ISAR - International Journal of Electronics and Communication Ethics - Volume 1 Issue 1, 2016

RESEARCH ARTICLE OPEN ACCESS

Review on Failure Analysis for the Reliability Power Transformer by Using Fault Tree Analysis

Gourav Chehal[1], Abhishek Thakur[2]

[1]M.Tech student, EEE, Anurag Group of Colleges, Nalgonda Dist, Telangana, India
[2]M.Tech student, EEE, CVSR College of Engineering, Nalgonda Dist, Telangana, India

Abstract:

A current electric power system is a very huge and complex network containing of generators, power transformers, transmission lines, distribution lines, and other devices. Power transformer is one of the most significant electricity equipment in power system. It plays vital roles both in transmission and in distribution system by transmitting the electricity energy. Power transformers state should be maintained for the reason that of its significance to electricity network. There is a growing need for better diagnostic and monitoring tools to evaluate the condition of transformers. Numerous monitoring testing and condition assessment methods have been used by utilities. In this paper, we suggest a new method in order to evaluate power transformer state by using fault tree analysis. Lastly, this paper presents the fault tree method, a simple method and easy to apply for the power transformer system and recommend to services as an substitute method in order to contribute for solving the trustworthiness problem assessment of power transformer to safeguard the safety operation.

Keywords — **Fault tree, Power Transformer, Reliability, Importance Measures.**

1. INTRODUCTION

The objectives of every electric power utility are to preserve network integrity and stability throughout, and to stimulate higher reliability of power supply to customers without disruption. Power transformers condition should be continued for the reason that of its importance to electricity network. There is an growing need for better diagnostic and monitoring tools to assess the condition of transformers.

Transformer failure is able to have a important economic impact due to long lead times in attaining, manufacturing, and installation in addition to high equipment cost. Agreeing to the Electric Power Research Institute (EPRI), prolonging the useful life of power transformer is the single most vital strategy for increasing life of power transmission and distribution infrastructures, beginning with generator step-up transformers at the power plant itself.

1.1 Power Transformers Assessment:

A modern electric power system is a very huge and complex network comprises of generators, transformers, transmission lines, distribution lines, and other devices. The purpose of the electric power system is to create, supply, transmit and use electric power. This power system is also recognized as the grid and can be generally divided into the generators that supply the power; mostly electricity generation originates from coal, natural gas, biomass, nuclear fission, wind, solar, and hydropower. The transmission system that transports the power from the generating centre to the load centre, and the distribution system that nurses the power to nearby homes and industries, such structure as those shown in Figure 1.1.

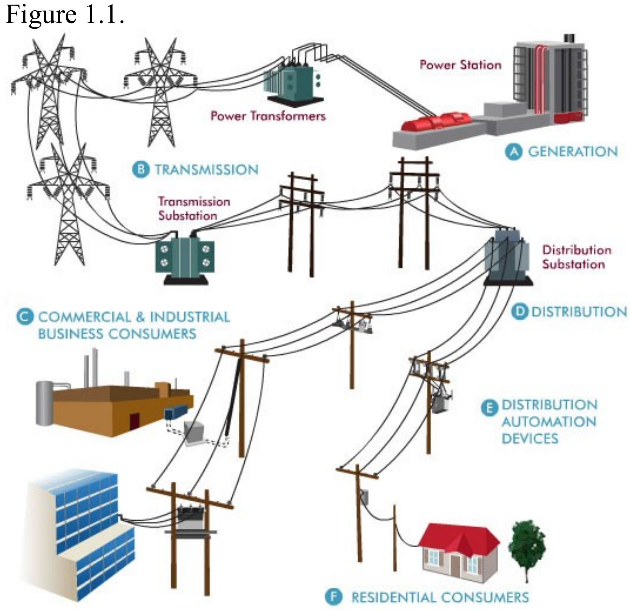

Figure 1.1 Power generation and distribution system

The term power transformer is used to mention to those transformer is used amongst the generator and the distribution circuits, and these are generally rated at 500 kVA and above. Power systems normally consist of a large number of generation locations, distributions areas, and interconnections within the system or with neighbouring systems, such as a neighbouring service. The complexity of the system leads to a variation of transmission and distribution voltages. Power transformers need to be used each of these points where there is a transition among voltage levels.

