Frequently asked

Questions

What is the difference between resistivity and resistance for a wireline cable?

How do I find characteristic impedance of wireline cables?

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Resistivity of Conductor Insulation and Characteristic Impedance of a Wireline

Q:1 The conductor in a wireline cable is insulated using a polymer material, which contains high dielectric properties. Camesa specifies insulation resistance in terms of MΩ per 1000 ft. @500 VDC (or MΩ per km @500 VDC). This is the resistance of the insulation material between the copper conductor and the steel armor wires. It is an important property of the wireline, required especially while checking the line for possible cases of insulation breakdown, due to any damage or exposure to extreme temperatures.

Volume resistivity of the insulation material is the measure of how strongly a given material opposes the flow of an electric current. The volume resistivity of the material is generally specified by the manufacturer of the polymer in terms of Ohm-cm. A high resistivity indicates a material provides high resistance to electric charge, which is a desirable property in an insulator. However, the resistivity of a polymer also depends on the temperature at which it is exposed. Resistivity of the material increases with temperature. Therefore it is crucial to use the plastic within the rated operating temperature. This means that attention needs to be given while choosing a wireline cable for a particular depth or well temperature. The temperature ratings of plastic insulation used in Camesa's wireline cables range from 300°F (149°C) for polypropylene copolymer, to as high as 600°F (316°C) for perfluoropolymers (TE).

Another difference between resistivity and resistance is that the resistivity of a material is an intrinsic property and is independent of physical dimensions such as length, or voltage applied to it. Whereas, the insulation resistance depends on the physical dimensions of the cable type and also voltage applied and therefore needs to be specified for each cable type. It is beneficial to a wireline end-user to know the temperature rating of the type of insulation used in a particular cable type and its corresponding minimum insulation resistance while selecting a wireline.

Q:2 Characteristic impedance (Z_0) of a wireline, is a characteristic property of a cable type depending on its construction and the materials used. It is a function of the frequency of the applied voltage and does not depend on the length of the wireline. It is defined as the ratio of the amplitudes of voltage and current of a single wave propagating along the line; that is, a wave travelling in one direction in the absence of reflections in the other direction. Characteristic impedance is expressed in Ohm and corresponds to the input impedance of the wireline of infinite length.

It also corresponds to the input impedance of a transmission line of finite length that is terminated in its own characteristic impedance. Generally, characteristic impedance has a resistive and reactive component. At very high frequencies, the reactive component becomes negligible and the characteristic impedance approaches a fixed value which is mostly resistive. For example, wireline cables have an impedance of 50 or 75 Ohms at high frequencies. Typically, twisted-pair telephone cables have an impedance of 100 Ohms above 1 MHz.

Characteristic impedance of the wireline determines the maximum power transfer between the source and load. Thus, for sending signals over a line, the transmitting equipment must have an impedance (viewed from

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its output terminals) equal to that of the characteristic impedance of the line to get the maximum power transfer into the line. At the other end of the line, the receiving equipment must also have the same impedance as the line to have maximum signal out of the line to the load. In case of impedance mismatches, the signal is reflected back into the line, or to the source causing problems and is therefore undesirable.

For wireline cables, the resistance is determined by the diameter or weight of copper, the inductance is very small, and the shunt conductance is small. The major influence on characteristic impedance and other secondary coefficients is the capacitance. This is largely determined by the type of insulation (dielectric) used. Characteristic impedance, for high frequencies, can be stated in terms of the physical dimensions of the cable.

$$Z_0 = \left(\frac{138}{\sqrt{\xi}}\right) \times \log_{10}\left(\frac{(D+1.5e)}{kd}\right) \ Ohm$$

For example, the characteristic impedance (Z_0) for Camesa's 1N32WG cable is as follows:

$\xi \approx$ 2.155;   Relative permittivity of the insulating material PTFE

$D =$ 3.937;   Inner diameter of outer conductor (or core outer diameter) (mm)

$d =$ 5x0.361=1.805; Bare diameter of center conductor (5 x copper conductor dia.) (mm)

$k =$ 0.97;   Stranding factor (1 strand: $k = 1$; 7 strands: $k = 0.94$; 19 strands: $k = 0.97$)

$e =$ 1.1303; Diameter on single armor wire (mm)

Therefore,

$$Z_0 = \left(\frac{138}{\sqrt{2.155}}\right) \times \log_{10}\left(\frac{(3.937+1.5\times1.1303)}{0.97\times1.805}\right) = 47.70 \ \Omega$$

The characteristic impedance for 1N32WG cable is 47.70 Ω.
As you may see, the characteristic impedance for any cable depends on conductor sizes, spacing between them and type of insulation used. Any change in these will affect the characteristic impedance.

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