Cable Degassing, Strand Filling Mastic and Cable Defects

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ABSTRACT

On the basis of a study including tens of thousands of field tested cables and laboratory dissections of defects, the frequency of manufacturing defects have doubled in the last 10 years. While the number of defects is still relatively low, one can argue that any preventable, systemic issue should be addressed. One challenge to the quality control process manufacturers have consistently pointed to is insufficient degassing temporarily hiding defects from factory partial discharge quality control (QC) testing. The likely causes, including a reaction between uncured semicon and strand-fill, ways to improve factory QC processes, and potential solutions to address the problems are discussed.

KEYWORDS

Field Testing, Partial Discharge (PD), Degassing, Quality Control, Defects, MV cables, Strand Filling, Mastic

INTRODUCTION

A recent study on tens of thousands of field samples has identified systematic occurrence of manufacturing defects passing factory production testing. The number of positively identified manufacturing defect cases as a percent of cable tested has more than doubled in the last decade. A review of several case studies has identified defects that could only have occurred during the factory manufacturing process. Manufacturers typically assign the root cause of these non-detections in the factory to partial discharge test malfunction, mechanical stresses during installation of the cable (i.e. bending and/or pulling) causing defect sites to now exhibit PD, or degassing issues. Research into the manufacturing process, quality control processes and the fundamental chemistry in dielectric cable extrusion has identified deficiencies and likely root causes for the confounding of partial discharge test measurements and results. Ideas to improve the quality control process and address the design issues that hamper defect detection will be discussed.

BACKGROUND

Non-Destructive Routine Testing of Finished Cable

Final inspection and testing requirements for insulated cable can vary with the applicable cable standards and customer specifications used for design and manufacturing. Invariably, partial discharge (PD) testing with an overvoltage is used to demonstrate defect-free manufacturing. The presence of defects, such as voids, which may or may not immediately result in full dielectric breakdown during the factory test, are detectable through the partial discharge test. The detection of defects is critical, as they will likely cause failure earlier than the design life of the cable. Since the performance impact of these defects are not immediately realized, systemic issues that mask their detection, should be addressed.

Role of Degassing in the Cable Manufacturing Process

Degassing is a critical step in the cable manufacturing process for extruded cross-linked polyethylene (XLPE) materials. In peroxide crosslinking of polyethylene, a peroxide (such as dicumyl peroxide) is mixed with natural polyethylene and then extruded at high temperatures. At these high temperatures, the peroxide decomposes into peroxide radicals, which pull hydrogen atoms from the polyethylene chains. The exposed carbon bonding sites from the polyethylene chains attract to other carbon bonding sites from other chains and form the strong cross-linking bonding that gives XLPE its good thermal stability. However, the peroxide radicals can also form volatile byproducts such as cumyl alcohol, acetophenone, methane, and water [1-2]. Methane presents a safety concern as the gas can be flammable in sufficient quantities during the installation and energization process.

Degassing also plays a role in the detection of manufacturing defects during the quality control process. Due to the polar nature of the cross-linking byproducts, electrical stresses can be reduced around defects that create stress enhancements, that would normally experience partial discharge of electrical breakdown. The byproducts in gaseous form can also pressurize voids within the insulation, preventing the inception of partial discharges and electrical tree growth. The mechanism of this inception voltage increase for internal discharges was demonstrated by Frederich Paschen (Paschen's Law), and is linked to the mean free path of an electron being excited by an electric field inside the gas. Under sufficiently high pressures as opposed to low-pressure voids, electrons have greater probability of colliding with gas molecules and be scattered in random directions [3]. Sometimes, this random redirection will even be in opposition to the electric field and cause a deceleration effect, requiring an increase in the ionization energy of the gas to create a discharge.

Due to these considerations, cable manufacturing standards covering utility power cable typically require degassing programs at ambient temperature. For example, the ICEA standard for MV cable presently requires a 7 day wait period before electrical testing for all voltages with no other specific requirements. With some standards, manufacturers have the option to reduce degassing times by increasing the degassing temperature, but have the responsibility to guarantee adequate degassing through chemical inspection means such as gas chromatography, liquid chromatography, and