Water trees are a chemical degradation of polymeric insulation such as XLPE or EPR that only occurs in the presence of water and an electrical stress.

Water tree failures

In the 1970s and 1980s many polymeric cables failed after 3 – 10 years in service because of water tree degradation of the insulation. The failures were most prominent in North America and in Northern Europe where they had moved rapidly to the new technology of polymeric medium voltage cables. These early cables were almost entirely manufactured by a twin extrusion of inner screen and insulation with a graphite paint and taped outer screen. Most CV lines in those days used steam-curing technology.

Countries that moved to MV polymeric cables later, such as the UK which started using these cables in volume during the early 80s, have had far fewer reported cases of water tree related failure. The vast majority of these cables were manufactured using triple extrusion on dry cure CV lines or Monosil lines. The other key change has been the increased efforts to maintain cleanliness of the materials during manufacture. These cables have 20 years service experience without significant water tree ageing problems. However, recovered samples of serviced aged cables from a range of manufacturers and covering the range of materials do show evidence of water trees.

Water tree technical summary

Great efforts were spent in researching the cause of these failures and developing preventative measures. Ten key points extracted from the myriad of technical papers written on the subject are as follows.

- Water trees need a sufficiently high moisture content within the insulation to grow, they do not need free water.
- Water trees only grow if the electrical stress is above a threshold limit (so do not affect LV cables).
- Water trees initiate from inhomogeneities within the insulation or at the insulation/screen interface.
- Two types of tree are defined, those growing from either screen are called vented trees and those within the insulation are called bow tie trees.
- Generally vented trees continue to grow while bow tie trees reach an equilibrium size, so vented trees are of greater concern.
- Steam curing introduces thousands of microvoids within the insulation which enable it to hold a greater level of moisture and also provide water tree initiation sites.
- Some additives can retard the growth of water trees all other factors being equal, these additives tend to be highly polar and also affect the dielectric properties of the insulation but not sufficiently to cause concern at MV.
- Nobody has yet succeeded in making a water tree proof cable.
- Painted screens do not provide a perfect interface to the insulation and provide sites for tree growth.
- Accelerated ageing tests have been developed that correlate well with service experience and distinguish between good and bad cables.
- There remains technical debate about many water treeing issues but four key factors in reducing/eliminating water tree failures are generally agreed.
- Don’t use steam cured CV lines.
- Minimise contamination of insulation and semiconducting screens.
- Maintain smooth insulation screen interface.
- Triple extrusion.

The widespread use of dry cure lines, with better material handling and triple extrusion has greatly reduced water treeing as a cause of early onset failure.

Specifications for tree retardancy

Internationally cable specifications do not cover the subject of water treeing consistently. Some specify the use of tree retardant materials without any qualification or test criteria. This is poor specification writing as materials designated as tree retardant by the suppliers are not, in themselves, sufficient to prevent water tree related failure. Even specification of a particular grade of material is not sufficient as poor manufacture can still lead to service problems.

Testing for water tree resistance

The principle of testing is to age the cable cores by applying an overvoltage while the cables are in contact with water and then testing to breakdown to determine the residual breakdown strength of the insulation.

In Europe there are two main tests: one requires two years ageing at normal frequency of 50 Hz and the alternative accelerates the process by using elevated frequency of 500 Hz which reduces the ageing time down to 3000 h. This test was originally developed by KEMA who are acknowledged as World experts on water ageing of polymeric cables and have carried out many years of extensive research into this subject. Published papers by KEMA, DOW, BICC, Sintef and others demonstrate the equivalence of the tests [1, 2 and 3]. Although the test equipment is more specialised the shorter duration of this test makes it very attractive to both manufacturers and users of cable.

In this test, cables are preconditioned by saturating with water and then subjected to 3000 hours ageing in water at 2.5 Uo using a high frequency of 500 Hz to further accelerate the ageing process. The aged
cores are then subjected to voltage breakdown testing and must achieve certain threshold limits to pass the test.

It is important to note that the test is not a materials test. Although the choice of a high quality material is essential in achieving good electrical performance and long life it is not in itself sufficient. The manufacturing process must also be of the necessary high standard. Any contamination of the insulation or feature on the insulation-screen interface can provide a site for potential water tree growth and lead to premature failure. Therefore great care must be taken to ensure that the cleanliness of the material is maintained, that the extrusion equipment uses a modern triple head with a dry curing technique and that the process conditions are carefully controlled. These measures combined with a stringent quality assurance and control regime will prevent contamination or degradation during the extrusion process. It is the combination of high quality process with appropriate material that gives the cable the necessary properties to ensure a long life.

If the test is carried out at KEMA they also report the results graphically showing the test performance in comparison with a summary of all the test results carried out by KEMA over many years (Fig. 3). Results in the upper left quadrant are considered to be good as the tree growth is low and the breakdown stress remains high.

Conclusion
Although great improvements have been made in the wet ageing performance of MV polymeric cables it is still prudent to take precaution in the specification and choice of suppliers to minimise the risk when purchasing such cables.

- Specify triple extruded, nitrogen cured XLPE
- Ask for evidence of breakdown test data which can indicate whether the cable insulation or screen has contamination introduced during the process.
- Insist that the cable manufacturer has carried out an appropriate wet ageing test on their cable using the insulation and screen grades they will be supplying.
- Specify a fully water blocked cable so that exposure to water is limited even in the case of the cable being severely damaged i.e. ensure that water cannot travel along the cable conductor or the outer layers of the construction.

References

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