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The development of an ultrasound quality monitoring process for the manufacture of enhanced reliability HV and EHV XLPE cables

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XLPE cables are established in ac and dc HV systems at 60-180 kV and are being applied in long length applications at EHV (200-500 kV). Manufacturing quality and service reliability have been the key drivers in the development of extruded cables from the first 10 kV application through to 500 kV. These technologies have permitted high operating stresses of 13-17 kV/mm to be applied at 400-500 kV. At 110kV-150 kV, operating stress has been increased to 8 kV/mm.

The historical developments that have made EHV XLPE cables possible are reviewed, e.g. the technologies of quality monitoring and testing, extrusion equipment and specialised materials. The first PE cables were extruded in mono or dual processes. They contained material and process defects. In-line quality monitors were used to detect defects; improving knowledge and accelerating development of manufacturing equipment and materials. The introduction of extruded insulation screens significantly improved cable reliability, however it precluded use of existing in-line electrical and optical monitors. Quality was assessed by discrete sampling from the material silos and from cables. Each cable length was subjected to electrical routine tests. However it was experienced that sporadic defects can occur at repeated distances along the conductor screen and XLPE insulation. Large defects produced electrical stress raisers of high magnitude (x15); resulting in electrical failure at routine test. It was realised that smaller defects could pass into service. This risked premature service failure of the cables, with resulting cable replacement costs and long circuit outage times. These experiences confirmed that a quality monitoring gap existed in XLPE cable manufacture. This situation remained unchanged until four years ago.

The development is described of a new type of continuous in-line monitor, which improves quality and significantly enhances the reliability of XLPE cables. The equipment was specified for the XLPE cable industry with the objective of permitting inspection of the interface between the semi-conducting conductor screen and insulation. The equipment monitors the extruded core as it emerges from the factory CV line; initiating an alarm and identifying the size and position of any undesirable defect. The technology uses the principle of ultrasound together with advanced digital signal analysis to extract detailed information from defects and geometric inconsistencies. Development trials were first performed to find the optimum combination of ultrasound frequency and penetration depth for a range of LV, HV and EHV cable sizes and extrusion line speeds. It was confirmed that the monitor was highly efficient in the detection of particles and bubbles in the insulation, with an ability to discriminate 40 microns, to detect defects on the conductor screen down to 70 microns and in the insulation down to 200 microns. Examples of cable detection trials and factory applications are given.

Having measured the dimensions and aspect ratios of defects within full sized cables; the shapes were field plotted to calculate their stress raising magnitude. The prospective reduction in cable life was then determined using an inverse power law relationship. Sensitivity studies were performed demonstrating that complete in-line monitoring is now achievable and that significant enhancements in cable reliability are assured.