1.2 The Importance of Power Transformers Assessment

Power transformer is one of the most significant electricity equipment's in power system. It plays a vital role both in transmission and distribution system by transmitting the electricity energy, from one voltage level to another, under magnetic induction reaction. When a failure happened on a transformer, it also means that the electricity cannot be delivered to customer. The sizes of the transformers vary from as low as few kVA to over a few hundred MVA, with spare cost ranging from a few hundred dollars to millions of dollars. Power transformers are generally very dependable, with a 20-40 design life. The practice life of a transformer can be as long as 60 years with proper maintenance. Though, the in-services failure of a transformer is possibly dangerous to efficacy a personnel which causes explosions and fire, possibly damaging the environment through oil leakage. Its repair or replace might lead to substantial loss of revenue.

The necessity of power transformer condition assessment in the field of power systems are as follows:

a. The outages of power system.

The outage of power transformers can influence power system reliability. It is tough to directly measure the influence of an outage for the reliability of power grid. But it is probable to evaluate it by means of some conditions.

b. High cost of maintenance and replacement.

Power transformers are essential parts of power system. When they get damaged or they might fail. Then they have to be repaired or even changed. Power transformers life-span is lengthened in order to evade high replacement costs. This in turn upsurges the effort for maintenance and repair. Thus, costs move moderately from replacement to maintenance and repair.

c. High growth of electricity demand.

World electricity demand is predictable to be doubled up amid 2000 and 2030 at a yearly growth rate of 2.4 % each year. Electricity demand growth has the strongest drift in developing countries, where the demand climbs by over 4 % per year over the projection period, more than tripling by 2030.

d. The aging effect and utilized of old transformer:

The age distribution of the transformers is reflective of power system equipment around the world, with a high fraction of transformers older than 20 years. Apart from this, older transformers also conquer strategic nodes on the network.

e. Computer and software errors:

Currently, power transformer protection system functions based on software system using PLC (Programmable Logic Controller). If any abnormal state in the power transformer, its protection system will be mechanically activated; so that the damage of any equipment's can be reduced. The dependability of computerized protection system of power transformer must be evaluated for assurance of system protection.

1.3 Power Transformers Design and Construction:

Transformer function is based on the principle that electrical energy is transferred resourcefully by magnetic induction from one circuit to another. When one winding of a transformer is strengthened from an alternating current (AC) source, an alternating magnetic field is established in transformer core. Alternating magnetic lines of force, named flux, circulate through the core. With a second winding around the same core a voltage is tempted by the alternating flux lines. A circuit, connected to the terminals of the second winding, results in current flow. The construction of a transformer rests upon the application. Transformers intentional for indoor use are chiefly of the dry type, they can also be liquid submerged. For outdoor use, transformers are commonly liquid immersed.

The performance of power transformer hinge on on dielectric insulation and cooling system, for the reason that these two systems are closely related, firstly, the amount of heat both the core and winding conductors determines the stability and durability of the insulation, and the dielectric insulation system itself is intended to carry off some of the heat.

1.4 Power Transformers Failures:

During the course of its life, the power transformer as a whole has been suffering the effect of thermal, mechanical, chemical, electrical and electromagnetic stresses during normal and transient loading situations. A failure eventually happens when any operating stresses overdoes its strength of the above key properties. In addition, failure procedure in power transformers are frequently complex and so cooperation among manufacturers, utilities, academics is essential to understand then.

Figure 1.2: The power transformer, Source: Sumatera interconnection system, PLN

1.5 Power Transformer Monitoring and Diagnostics Method

The power transformers are in general categorized into groups from the condition point of view: normal, aged and normal, defective, faulty, and failed. When the transformer is normal, no remedial action is reasonable since there is no sign of degradation. Normal aged transformer cannot be totally free defect but it is generally taken acceptable. Defective transformer steadily deteriorates more unless remedial action is carried out. Faulty transformer might or might not be possible to increase condition by remedial action.

