CONDITION ASSESSMENT OF POWER CABLE SYSTEMS IN THE ENERGIZED STATE

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ABSTRACT

CableWISE technology is an excellent predictive maintenance tool that has been used to assess the condition of electrical equipment in the energized state while operating in electrical utility and industrial plant environments. It is an on-line totally passive technique which allows the measurement of signals at high frequencies emitted by the cable system while it is operating in service. The technique is particularly applicable for identifying the type of defects that cause aging and loss of life of cable system components. The analyses of the results are used to assess the severity of aging in cables, splices, terminations and the electrical equipment connected to the system. This non-destructive, non-invasive approach assists the user in establishing a predictive maintenance program in a proactive manner. This paper describes the rationale for studying signals prior to and after partial discharge inception.

KEYWORDS

Diagnostics, Partial Discharge, Pre-Discharge Signals

INTRODUCTION

Insulating materials deteriorate with time. In some cases deterioration can progress to the point where breakdown occurs prematurely. This applies to paper-insulated cables as well as to extruded cables. While paper insulated lead covered cables (PILC) have significantly long useful lives, the fact is that they are also reaching their end of life (at different aging rates) and it is important to understand the degree of degradation that cable systems have undergone upon aging. The deterioration mechanisms in paper insulation involve moisture entry (which facilitates thermal runaway), partial discharges (in oil starved butt spaces & tapes) voids and cavities, tracking and eventual formation of wax due to aging.

The service life of medium voltage extruded cables based on HMWPE and XLPE insulation has historically been shorter then anticipated relative to when these insulation materials were first applied by the cable industry. This subject has been discussed thoroughly in the past; causes of rapid deterioration have been defined and are known to have resulted from multiple sources along the 'chain of usage'. Issues have related to materials (contamination, ion presence serving as loci for water treeing, polymer nature), manufacturing (entrapped moisture within the insulation wall) and user practices (e.g. DC HiPot testing) that contributed to problems leading to premature loss of life. While most of these practices have been improved upon, nevertheless there are millions of meters of installed cable subjected to these earlier practices. With increased knowledge of these issues, modifications (including use of ethylene copolymers (EPR) and 'tree-resistant' XLPE) have led to improved and longer life installed extruded cable systems. However, with so many meters of the older systems still installed, the growing issue has become one of economically managing an aging system that is known to be of inferior quality relative to those cable systems that are being installed today. In other words, how does one decide whether and when to rejuvenate, repair or replace? Allowing the cable system to operate until failure has its own hazards, such as failures that will most often occur under harsh storm conditions (making replacement difficult), incorporation of splices onto aged systems that may better be replaced, etc. The merits of an on-line predictive approach as a diagnostic tool to assess the future performance of PILC and extruded cable systems, the limitations of non-predictive testing, and the issues that must be considered in setting up and using the predictive technology are reviewed in this paper.

Predictive Technology

Predictive methodology employed by CableWISE involves signal detection both prior to and during partial discharge inception. While partial discharge detection has been studied in depth, study of pre-partial discharge signals, their detection, measurement, and significance with focus on application of information from these signals as a diagnostic tool for predictive purposes, has not attracted as much attention. Prior focus on pre-discharge phenomena has focused primarily on charge storage, transfer and release, and the influence of these events on the mechanisms of aging, degradation and breakdown (1). This paper discusses signal detection from pre-partial discharge events, their application as a cable diagnostic tool, as well as conventional partial discharge detection and signal interpretation.

Signal detection R&D efforts with extruded cable materials have been presented earlier by Morel et al (2). Dorris, Pace, et al (3) had earlier demonstrated that signals from water trees could be measured in the absence of partial discharge (using specially designed sensitive equipment). Bruning (4) demonstrated that chemical changes could result without partial discharge. The work by Dorris and co-workers was performed on previously water-treed PE, while the latter work was with previously un-aged PE. Signals that were detected by Dorris, et al. in water treed regions of a low density polyethylene sheet were categorized as a 'slow' pulse and a 'fast' pulse; they reported current waveforms as small as 66 nA being reliably detected for the former. For the latter, charges as small as 1.2 fC could be reliably measured. Noise filtration, an obvious concern, was discussed. The detection of signals from water trees, in the fC range demonstrates that with proper equipment, signals that emanate from aged insulation material can be measured in the absence of true partial discharges.