimum number of turns of cable applied is not less than that given by the formula

$$N = \frac{L}{X}$$

where

N = number of turns of cable
L = length of mandrel traverse in mm (in)
X = maximum outside diameter of cable in mm (in)

In determining compliance with this requirement, a minimum of 12 turns of cable shall be applied to the mandrel.

Cable Pair Size	Mandrel Diameter
50 pairs or less	150 mm (6 in)
51 to 100 pairs	250 mm (10 in)
101 pairs & over	Use the formula above to establish mandrel diameter

5.12.1.2 Cables as specified in 5.1.1 shall be capable of withstanding the dielectric strength requirements of 5.10.1 after performing the mandrel test.

5.13 Certified Test Report. A certified test report covering the user's specified tests shall be completed for each length of cable and shall include data on the following as may be required by the user.

5.13.1 Routine Tests

(1) Continuity (indicate test requirements satisfied).

(2) Dielectric Strength (indicate test requirements satisfied).

5.13.2 Special Tests

Conductor resistance

(average of conductors tested and maximum resistance)

Resistance unbalance

(average of pairs tested and maximum value)

Mutual capacitance

(average of pairs tested)

Capacitance unbalance

(average of adjacent pairs and maximum value)

5.14 Ordering Cable. Procurement of cable shall state that the cable should be manufactured per this standard and should show the following information:

(1) Total length (with tolerance specified)

(2) Number of pairs, stranding, shielding, and gauge

(3) Minimum and maximum shipping lengths in which it is possible to use a cable without splicing

5.15 Shipping

5.15.1 Standard Pair Complements

5.15.1.1 Cable, with the standard pair complements specified in Section 5, shall be manufactured in the longest convenient lengths possible depending upon purchaser's requirements.

5.15.1.2 The drum of each shipping reel shall be wrapped with heavy paper and the final layer of cable on each reel shall also be wrapped with heavy paper.

5.15.1.3 All cable reels shall be shipped suitably lagged or wrapped to afford protection to the cable during transportation.

5.15.1.4 The inner and outer ends of the cables on a reel shall be readily accessible for testing purposes.

5.15.2 Special Pair Complements. Cables, with special pair complements, shall be manufactured in the length ordered.

5.15.3 Preparation for Shipment

5.15.3.1 Cable ends shall be sealed to keep moisture out of the cable core during transportation between supplier's plant and destination.

5.15.3.2 Each reel shall be plainly marked with the length, number of pairs, and gauge of the cable it contains, and such other information as may be specified on the order.

6. Testing and Test Methods

6.1 General. All cables shall be tested at the factory to determine their compliance with the requirements given in Section 5. When there is a conflict between the test methods given in Section 6 and publications of other organizations to which reference is made, the requirements given in Section 6 shall apply.

Tests shall consist of the following, as required, namely (1) design or qualification tests on selected samples, and (2) routine production tests on entire lengths of completed cables.

The test methods described in Section 6 are not completely applicable to all types of cables, nor do they include every test applicable to a particular type of wire or cable. To determine which tests are to be made, refer to the parts in this standard that set forth the requirements to be met by the particular material or type of cable.

6.2 Design Tests. Tests on samples shall be made on samples selected at random. Each test sample shall be taken from the accessible end of different coils or reels. Each coil or reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be specified under the individual tests. The extent of the design tests shall be by agreement. Tests shall be conducted in accordance with 6.4 and 6.5 and as per ANSI / ICEA S-56-534-1983, or other referenced standards.

6.3 Routine Production Tests. Tests shall be conducted on samples or full reels as specified and shall consist of both physical and electrical tests. Routine production tests shall be made covering the following:

(1) Wire gauge
(2) Insulation thickness
(3) Verification of length of pair twist*
(4) Cold bend*
(5) Water absorption*
(6) Conductor resistance and resistance unbalance
(7) Insulation resistance
(8) Mutual capacitance and capacitance unbalance
(9) Dielectric tests
- conductor to conductor
- conductors to shield
- conductors and shield to ground

NOTE: Tests * should be considered as optional at purchaser's request.

6.4 Physical Tests

6.4.1 Test Temperatures. Physical tests on samples shall be made at room temperature not less than 20°C (68°F) or more than 28°C (82.4°F). The test specimens shall be kept at room temperature for not less than 30 minutes prior to the test.

