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Sample Size Planning in Experimental Research of Dielectric Stress in Oil-barrier Transformer Insulation

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Abstract

An approach for experimental research planning, based on Monte Carlo experiments, is suggested in this paper. The analysis is performed for AC permissible stress research in oil-barrier insulation system where paper insulated electrodes are used for insulation models production. The influence of sample size and high voltage test censoring on the accuracy of permissible stress estimation is examined as well as the possibility of using Monte Carlo experiments in costs and time-consumption optimization.

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Keywords: transformer insulation, experimental research, sample size, test censoring, Monte Carlo experiment

1. Introduction

The service life and operation safety of power transformers depend largely on the condition of transformer insulation system. Transformer can be in service until its insulation system is able to withstand all kinds of service stresses. Transformer insulation system is designed in such way that actual (expected) el. stress in a transformer is always lower than permissible el. stress, which is the stress level with low probability of partial discharge (PD) inception or breakdown (usually 1 % or less). Due to a fact that well-proven and widely accepted breakdown theory in liquids has not yet been found, permissible el. stress values in transformer insulation are derived from experimental studies where the statistical nature of breakdown process in transformer insulation system is examined

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[1]. In experimental studies transformer insulation models are subjected to high voltage tests where PD inception or breakdown voltage is measured.

In order to obtain experimental results that are applicable in practice, paper insulated electrodes should be used in models because this type of electrodes is generally applied in transformers due to good dielectric properties [1]. The practical problem with paper insulated electrodes is costly and time-consuming production process because only one breakdown result can be obtained in individual oil-barrier insulation model testing (paper insulation dielectric properties cannot be recovered after breakdown). Consequently, experiments on transformer insulation models are generally performed on the small sample size (number of test samples). If the sample size is too small, high voltage tests can be censored to obtain more information from the limited number of models. This means test can be stopped at predefined stress level without any event (PD inception or breakdown) registered, as described in chapter 2. Conducting a study with the non-adequate sample size can lead to significant errors if the sample size is too small, or to the larger costs and time-consumption than necessary if the sample size is too large. Therefore, the definition of sample size is a frequently discussed topic in experimental research planning.

The aim of this paper is to suggest and to demonstrate on practical example an approach for sample size and test censoring planning in insulation model testing. Research concept for oil-barrier insulation testing, previously reported by authors [1], is chosen for this purpose as an example. Model geometry and high voltage test method used in [1] are shown in Figure 1.

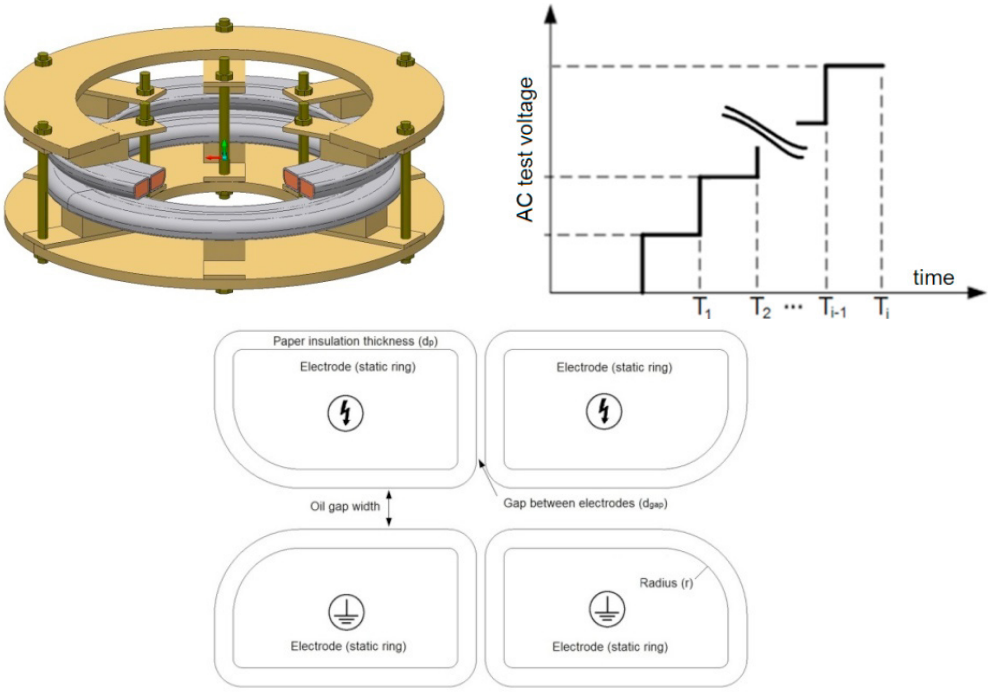

Figure 1. Model drawing (upper left), AC voltage raise method (upper right) and model cross-section (lower) used in research reported in [1]

In this research concept, AC tests (ramp in steps method) are performed on paper insulated electrodes in homogeneous el. field. Due to large model dimensions, a wide range of investigated oil gap widths (3 mm to 30 mm) and application of paper insulated electrodes, costs and time duration of this research could be relatively large [1]. Therefore, the goal of this paper is to check the influence of the following parameters on statistical analysis quality:

(1) combination of oil gap widths that should be tested
(2) number of models for each oil gap width
(3) test censoring