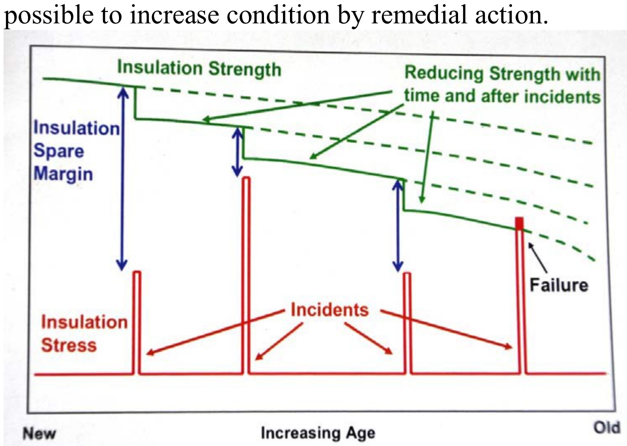

Figure 1.3: A conceptual failure model proposed by CIGRE WG 12.18

Failed transformer cannot be preserved in service. Remedial action is necessary before the transformer can be reverted to service.

2. Quantitative Fault Tree Analysis of Power Transformer

2.1 Fault Tree Method:

2.1.1 Fault Tree Analysis

The fault tree analysis is a tool to recognize and assess the combinations of the undesired events in the context of system operation and environment that can lead to undesired state of the system. It is familiar worldwide as a significant tool for safety and reliability in system design, development and operation. The undesired state of the system is signified by a top event. Fault tree analysis can be used to recognize the system weakness and evaluate possible upgrades. Additionally, fault tree analysis can be used to analyze causes and give potential remedial measures for an observed system failure. This process has been used and refined over the ensuing years, is attractive for the reason that it does not need extensive theoretical work and it is a practical tool that any engineer can learn to use easily. A fault tree is categorized as static or dynamic based on the kinds of gates used. If only static gates such as AND, OR and k-out-of-n are used in the fault tree, it is termed a static fault tree. If a fault tree comprises sequence-dependent gates as well as static gates, the tree is termed a dynamic fault tree.

2.1.2 Quantitative Fault Tree Analysis:

In assessing the condition of power transformer by using fault tree analysis, the first step is modelling the system and failures orders with a fault tree. A quantitative analysis is used to recognize the likelihood of occurrence of the top event in the fault tree and those of each minimal cut set. Quantitative results comprise the top event unavailability, undependability or failure rate. The top event parameters are describes as follows:

Unavailability: A(t) the probability that the system failure mode exists at time t.

Unreliability: R(t) the probability that the system failure happens at least once from time t to time t.

Failure rate: the rate at which the system failure mode happens.

All of these quantities can be used to judge the acceptability of the system performance.

To perform quantitative fault tree analysis, initially failure rates need to be obtained and entered in the calculation properties for each lowest-level event in the fault tree. When quantitative fault tree are calculated, the undependability of the system can be calculated. These measures, rather than reliability, are computed because fault trees are prepared around failures rather than successes.

2.1.2.1 Quantification of the fault tree static gates:

To compute the probability of occurrence of top event in fault tree, it is essential to understand the relation among the top, intermediate, and basic events. To enumerate the probability of the top event of the power transformer fault tree, a probability for each basic event in the fault tree need to be delivered.

2.1.2.2 Dynamic gates

A dynamic fault tree model cannot be simply assessed using traditional fault tree analysis methods, such as those that are based on cut sets or other Boolean logic methods. Since the dynamic fault tree gates must seizure the order in which events happen, not simply their probability of occurrence, a Markov model used for solution. The equivalent Markov model can be created from the dynamic fault tree and then solved using ordinary integrals equations or some approximations.

In the fault tree of power transformer system dynamic part of the system is presented in figure 2.1 and figure 2.2.

