A new algorithm to define a health index for HV and MV polymeric cables

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ABSTRACT

The health condition of HV and MV cables is a fundamental issue that needs to be managed properly by electrical asset managers, trying to reduce maintenance costs, keep the reliability at the desired level for the specific asset and increase as much as possible the return of investment, ROI. A cable system is typically made by three sub-components, i.e. cable, joints and terminations, which may have different diagnostic options and different weights to be associated to the diagnostic markers to estimate the whole cable system health index, HI. This paper indicates a way to achieve a unique HI estimation for a cable system, considering the most important diagnostic properties, and a new procedure to weight properly the diagnostic markers in order to have larger dependence of HI on those properties, such as partial discharges, which may cause very high aging rate and, thus, cause premature failure than anticipated life.

KEYWORDS

Health Index, Cables, Reliability

INTRODUCTION

Knowing the health of a cable during its service life and understanding possible actions to be taken to achieve the specified reliability are important for effective and proactive operation of HV and MV cables in any type of electrical asset. Today's best practice is for cable specification and design to be focused on achieving a predictable life and failure probability. But factors beyond those considered in the design can influence the operational life. These include manufacturing or commissioning flaws, service stresses different from those considered in the insulation system design (due, e.g., to changes of electrical asset topology and composition), inception of partial discharges and load conditions. A vexing problem for a system designer, however, is that there is little engineering data on the effect of deviations from design conditions on life. Consequently, it is not known which deviations are benign and which significantly reduce life.

An effective approach to managing this uncertainty is to monitor diagnostic properties during the life of the electrical apparatus. The measured data can then be used to develop condition-based maintenance procedures, as well as analytics, to reduce maintenance cost and increase the ROI of cable and related electrical asset. However, measuring diagnostic properties and then correlating the measured data with electrical insulation conditions is a task which still has not been addressed properly by researchers. There are properties, as Dissolved Gas, which have a good understanding and standardization background [1], others, as partial discharges, that are investigated by experts and using patterns which encompass phase, amplitude and repletion rate information [2, 3], but they are not straightforwardly related to failure time or, more generally, to insulation conditions. The challenge is to obtain diagnostic measurements that lead to a simple and reliable indicator of the insulation conditions, which can be used by the asset or maintenance manager to plan any type of action (e.g. run, repair, replace, rrr) on the electrical apparatus of the asset.

A potential answer to this challenge is to develop a health index (HI) of an electrical apparatus which can provide, by a number or a traffic lights, the basic information about whether an electrical insulation is still working properly, i.e. according to the design (green), there is a concrete indication that some degradation process is occurring (yellow), so that its reliability is at risk, or there is the evidence of high probability of incoming failure, thus need of rapid action (red).

This paper proposes an algorithm to calculate a health index, HI, for insulation systems where the diagnostic properties belong to two different categories. One is composed by properties whose variation has "low" impact on HI, being associated to slow aging mechanisms. An example of this first category could be dissipation factor, permittivity, conductivity, overheating (if contained in e.g. ±10°C, which means halving or doubling life). The second category is comprised of properties which are associated with fast aging mechanisms, thus having a "high" impact on HI (the terms "low" and "high" are relative also to the extent of variation of insulation degradation in relation to the value and trend of a property). This is typically the case of partial discharges, PD, under AC and DC supply, and space charge under DC. When dealing with organic materials, the presence of PD, even of relatively small magnitude, indicates high probability of premature failure (i.e. failure occurring at time shorter than the insulation system design specifications), that is, or significantly reduced insulation health. Likewise, amounts of space charge able to cause internal (Poisson) field magnification in insulation may shorten considerably life (according to the inverse power law [4, 5]).

Therefore, the main objective of this paper is to derive a HI which, in contrast to what has been done until now, can prompt a maintenance action not only as a function of score and weight of a diagnostic property, but also based on its harmfulness and influence on aging rate. A list of diagnostic properties and some HI calculations examples relevant to polymeric cables will complete the paper and show its potential usefulness for asset managers and cable companies.

HEALTH INDEX OF INSULATION SYSTEMS: PREVIOUS AND NEW APPROACH

The proposed HI is a conditional failure probability based on the measurement (continuous or periodic) of diagnostic properties X, that is, [6, 7]:

$$HI = 1 - \Pr(F|X) \qquad (1)$$