What's new in cable?

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Some interesting developments across the cable industry, without restricting the discussion to any particular company.

Cables are very simple, or so some people think – just take a long thin piece of metal and slop some insulation around it, and there's an insulated power or signal cable! If it's an overhead conductor that is needed, then leave out the insulation ...

Really? If it were that simple, then cables would be very boring. Fortunately for us in the industry, as soon as we start to look at all the options, and the conflicting requirements, we can see that cables are anything but simple. Cables must be able to routinely work at temperatures that a hand cannot tolerate, and must be able to handle mind-boggling currents, all be it for a short time, without damage. Often they must ensure the current stays in the conductor, when massively persuasive forces are trying to get it to do otherwise. Cables can be fixed or flexible, and they can be seen as resistors, inductors, capacitors or even as wave guides. On top of this there is even an expectation that they will be cheap!

Pushing the voltage

In South Africa the highest rated voltage at which cables have been used has been 132 kV. With the Ingula pumped storage project, this will be raised to 400 kV, once the station is operating. Elsewhere in the world, the upper limit is around 600 kV, both ac and dc, and using both lapped and extruded insulations. Such cables have been successfully used for feeders over 100 km long in the case of ac, and over 500 km in the case of dc. However, overhead line systems are leading with respect to voltage, with some 1,2 MV systems already in use in the former Soviet Union and Japan. The next big step for cables will be 800 kV, although there is not much information on such cables in the public domain yet. Of course, developing such cables is only part of the work, as they are of no use unless they can be jointed and terminated successfully! Interface component technology can be more challenging than the cable itself.

Fire performance

At the lower end of the voltage scale are the fire performance cables. Be careful! 'Fire performance' can mean many things, so we usually describe different characteristics, such as flame propagation, smoke emission and halogen gas emission. The most advanced cable is often termed a 'fire survival' cable. It does not survive fires, but it can maintain emergency electricity supplies long after regular cables have failed. These cables have traditionally been made using mica glass tapes over the conductors, but these tapes are difficult to handle, and taping is slow. The material manufacturers have come up with an interesting solution: insulation that turns into a ceramic as it burns. The cable loses all flexibility, but its dielectric properties are preserved and will continue supplying power.

The XLPE water tree debate

In the ideal cable world, where everything is perfect and XLPE is as clean as an operating theatre, the problem of water trees doesn't exist. However, we do not live in this ideal world, and the fear of water trees, whether justified or not, persists. So how is this fear addressed? In South Africa we have three possibilities:

- All MV XLPE cables types used here must pass a mandatory and comprehensive accelerated ageing test. Cables that use high quality clean insulation will pass this test.
- If the customer is not happy that this has addressed his fears, it is now possible to water block cables against both longitudinal and radial migration of water. This helps because water trees will only grow in the presence of moisture. Radial water barriers can take the form of impermeable metallic layers such as aluminium and lead.
- For the customer who is still not totally comfortable, the suppliers

An accelerated ageing facility for testing MV XLPE cable.

A fire performance test facility, with a flame propagation chamber on the left and a smoke emission chamber on the right.

ACSR	– Aluminium Conductor Steel Reinforced
AEMSA	– Association of Cable Manufacturers of South Africa
HTS	– High Temperature Superconductor
PP	– Polypropylene
SABS	– South African Bureau of Standards
XLPE	– Cross-linked Polyethylene

Abbreviations

of insulating materials have developed polymeric systems that have either an additive, or comprise a co-polymer, that reduces the likelihood of water trees-initiated breakdown.

Alternative for MV XLPE?

An idea that is being explored internationally is the use of a specially developed polypropylene (PP) insulation, instead of cross linked polyethylene insulation. The idea here, is that while the polypropylene does not cross link, it does mesh at a molecular level, giving the insulation properties similar to XLPE. This means that the manufacturing process is much simpler, has lower manufacturing energy costs - and the material can be recycled. This is not the case with XLPE which, after it has been cross linked cannot be re-extruded. How well does it work? We do not know yet, but after the XLPE water tree debacle of some years ago, Engineers are likely to be cautious. Nevertheless, application in MV cable networks in Europe is growing with downstream interest in higher voltage cable as, unlike for XLPE, PP dielectric systems do not require degasing.

Combating theft

Firstly, is the theft of cables really a social problem? If so then can technical solutions ever be effective in the long term, without the social problem being addressed? Of course, if the social problem is addressed then, technical solutions will not be necessary.

Secondly, there are many ways of making cables that are less desirable to the would-be thief.

- *Poison or contaminate the metal conductor.* Bi-metal conductors, such as tinned copper, copper coated aluminium, copper coated steel, and even copper coated brass are all materials that are difficult to recover, making them difficult for the thief to sell. On the flip side this also makes them environmentally unfriendly, because recovering the component metals requires a lot of energy. It also reduces their current rating.
- *Batch mark cables.* With this method cables are somehow marked, chemically, physically, or any other way, so that the batch can be identified. The challenge here is to somehow prove that while many people can legally own cable from a particular batch, the suspected thief acquired his piece illegally.
- *Unique mark cables.* With this approach, cable is marked with a code that changes either at very short lengths, or at very short time intervals. It is possible, for example, to mark conductor with unique number that changes every second, and then record to whom this conductor is sold.