6.4.2 Mechanical (Dimensional) Tests

6.4.2.1 Conductor Tests

6.4.2.1.1 Cross-Sectional Area Determination. The test procedure shall be in accordance with section 6.3.2 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.1.2 Diameter Determination. The test procedure shall be in accordance with section 6.3.3 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.2 Thickness Measurements for Insulation and Nonmetallic Jackets. The procedure for measuring the thickness of insulations and nonmetallic jacket shall be in accordance with section 6.5 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.3 Thickness of Jute Beddings and Servings. Testing shall be in accordance with section 6.13 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.4 Thickness of Metallic Tapes. Testing shall be in accordance with section 6.14 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.5 Thickness of Metallic Sheaths. Testing shall be in accordance with section 6.15 of ICEA S-68-516 / NEMA WC8-1976 [15].

6.4.2.6 Thickness of Compound-Filled Tape. Testing shall be in accordance with section 6.10.1 of ICEA S-19-81 / NEMA WC3-1980 [13].

6.4.2.7 Verification of Color Code and Identification Marker. Visual inspection shall be made to determine conformance with color coding of binders, core coverings, and identification markers.

6.4.2.8 Verification of Maximum Length of Pair Twist. Pair twist measurement shall be made on pairs in the finished cable.

6.4.3 Aging Tests. The aging tests shall be made in accordance with section 6.10 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.2.6 Thickness of Compound-Filled Tape. Testing shall be in accordance with section 6.10.1 of ICEA S-19-81/NEMA WC3-1980 [13].

6.4.2.7 Verification of Color Code and Identification Marker. Visual inspection shall be made to determine conformance with color coding of binders, core coverings, and identification markers.

6.4.2.8 Verification of Maximum Length of Pair Twist. Pair twist measurements shall be made on pairs in the finished cable.

6.4.3 Aging Tests. The aging tests shall be made in accordance with section 6.10 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.4 Heat Shock. Testing shall be in accordance with section 6.4.13 of ICEA S-61-402/NEMA WC5-1973 [14].

6.4.5 Heat Distortion. Testing shall be in accordance with section 6.17 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.6 Cold Bend

6.4.6.1 On Polyvinyl-Chloride Insulation on Conductors. Testing shall be in accordance with section 6.4.15.1 of ICEA S-61-402/NEMA WC5-1973 [14].

6.4.6.2 On Thermoplastic Jackets. Testing shall be in accordance with section 6.19.3 of ICEA S-19-81/NEMA WC3-1980 [13].

6.4.7 Flame Test. Testing shall be in accordance with section 2.5 of ANSI/IEEE Std 383-1974 [4].

6.4.8 Tensile, Elongation, and Brittleness

6.4.8.1 Tensile Strength Test. Testing shall be in accordance with section 6.6 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.8.2 Elongation Test. Testing shall be in accordance with section 6.8 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.8.3 Brittleness. Testing shall be determined in accordance with ASTM D-746-1979 [10], using Specimen A.

6.4.9 Accelerated Water Absorption Test. Testing shall be in accordance with section 6.9 of ICEA S-19-81/NEMA WC3-1980 [13].

6.4.10 Chemical Resistance

6.4.10.1 Ozone Resisting Test. Testing shall be in accordance with section 6.8 of ICEA S-19-81/NEMA WC3-1980 [13].

6.4.10.2 Environmental Cracking. Testing shall be in accordance with section 6.19 of ICEA S-68-516/NEMA WC8-1976 [15].

6.4.11 Pressurization. The test used to determine the ability of the inner jacket to hold pressure shall be conducted by applying pressure to the inner jacket over the conductor pairs to an equilibrium pressure of 62 to 124 kPa (9 to 18 psi) gauge. After equilibrium is determined by the pressure gauges at each end of the reel, the pressure shall be allowed to stand for a period of at least 4 hours. To determine that the inner jacket has no holes or weak section, the pressure drop shall be less than 6.87 kPa (1.0 psi) gauge.

6.5 Electrical Tests

6.5.1 Conductor Resistance and Resistance Unbalance. Conductor resistance and resistance unbalance shall be determined as per ANSI/ICEA S-56-534-1983 [1].

6.5.2 Insulation Resistance

6.5.2.1 Test Apparatus. The test apparatus shall be in accordance with ASTM D257-1979 [10]. The test potential shall be a steady source of 100 through 500 V direct current.

