

Electric Power Conductors Volume III: Medium Voltage Cables

An Online Continuing Education Course for Engineers

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Electric Power Conductors Volume III: Medium Voltage Cables

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**This course is one of four courses on electrical power conductors.
The four courses are:**

- Volume I: Electric Power Conductors – Electrical Characteristics**
- Volume II: Electric Power Conductors – Mechanical Characteristics**
- Volume III: Electric Power Conductors – Medium Voltage Cables**
- Volume IV: Electric Power Conductors – Low Voltage Cables**

Each course is written as a stand-alone course and it is not necessary to take them in order. Because they are written as stand-alone courses there is some duplication of material among the four courses.

Introduction

In the electric utility industry, *medium voltage cables* are conductors suitable for operation at voltages of 5kV to 35kV in underground installations. This voltage class is commonly called a primary voltage line. The conductors are covered with an insulating material to electrically isolate the conductor from the surrounding environment. Overhead conductors in the voltage class are generally bare conductors with no insulation or covering. And unlike the residential and commercial markets, where voltages are typically less than 600-volts, the higher voltage places immense stresses on the insulation of the conductor. This makes the design, choice of materials used, and quality control in the manufacturing process critical to the reliability and longevity of the cable.

The benefits of primary underground installations include resilience to extreme weather events such as ice, snow, and windstorms and aesthetics. There are drawbacks, though. Underground primary lines are much more expensive to install than equivalent overhead lines; perhaps four times more expensive for a new installation and up to ten times more expensive to replace an existing overhead line. The underground cables have a shorter life span than overhead conductors, and the life cycle economics—including storm damage and other maintenance—generally favor overhead lines. Today it is estimated that about 40% of all new primary installations are underground.



Credit: General Cable

The utility industry has long realized the potential benefits of underground cables and has experimented with underground cables for almost a century. The earliest cables were paper-insulated, lead-covered (PILC) cable, and these cables had reasonable success. Since the 1960s, polymer insulated cables have been favored due to their superior dielectric strength and ease of installation.

One of the first polymer cables was the high molecular weight polyethylene (HMWPE) cable. The ease of installation, and lower costs than PILC, made HMWPE the choice cable for medium voltage applications. The industry soon realized that HMWPE cables were failing due to a phenomenon known as “treeing.” *Treeing* is a breakdown of the insulation due to voltage stress. The cable industry moved from HWWPE to cross-linked polyethylene (XLPE) for better resistance to the treeing problem, but it too suffered reduced life due to insulation failures caused by treeing. To mitigate the effects of treeing, manufacturers introduced *tree retardant* XLPE cables (TR-XLPE) and ethylene-propylene rubber designs.

Today TR-XLPE and EPR cables are the dominant insulations for medium voltage utility applications. There are numerous factors that influence the operating life and reliability of underground cables, and a comprehensive understanding of the individual materials that make up the cable is required to select a cable for a given application.

This course provides a background on the materials used in medium voltage cables and addresses the designs, materials, and manufacturing processes that influence the economical and reliable operation of a power cable. Issues such as conductor selection, insulation materials, sheath materials, neutrals, and cable jackets are addressed. The electrical characteristics unique to underground cables are also reviewed as well as installation issues.

The most popular medium voltage cable design uses either TR-XLPE or EPR insulation, has a concentric neutral, and a protective jacket. Figure 1 shows a representative sample of an EPR, concentric neutral, jacketed cable.

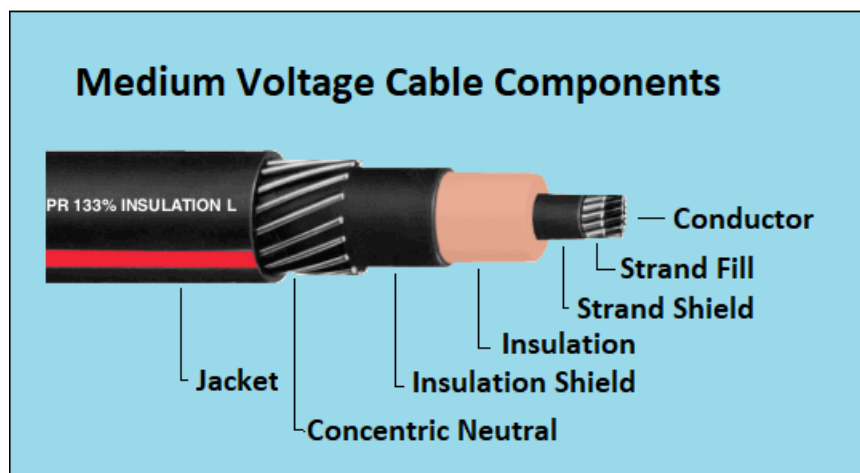


Figure 1

In the above figure, the electrical conductor is shown on the far right. The next item is the strand fill (not shown in the illustration). A strand shield then covers the conductor and strand fill material. The insulation is next, which in this case is EPR, followed by an insulation shield. The neutral conductor is applied over the insulation shield, and then a jacket is applied over the entire cable.

