Risk on failure, based on PD measurements in actual MV PILC and XLPE power cables

Yizhou **QIAN**; Technical University Eindhoven, Eindhoven, the Netherlands, q5022679@163.com
Paul **WAGENAARS**, Fred **STEENNIS;** DNV GL, the Netherlands, paul.wagenaars@dnvgl.com; fred.steennis@dnvgl.com
Denny **HARMSEN**; Alliander, the Netherlands, denny.harmsen@alliander.com
Piet **SOEPBOER**; Enexis, the Netherlands, piet.soepboer@enexis.nl
Pascal **BLEEKER**; Locamation, the Netherlands, pascal.bleeker@locamation.nl

ABSTRACT

Network owners and service providers are interested in the relation between partial discharge activity (PD level or PD intensity) and the expected remaining life of power equipment. Based on the PD monitoring results obtained since 2007 from Smart Cable Guard (SCG) systems the time between the start of PD activity and the moment the component fails is investigated using Weibull statistics. The results of this analysis are:

	start PD until fault	SCG warning level 1 until fault
PILC cable systems	16 years	3 years
XLPE cable systems	2 months	10 days

For example: after seeing for the first time PD activity in an XLPE cable system it will take 2 months to have a chance of 50% on resulting in a cable fault (row 3; column 2). After an SCG warning of the highest level the period is reduced to only 10 days (row 3; column 3).

KEYWORDS

fault, breakdown, on-line, medium voltage power cable, PILC, XLPE, partial discharges, monitoring, degradation, risk on failure

INTRODUCTION

Network owners and service providers are interested in the relation between partial discharge (PD) activity (PD level or PD intensity) and the expected remaining life (until a fault (failure or breakdown) of power equipment. A fault is here defined as a breakdown of failure, by which the conductor insulation has a short circuit to earth / ground or another phase conductor.

In order to learn such a relation, it is needed to follow the PD activity as a function of time until a fault occurs. A fault is here defined as a breakdown or failure, by which the main insulation has a short circuit. This was done with help of Smart Cable Guard (SCG). Smart Cable Guard is a known monitoring tool that can detect and locate PD activity in Medium-Voltage (MV) cables in service. It is in use since 2007. More about Smart Cable Guard can be found in among others the papers [1, 2, 3, 4, 5 and 6]. Smart Cable Guard makes the critical information on the development of PD activity from start until failure available on a large scale.

It is known that PD activity in MV Paper-Insulated-Lead-Covered (PILC) cables is not as harmful as the same PD activity in cross-linked polyethylene (XLPE) cables. However, it is unknown how long PILC and XLPE cables can withstand this PD activity. The results presented in this paper will give the (cumulative) failure probability versus time. This helps network owners to decide whether a certain PD generating defect should be replaced soon, later or not at all.

In the first section it is described how the PD measurement data is analyzed using Weibull statistics. In the second section the results of this analysis are discussed.

WEIBULL STATISTICS

Introduction

Weibull distribution is the most popular and widely used probability distribution function in reliability engineering. The Weibull algorithm has become a standard for modeling time dependent failure data. The relationship between the survival time after the first PD occurs and failure probability was investigated. This section focuses on presenting the Weibull cumulative curve, which represents the failure probability after the first PD activity has been detected. Firstly an investigation of failure probability on PILC cables and XLPE cables will be shown separately, and subsequently their failure probability curves will be applied on the detected PD clusters.

The Weibull probability density function is

$$f(x) = \frac{\beta(x-\delta)^{\beta-1}}{\theta\beta} e^{\left[-\left(\frac{x-\delta}{\theta}\right)^{\beta}\right]},\ x \gg 0$$

with

- β = the shape parameter
- θ = the scale parameter
- δ = the location parameter

The cumulative distribution function for the Weibull distribution is:

$$\mathrm{f(x)} = 1 - \mathrm{e}^{\left[-\left(\frac{\mathrm{x}-\delta}{\theta}\right)^{\beta}\right]}$$

Weibull statistics have the possibility to take into account a situation where the PD activity at a weak spot is still ongoing at the moment of performing the analysis as reported here, although there is not (yet) a fault.