



Optimal spares availability strategy for power transformer components

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ABSTRACT

The paper suggests a method to optimize the spare amount of power transformer components. The proposed strategy is conceived to provide minimum annual cost consisting of expected failures renewal cost, capital cost for spares and load curtailment cost. The method identifies minor and major failures. Minor failures are repairable, while major failures can be repairable or unrepairable. Power transformer is a complex system, consisting of six components (functional parts). It is assumed that each component has two independent, competing failure modes: wear-out failure mode, modelled by two-parameter Weibull distribution, and a chance failure mode, characterized by an exponential distribution. The application of the method suggested and the benefits it provides are demonstrated for one transformer station (TS) 110/x kV/kV with 2×31.5 MVA transformers. In addition, the influence of performing power transformer refurbishment on expected total cost has also been analyzed.

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1. Introduction

Equipment failures in distribution substations may cause interruptions in the power supply, which leads to power distribution company and customer costs. The customer costs depend on the consumer types and generally increase with the duration of the supply interruption. Power distribution company cost is in proportion to the degree of damages and the energy which has not been delivered to the customer [1,2]. The most severe consequences arise after power transformer failures, because the time for renewal of a damaged transformer can be very long and renewal process can be expensive.

Failures of power transformer are classified as repairable or unrepairable. Renewal time of repairable failures usually is not long and spare parts are not necessary. Unrepairable failures request using of spare parts, so renewal time depends of necessary spare parts availability. Purchase of spare parts will substantially reduce unrepairable failures renewal time, but it implies considerable investment cost. Whether purchasing of spare parts is justified or not can be established by performing cost/benefit analysis.

As it is known, failure rate is increasing with aging of equipment, Fig. 1 [3]. In this paper, it is adopted that exploitation period for power transformers is about 40 years. Fig. 1 infers that during the first several years the failure rate is very low, so it is quite reasonable assumption that purchasing of spare power transformer is

not necessary. With the help of precise statistical data, it is possible, during determination of optimal number of spare parts, to consider purchasing only some components, not entire power transformer.

A model which enables determination of optimal spare amount of power transformer components is formulated for the following cases:

- performing of transformer refurbishment is not planned during exploitation period and
- transformer refurbishment will be performed at the optimal point of time. Performing of refurbishment at the optimal point of time provides minimum load curtailment cost.

The application of the model suggested in the paper is demonstrated for one transformer station (TS) 110/x kV/kV with 2×31.5 MVA transformers.

2. Basic assumptions

At any point of time, the status of power transformer can be classified as either operating or failed. Failed status is a result of minor failures and/or major failures. Minor failures are repairable and can be repaired for $t \leq 24$ h. Major failures can be repairable or unrepairable.

Hence, probability that the component “k” of power transformer is in operating status equals

$$R_k(t) = \exp(-(\lambda_{k,mf} + \lambda_{k,MF})t) \exp\left(-\left(\frac{t}{\alpha_k}\right)^{\beta_k}\right) \quad (1)$$

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