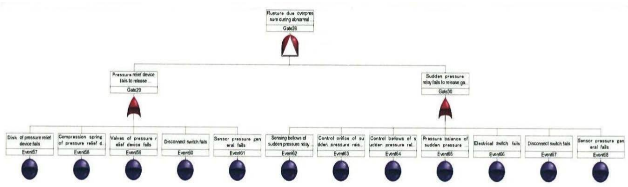

Figure 2.1 Dynamic fault tree of tank gate 28

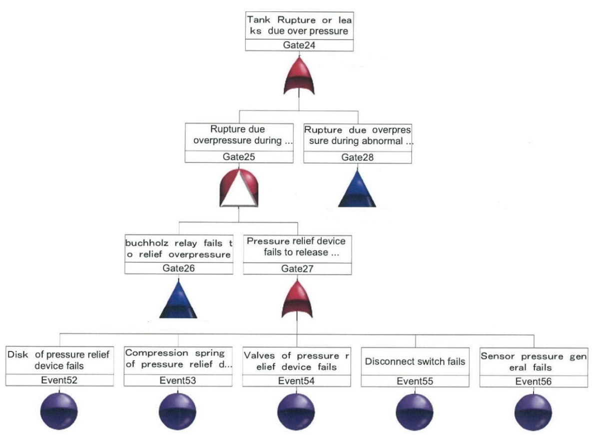

Figure 2.2 Dynamic fault tree of tank gate 25

2.1.3 Failure probabilities

Failure rates data of International Atomic Energy Agency (IAEA) data are measured as failure rates for certain basic components. These failure rates are a good assessment for the real failure rates of basic constituents of power transformer system.

2.2. Result and Analysis

2.2.1 Power Transformer Model:

A 275 kV power transformer in GI Simangkuk in Indonesia assists as an example in this paper. The power transformer`s is engaged to convert low voltage electricity which is created by hydro power plant Asahan I, to be high voltage electricity, then transfer it to high voltage transmission system of Sumatera interconnection system. The fault tree analysis was built in a hierarchical structure with a single top event. The top event in this study is the power transformer fails to convert low voltage of electricity to high voltage electricity. The fault tree model would be based on performing of quantitative fault tree analysis.

2.2.2 Top Event Occurrence Possibilities

The probability of occurrence of the top event, i.e., failure of the power transformer is acquired by Relex software on the probability occurrence of top event and subsystem at time t =0 until time t = 100000. At time t = 100000 hours the probability of the occurrence of the top event (power transformer failure) and intermediary events is given in figure 2.3.

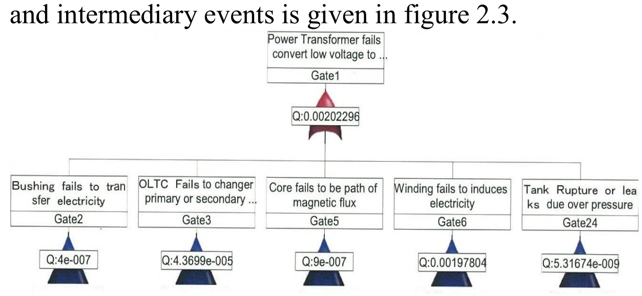

Fig 2.3: The probability of the top event and sub-system t time t = 100000 hours.

The possibility of the occurrence of the top event will be improved by the increasing operation time of the power transformer.

3. Components Importance Analysis of Fault Tree

Component importance analysis is a key part of the system dependability quantification process which is most operational towards safety progress. The importance measure is a useful guide during system development phase as to which element should receive more urgent attention in attaining system reliability growth.

3.1 Computation of Importance Measures

Importance analysis is a part of the system quantification procedure which permits the analyst to rank the contribution that each component makes to system failure of power transformer and thus recognize the weakest areas of the system. In this section, three importance measure analysis approaches are employed to estimate power transformer system.

3.1.1 Birnbaum Importance Measure (BIM)

A Birnbaum importance measure is the rate of change in the top gate probability with respect to the change in the inaccessibility of a basic event. Consequently, the ranking of events obtained using the Birnbaum importance measures is useful when selecting the event to upsurge when the actual efforts for development is the same for all events. The Birnbaum importance measure can be used to assess the effect of a development in component reliability on system reliability.

The BIM is defined as:

BIM (A) = P{TE|A} - P{TE|~A} (5.1)

Where: - A indicates the event whose importance is being measured

- ~A designates that this event did not occur
- TE designates the top event

3.1.2 Criticality Importance Measure (CIM):

The criticality importance measure of event A is the probability that element A is critical for the system. The top event will happen follow the occurrence of component A. While the Birnbaum importance measure deliberates only the conditional probability that event A is critical, the CIM also considers the overall probability of the top event happening due to event A.

