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Improved modelling of power transformer winding using bacterial swarming algorithm and frequency response analysis

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ABSTRACT

The paper discusses an improved modelling of transformer windings based on bacterial swarming algorithm (BSA) and frequency response analysis (FRA). With the purpose to accurately identify transformer windings parameters a model-based identification approach is introduced using a well-known lumped parameter model. It includes search space estimation using analytical calculations, which is used for the subsequent model parameters identification with a novel BSA. The newly introduced BSA, being developed upon a bacterial foraging behavior, is described in detail. Simulations and discussions are presented to explore the potential of the proposed approach using simulated and experimentally measured FRA responses taken from two transformers. The BSA identification results are compared with those using genetic algorithm. It is shown that the proposed BSA delivers satisfactory parameter identification and improved modelling can be used for FRA results interpretation.

1. Introduction

Power transformer is a major apparatus in a power system, and its correct functioning is vital to system operation. It is therefore very necessary to closely monitor their in-service behavior, in order to avoid catastrophic failures and costly outages and improve the management of maintenance and servicing.

Among various techniques applied to power transformer condition monitoring, frequency response analysis (FRA) is suitable for reliable winding displacement and deformation assessment and monitoring. It has been established upon the fact that frequency response shape of a transformer winding in high frequencies depends on changes of its internal distances and profiles, which are concerned with its deviation or geometrical deformation [1].

However, the interpretation of FRA data is mainly conducted manually by trained experts. Measured FRA traces are compared with the references taken from the same winding during previous tests or from the corresponding winding of a “sister” transformer, or from other phases of the same transformer. The shifts in resonant frequencies and magnitude of FRA traces are believed to be indicators of a potential winding deformation. However, the question of potential deformation location in a winding is still required to be investigated [2].

A range of research activities have been undertaken to utilize FRA in the development of suitable mathematical models of transformer windings. Considering the simplified equivalent model of transformer winding, various experimental research was performed with the purpose to observe the model behaviors in the frequency domain [3,4]. A winding equivalent model and an identification method of transformer equivalent circuit were proposed in [5,6], where equivalent circuits of transformer winding for the low, medium and high frequency ranges were discussed and its frequency responses were compared with experimental data in order to identify the models' parameters. These models represent the overall windings by combinations of single lumped elements: inductances, resistances and capacitances. This allows estimating only the overall winding parameters in a particular frequency range, which makes these models unsuitable for deformation analysis of each winding section.

The calculation of internal parameters plays an important part in accurate simulations of transformer winding frequency behavior. Modelling of a real winding in order to obtain frequency responses, being close to experimental ones, is an extremely complex task since a detailed transformer model must consider each turn or section of a winding separately. The reason is the fluctuation of real winding parameters such as inductances and resistances per turn length as well as interturn capacitances. The insulation property deviation should also be taken into account, which is frequency dependent.

In [7] efficient procedures to calculate turn self inductances, mutual inductances and capacitances were proposed which demanded additional experimental tests and knowledge of geometric and physical characteristics of a transformer. A transfer function approach is used in [2] to study the discriminating changes

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