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# Failure analysis of power transformer for effective maintenance planning in electric utilities

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ABSTRACT

In this paper, power transformer failures are analyzed and their root causes are systematically investigated in Tamil Nadu Transmission Corporation Limited (TANTRANSCO)/Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) electric utilities, based on 196 failure cases from the year 2009–2013. Failure analysis is conducted in two phases. Initially, voltage level, geographical zone and power transformer components based failure analysis are performed through statistical analysis. Secondly, the most significant factors that cause power transformer failures are identified by using root cause analysis (RCA). Finally, current maintenance practice is reviewed and an effective maintenance planning has been proposed for implementation in order to prevent these failures and to maintain the power transformers in good operating condition during their life cycle. This study provides a practical guidance to help maintenance personnel for the best utilization of the power transformer in electric utilities.



## 1. Introduction

Power transformers are the most expensive and strategic components of electric power system [1]. It plays an important role by interconnecting in every stage of power transmission and distribution system [2]. Practically, the power transformer is one of the high risk equipment in electric power system due to its harsh operating condition at various circumstances such as high temperature, emergency overloading and continuous operation in outdoor environment. These conditions lead to unexpected failure of power transformer. The failure of power transformer directly affects the reliability of the whole network [3]. Failures in power transformers may cause disturbances to operating systems, resulting in unprepared outages and power delivery problems. The power transformer failures in electric utilities can be very expensive and may take long time for renewal or replacement of damaged components [4]. The failure not only impacts the cost-effective factors but also causes image of the electric utilities lowered due to customer's dissatisfaction [2].

It has been reported in several literature that there are large number of power transformer failures in various electric utilities across the world. CIGRÉ working group [5] has conducted a survey on failures in large power transformers and found that about 41% of failures were due to on-load tap changers (OLTC) and about 19% were due to the windings, 13% were due to leakage, bushing with 12%, 12% were others and 3 percent were core failures. Minhas et al. [6] conducted power transformers failure analysis in Eskom network at South Africa during the period 1985–1995. Six failure modes were identified which

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includes lightning, core, tap-changer failures, ageing, and short circuit. In similar outage analysis study, Jagers et al. [7] found that Bushings, tap changers and windings represent about 79% of outage causes and the contribution of core related failures was only 2%. Jongen et al. [8] found that tap changer and bushing failure were the dominant causes of outage for transformers having a rated voltage ranging from 110 to 150 kV. Abdelfatah et al. [9] conducted an outage data analysis for 220 kV power transformers in Egypt Electricity Company, over the period 2002–2009 and found that outage causes were related to Transformer related outage category – buchholz and pressure relief, protection system fails, breakdown and damage, fire fighting systems, hot spots, oil leakage, flash over; Power System related outage category – outage of incomers, bus bar protection failures; Human factors related – operational and maintenance mistakes, etc. Thanapong suwanasri et al. [10] studied the failure statistics of transformers in Thailand at a rated voltage of 230/115/22 kV and the failure analysis showed that unknown failures was the highest with 41.3% followed by 31.7% of bushing, 17.5% of tap changer, 7.9% of leakage, and 1.6% of winding. McElroy [11] reported four single-phase EHV autotransformer failures due to transformer winding resonance in an American utility. Previous studies reported only transformer component related failures through statistical analysis but associated root causes were not explored. This paper not only identifies the failure mode, the root causes of the failures are also investigated.

This study is carried out based on 196 failure cases collected from the year 2009 to 2013 in Tamil Nadu Transmission Corporation Limited (TANTRANSCO)/Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) electric utility context in Tamil Nadu. The major problem in TANTRANSCO/TANGEDCO is the frequent failure of power transformers, resulting in fire, oil spillage, electric system outage and complete damage of equipment thereby increasing the unforeseen repair or replacement costs. This also leads to loss of revenue to electric utilities. The main objective of this study is to analyze the failures of power transformer and, to minimize those failures by appropriate maintenance planning. Two methods are employed in this study for failures analysis. First, statistical analysis is used in determining the various indices of power transformer failures. Second, root cause analysis (RCA) is used in identifying the root causes of failures in power transformers. Finally, condition based maintenance (CBM) is proposed in order to predict the current condition of the power transformer for preventing failures.

The structure of the paper is organized as follows. Section 2 discusses the methodology used in this study, Section 3 describes the data collection, Section 4 discusses on the statistical analysis performed to identify power transformer failures, Section 5 discusses on the root cause analysis performed, Section 6 reviews the current maintenance practice in electric utilities, Section 7 describes the effective maintenance planning for preventing power transformer failures, Section 8 provides the results and discussion and Section 9 concludes the paper.

## 2. Methodology

The study is conducted based on the failure data gathered from the TANTRANSCO & TANGEDCO electric utilities. The methodology for the power transformers failure analysis is shown in Fig. 1. The power transformer failure analysis is conducted in two phases. In the first phase, statistical failure analysis of power transformers is conducted. The failure data collected has been split up into three different groups as voltage, geographical zone and power transformer component based failures. The purpose of this grouping is to identify the highest failure impacts that occurred in each of the population.

In the second phase, power transformer component based failures are further analyzed in order to identify the root causes for failures. Root cause analysis (RCA) is an essential step to identify the causes for failures of power transformer. RCA is facilitated by the use of various standard techniques such as check sheets, pareto analysis, brainstorming, reliability and maintainability circles, benchmarking, fail safe methods and cause and effect diagrams. These techniques are often used in continuous and they are effective tools in identifying and solving maintenance and reliability problems [12].

A distinctive advantage of cause and effect diagrams is a graphical tool that is used to identify all potential failure causes for each failure and effects in a systematic way [13]. The cause and effect diagram, also known as the fishbone diagram because of its fish like shape and Ishikawa diagram in honor of its developer [14]. In this study, cause and effect diagram is constructed to identify the factors influencing failures in power transformer components.

Finally, Time Based Maintenance (TBM), the current practice in TANTRANSCO & TANGEDCO is reviewed and Condition Based Maintenance (CBM) is developed for effective maintenance implementation in electric utilities. The motive, advantages, CBM basis condition assessment techniques, interpretation criteria and CBM decision model for effective maintenance planning are described. This would enhance the power transformer operation for the best utilization in electric utilities.

## 3. Data collection

The state owned TANGEDCO is responsible for generation, purchase of bulk power and distribution of electric power for low voltage consumers whereas the state owned TANTRANSCO is responsible for transmission and selling bulk power to the distribution companies, high voltage (HV) and extra high voltage (EHV) consumers. The TANTRANSCO/TANGEDCO consists of 842 numbers of substations in various voltage levels. Among these substations, large numbers of electrical equipments are failing every year due to various factors including poor maintenance, overloading of electric network and aging reasons. The power transformer is one among the major frequent failure component.