Figure 2 is a cross-sectional view of the cable shown above.

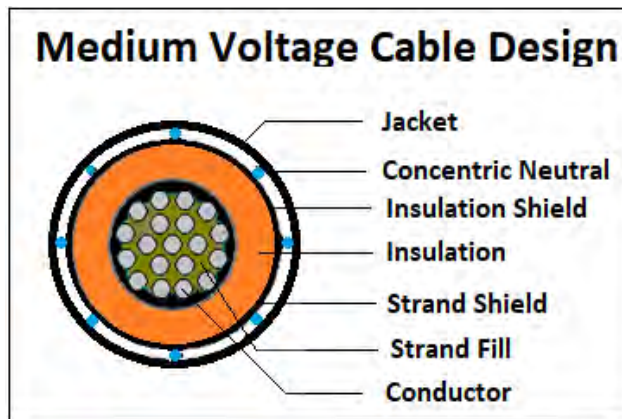


Figure 2

Other forms of medium voltage cable include unjacketed concentric neutral cable, flat-strap concentric neutrals, longitudinally corrugated (LC) neutrals, and shielded cables.

In the United States, cable designs are based on standards developed by the Institute of the Electrical and Electronic Engineers (IEEE), the American Society of Testing and Materials (ASTM), and the Insulated Cable Engineers Association (ICEA).

The following chapters cover the design characteristics of medium voltage cables, including the conductors, insulation, shields, neutrals, jackets, and fabrication techniques, and installation design concepts.

Chapter 1: Conductors

Medium voltage cables use either copper or aluminum materials or some alloy thereof. The selection of either copper or aluminum is based on the material price, electrical characteristics, and physical characteristics. Table 1 shows typical 15 kV TRXLPE cable specifications.

Table 1 15kV TRXLPE Cable Aluminum Conductor - 100% Insulation Level										
Conductor		Neutral	Thickness (Mils)			Diameter (Mils)		Wt.	Ampacity (amps)	
Size	Stranding	No.-Size	Insulation	Insulation Shield	Jacket	Conductor	Cable	Cable (Lbs./1000 Ft)	Direct Burial	In Ducts
2	Solid	10-14	175	30	50	258	961	453	168	119
1/0	Solid	16-14	175	30	50	325	1028	591	218	155
1/0	19	16-14	175	30	50	352	1056	609	218	155
2/0	19	20-14	175	30	50	395	1098	703	248	177
4/0	19	20-12	175	30	50	498	1234	993	324	230
350	37	18-14	175	40	50	661	1396	1055	389*	319*
1000	61	20-10	175	40	80	1117	1988	2473	642*	542*

* These ampacities based reduced neutral (1/3 neutral)

Materials

The electrical conductivity of copper is greater than that of aluminum, and the electrical conductivity of annealed copper is the standard by which all other conductors are measured and is defined by the International Annealed Copper Standard (IACS). The conductivity of hard-drawn copper is 97% of the IACS standard, and 1350 aluminum has a conductivity that is 61.2% of the conductivity of annealed copper. All references to conductivity and resistivity in the IACS are based on a temperature of 20C.

Table 2 shows the resistivity, conductivity, and thermal coefficient of resistance for several popular conductor materials.

Table 2 Electrical Properties of Materials			
Material	Conductivity	Resistivity ($\Omega\text{-in}^2/1000'$)	Temperature Coefficient of Resistance per C
Annealed Copper	100%	0.008145	0.00393
Hard-Drawn Copper	97%	0.008397	0.00381
1350-H19 AL	61.20%	0.013310	0.00404
6201-T81 AL	52.50%	0.015515	0.00347
Steel Core	8.00%	0.101819	0.00327

Copper is strong, easy to join, resists creep, and resists corrosion. Because of its higher conductivity, a copper conductor can be smaller than an aluminum conductor for a given ampacity. Aluminum conductors are cheaper than copper conductors but have lower conductivity and are more susceptible to corrosion than copper and more flexible. The predominant aluminum alloy used in overhead and underground conductors is 1350-H19 aluminum.

Material Characteristics

Underground conductors are made of aluminum or copper. Overhead conductors are made of aluminum or steel-reinforced aluminum. There is a trade-off, however, between strength and conductivity. Steel-reinforced aluminum has higher strength but lower conductivity than pure aluminum. The trade-off is more pronounced in pulling tensions.

The aluminum alloy used in overhead and underground conductors is 1350-H19 aluminum. For larger conductors, steel-reinforced aluminum is used. A common AAC conductor is 1350-H19 aluminum.