The Criticality importance measure is defined as:

CIM(A) = BIM(A) * P{A}/ P{X} = (P{TE|A} - P{TE|~A}) * P{A}/ P{TE} (5.2)

Where : - X is the the top event occurs

3.1.3 Fussell-Vesely Importance Measure (FVIM)

In the cases where event A contributes to the top event but is not necessarily critical, the Fussell-Vesely importance measure can be used. For an occurrence to subsidize to the top event, at least one cut set containing event A should occur. The Fussell-Vesely importance measure is the ratio of the probability of incidence of any cut set comprising event A and the probability of the top event.

3.2 Importance Measures calculation and results

The fault tree of power transformer system with single top event acquires five subsystems. The sub systems are bushing winding, core, OLT and tank. The fault tree of power transformer comprises 68 basic events with 97 number of cut sets.

The significance measure BIM, CIM and Fussell-Vesely importance measure of the basic events are formed from RELEX fault tree analysis software. The winding sub-system comprises the higher ranking of significance basic events in power transformer system. These are event 26 and event 47 (oil temperature indicator error in calibration), event 27 and event 48 (sensor of temperature failure), event 29 (oil level indicator error calibration), event 30 (sensor oil level indicator failure). These approaches present the rank of the component importance measures quantitatively according to their contribution to system consistency and safety. This result shows that only 14 basic event give 89 % contribution to the power transformer system dependability.

CONCLUSION

First of all, considered the significance and brief explanation of assessment and monitoring of power transformer. we defined the need of valuation and maintenance of power transformers such as outages effect of failures, high cost of maintenance and replacement, growth in world demand, aging effect and use of old transformer, and computer protection system failure. Formerly, we considered the quantitative analysis of power transformer fault tree. Later, we steered quantitative fault tree in evaluating the dependability of power transformer for a switchyard. Later, we conduct significant measures analysis of power transformer system components. We presented an application of the significance measures analysis of a power transformer system by using Birnbaum importance measures, critically importance measure, and Fussel- Vessely importance measures. These approaches present the rank of the constituent importance measures quantitatively conferring to their contribution to power transformer system reliability. In conclusion, the fault tree method is a simple method and easy to relate for the power transformer system and endorse to utilities as an alternative method in order to donate for resolving the dependability problem assessment of power transformer to confirm the safety operation and distribution.

1. REFERENCES

1. Failure Analysis of Power Transformer Based on Fault Tree Analysis by Josep Franklin Sihite, Page No: 14-82.
2. Y.-S. Fu, F.-Z. Liu, W.-Z. Zhang, Q.-I. Zhang and G.-X. Zhang, “The Fault Diagnosis of

Power Transformer Based on Rough Set Theory," Proceedings of the China International Conference on Electricity Distribution, Guangzhou, 10-13 December 2008, pp. 1-5.

3. H. Tanaka, L. T. Fan, F. S. Lai and K. Toguchi, "Fault-Tree Analysis by Fuzzy Probability," IEEE Transactions on Reliability, Vol. 32, No. 5, 1983, pp. 453-457.
4. S. Tyagi, D. Pandey and V. Kumar, "Fuzzy Fault Tree Analysis for Fault Diagnosis of Cannula Fault in Power Transformer," *Applied Mathematics*, Vol. 2 No. 11, 2011, pp. 1346-1355.
5. Indian Standards Specification for Power TransformersIS 2026 – Indian Standards Institution Publications
6. [Tamil Nadu Electricity Board Manual on Pre-commissioning& Periodical Testing of Electrical Installation
7. Manual on Transformers by G.N.Mathur, R.S.Chadha –Central Board of Irrigation and Power.
8. Z. Moravej, D.N. Vishwakarma, S.P. Singh, ''Application ofradial basis function neural network for differential relayingof a power transformer'', *Computers and ElectricalEngineering 29*, pp. 421–434, 2003.
9. Cˇepin M, Mavko B. A dynamic fault tree. Reliability Engineering and System Safety 2002;75(1):83–91
10. Hessian RT, Salter BB, Goodwin EF. Fault-tree analysis for system design, development, modification, and verification. IEEE Transactions on Reliability1990;39(1):87–91
11. Haarla L. A method for analysing the reliability of a transmission grid.Reliability Engineering and System Safety 2008;93(2):277–87.