The latter is a method currently being explored in South Africa. It is in the interest of everyone on the right side of the law, that if a marked conductor is found in suspicious circumstances, it can be readily traced using a system that is not unique to each supply authority, of which we have many, and is not unique to each manufacturer, of which we have a few.

To this end, the Association of Cable Manufacturers of South Africa (AEMSA) has drafted a standard for this marking. The SABS is also working on such a standard, and in order to not work against one-another, the AECMSA has handed its draft over to the SABS.

Overhead conductors

The bulk of this article is about insulated cables, but there have also been developments with overhead conductors. How can we improve on simple bare conductor? Much of the overhead conductor used in South Africa is ACSR, where an 'uncompacted' steel core is surrounded by one or more layer of 'uncompacted' aluminium wires and with a limited thermal rating of ± 80°C.

Firstly, the core can be improved. Steel has its limits, so some suppliers are replacing it with a composite fibre core – the two dominant technologies being glass/ carbon and aluminium oxide fibres. Composite cores can be a single ‘rod’, or they can be of a number of ‘rods’ stranded together. The advantage of this type of core is that

A modern MV and HV triple head XLPE extruder.

A typical HTS cable. The three concentric conductor layers are barely visible, yet each can handle almost 2 000 A.

for its strength it is lighter than steel, and it does not expand as much as it heats up. Secondly, more aluminium can be added to the same diameter cable. Simply compacting the aluminium will harden it and increase its resistance, so instead this can be done by shaping the individual strands allowing them to fit neatly together.

Thirdly, steel corrosion protection using zinc-based galvanising remains in use for traditional conductors, eg ACSR, but cannot be used in high temperature conductors. When operated above 180°C, testing has shown that the internal temperature of the conductor can cause standard zinc coatings to degrade. Solutions to this challenge can be to use either an aluminium clad or Zinc-5% Aluminium-Mischmetal Alloy coated core. Higher thermal ratings up to 230°C can be achieved by the use of zirconium alloys in place of EC aluminium wires.

High temperature superconductors

No discussion on developments in the cable industry would be complete without at least some mention of superconductors. Although there are many different superconductors that are now known to science, the cable industry is focused on a ceramic that is often referred to as a high temperature superconductor (HTS). The 'high temperature' in question is around 77 K, which by most people's measure is not exactly hot. However, it is much hotter that the 0 to 4 K range where superconductivity was first observed.

Most, if not all, of the HTS cables developed have similar basic components. The 'wire' is a flat ceramic, approximately 3 mm by 0,01 mm, encased in stainless steel. This little 'wire' can handle up to around 90 A. The cable is then constructed using these 'wires', for example, arranged concentrically around a hollow centre, and the cable is cooled using liquid nitrogen. Conveniently, liquid nitrogen is a good dielectric. As yet there is no commercial HTS feeder installed in the world. The concept is still in development and the feeders installed are therefore all experimental, and monitored closely.

The advantage of HTS is that is can handle huge currents without loss. This means that large amounts of power can be conveyed without the need for the high voltages usually associated with such power. For example, at main substations in the urban environment of the future large step-down transformers could be replaced with refrigeration units, as the incoming voltage would be the same as the distribution voltage. Could we eventually see domestic supplies at 12 V?

The power of particles

Nanotechnology application is further enhancing the processing and field performance of cable dielectric and sheathing systems. This technology relates to manipulation of polymer and compound structures in a size range of 3 - 100 nm and is expected to herald unique and so far untapped properties.

War of the currents

At the turn of the 20th century, George Westinghouse, Thomas Edison and Nikolai Tesla fiercely contested the benefits of ac versus dc. As we know Westinghouse and Tesla won the battle with ac but the emergence of power electronic components has seen strong re-emergence of dc systems originally pioneered by Edison. These developments have found their way in insulated power cables and overhead conductors and offer added performance attributes particularly in respect of ac loss reduction and linking large networks.

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What is not measured is not understood

The measurement of partial discharge activity in MV, HV and EHV polymer insulated power cables is a critical aspect of current technology. Over the last 20 years, these measurements have extended from controlled factory test bays to continuous online field measurements thus offering added condition monitoring opportunities. Other diagnostic measurements of dielectric loss-angle and distributed temperature sensing using optical fibre technology are providing added operational and financial gains from cable assets.

Magnetic field effects

Typically a single large MV XLPE insulated 3-core copper-conductored cable can convey ± 35 MVA. These cables have diameters in excess of 100 mm and are heavy and difficult to handle thus raising interest in single-core cable installations. However, when the symmetry of a three-core cable is replaced by a spaced single-core configuration, often unexpected magnetic field effects result which need to be carefully managed. Considerable gains have been made with multi-conductor analysis of single-core installations using advanced matrix mathematics thus ensuring knowledge of steady state and transient induced voltage and currents and overall link performance.

Conclusion

There is so much more to cables than just insulated wire, with much more to come. Watch this space!

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