6.5.2.2 Test Procedures. The insulation resistance shall be measured after the completed cable alternating-current voltage tests or before any direct-current voltage tests as specified in ANSI/ICEA S-56-534-1983 [1]. Where the voltage tests are made on wire or cable immersed in water, the insulation resistance shall be measured while the cable is still immersed. Single conductor cables shall be tested between the conductor and metallic sheath or water. Multiple conductor cables with nonshielded conductors shall be tested between each conductor and all other conductors and sheath or water. Multiple conductor cables with shielded conductors shall be tested between the conductor and shield. The conductor under test shall be connected to the negative terminal of the test equipment and readings shall be taken after an electrification of 1 minute.

Each coil, reel, or length of wire or cable shall have an insulation resistance in megohms per 1000 ft at a temperature of 15.6°C (60°F) of not less than the value of R calculated as follows:

$$R = K \log_{10} \frac{D}{d}$$

where

R = insulation resistance in megohms per 1000 ft

K = typical constant for the grade of insulation at 15.6 °C (60 °F) for:

rubber-like compounds—10 000
PVC—500
polyolefin—50 000
D = diameter over the insulation
d = diameter under the insulation

6.5.3 Mutual Capacitance and Capacitance Unbalance

6.5.3.1 In addition to the following, mutual capacitance and capacitance unbalance shall be determined as per ANSI/ICEA S-56-534-1983 [1].

6.5.3.2 Mutual Capacitance—Pairs. The mutual capacitance shall be measured on each pair in cables having 6 to 25 pairs. In cables having more than 25 pairs, each pair in at least 25% of the groups shall be measured. A frequency of 1000 Hz ± 100 Hz and a voice frequency capacitance bridge shall be used for measurements. Cables with conductors larger than 19 AWG shall not be measured.

6.5.3.3 Mutual Capacitance—Quads. Mutual capacitance of pairs in quads shall be measured at 1000 Hz ± 100 Hz. The minimum number of quads to be tested in each selected length of cable shall be as follows, the two pairs and the phantom being in each quad:

Number of Quads in Cable	Number of Quads To Be Tested
Up to 5	All
60 to 12	5
13 to 27	8
28 to 37	10

6.5.3.4 Capacitance Unbalance—Pair to Pair. Capacitance unbalance for 1000 ft or 1 km lengths of completed cable shall conform to the requirements for the individual rms value specified. A frequency of 1000 Hz ± 100 Hz and a voice-frequency capacitance bridge shall be used for measurements. In cables with 25 pairs or less and in each group of multigroup cables the unbalances to be considered are all of the following:

(1) Between pairs adjacent in a layer

(2) Between pairs in the center, when there are four pairs or less

(3) Between pairs in adjacent layers, when the number of pairs in the inner (smaller) layer is six or less (here the center is counted as a layer.)

6.5.4 Crosstalk. The rms output-to-output far-end crosstalk loss for cables of all gauges, including composite configurations, shall be in accordance with ANSI/ICEA S-56-534-1983 [1].

6.5.5 Dielectric Tests

6.5.5.1 Between Tip and Ring Conductors. In each length of cable the insulation between all tip conductors and all ring conductors shall be capable of withstanding the following dc voltage for 3 seconds:

Conductor Size (AWG)	Nonfilled Cables dc Voltage Minimum (kV)	Filled Cables dc Voltage Minimum (kV)
26	2.4	2.8
24	3.0	4.0
22	3.6	5.0
19	4.5	7.0

6.5.5.2 Conductor to Shield. In each length of cable the insulation between the shield and all conductors in the cable shall be capable of withstanding 20 kVdc voltage for 3 seconds for filled cables and 10 kVdc voltage for nonfilled cables.

6.5.5.3 Conductor and Shield to Ground. In each length of a filled or nonfilled cable the insulation withstand of the outer jacket to the conductors and shield shall be 30 kVdc for 3 seconds.

NOTE: At user's option this test can be conducted while cables are immersed in water for a specified time.

6.5.6 Impulse and Surge Tests. Use ANSI/IEEE Std 82-1963 [3].

NOTE: At user's option, impulse and surge tests can be specified for communications cables.

6.5.7 Dielectric Tests After Installation. All cables shall be capable of withstanding all dielectric withstand voltage tests after installation.

Annex
Insulation and Jacketing Polyolefin Compounds for Conductor

General Description

The material shall consist of a polyolefin resin containing 0.1% of an approved nondiscoloring antioxidant and coloring agents. The material is intended primarily as insulation on wires and cable and shall meet the requirements of ANSI/ICEA S-56-534-1983 [1].