

Condition Monitoring of Power Transformer Using Failure Modes and Effects Analysis (FMEA)

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ABSTRACT: This paper presents condition monitoring of power transformer using failure modes and effects analysis (FMEA). The power transformers in addition to playing an important role in the efficiency and reliability of power transmission network, are also the most expensive network equipment. Many faults occur in the power transformer, the affect of which can be from mild to severe. So, it is necessary to monitoring the condition of power transformer using failure modes and effects analysis (FMEA) technique. FMEA is a procedure to identify and assess consequences or risk associated with potential failure modes. It assigns a numerical value (Risk Priority Number), which is determined by each risk factor's occurrence (O), severity (S) and detection (D). The output of FMEA technique could be graphical charts, worksheet tables and matrices to sort the most critical components. Recommendation of remedial actions for each failure mode has been given to improve the availability and reliability of the power transformer.

KEYWORDS: Power transformer, condition monitoring, failure modes and effects analysis (FMEA), risk priority number (RPN), XFMEA software.

I. INTRODUCTION

Power transformer in addition to playing an important role in the efficiency and reliability of power transmission network, are also most expensive network equipment. It is important to know when the transformer is the most dangerous element because it contains a great quantity of oil in contact with high voltage elements. Thing favors the risk of fire and explosion in case of abnormal circumstances or technical failures. So it is necessary to plan and focus the effects by set of priorities with general aim is to improve the reliability of system and consequently, to reduce their failure risk.

Condition monitoring techniques have been used extensively for large scale machineries and structures. In order to ensure the continuity of electrical power supply, it is required to continuously monitor the power transformer condition. There are a number of condition monitoring techniques that can applied to examine condition of power transformer. In general, the available condition monitoring techniques can be divided into electrical, chemical, mechanical and thermal methods.

Failure modes and effects analysis (FMEA) is an engineering method used to recognize, organize and mitigate potential problems from the System, Design, and Process before the issues are realized. All FMEA processes concentrate on outline (design) and evaluate the effect of failure on system security and performance. On the other hand, FMEA worksheets are normally categorized based on whether they inspect item arrangement/design or the processes required in developing and the product usability or assembling the product.

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II. RELATED WORK

FMEA is used for the study of different parts of power transformer. In this, power transformer's failing modes, effectiveness and causes are highlighted by RPN with the use of graphic, metrics and worksheets [1], [3] & [10]. (FMEA) was used to reduce or eliminate the failure of the Geo-thermal power plant, in which risk priority number (RPN) has the highest level of faulted values. This resulted in software XFMEA applied to maximize reliability and save time [7]. FMEA technology is used to improve and repair military equipment [9]. (FMEA) was used to reduce or eliminate the failure of the Geo-thermal power plant, in which risk priority number (RPN) has the highest level of faulted values. This resulted in software XFMEA applied to maximize reliability and save time [5].

III. FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

Some basic steps used for implement FMEA technique. First of all define the components of power transformer and Identify failure modes related with system failures. Recognize potential effects of failure modes. Determine the failure effect and the initial severity rating. Determine all failure causes for each mode. Recognize available identification techniques for each cause. Identify & assign the recommended actions for every cause.

For this situation the estimation of every parameter was acquired from the accidental and disappointment measurements information of power transformer.

FMEA determines the numeric value for each risk related to each failure by using the severity, occurrence and detection, due to calculation of Risk Priority Number (RPN) due to each failure:

$$RPN = \text{Severity} * \text{Occurrence} * \text{Detection}$$

IV. FAILURE DATA COLLECTION OF THREE POWER TRANSFORMERS

Failure data collection of power transformer (160 MVA) as per as the data collected five components of this transformer have been found to be fault prone but only top three faults discussed in this paper . The number of hours of failure contribution of each component and along with percentage contribution in table 1

Table 1 Percentage failure contribution of components of T1 (160 MVA)

Sr. No.	Faults	Numbers of hours	Percentage
1	Windings	72	27.80%
2	Cooling system	67	25.90%
3	Bushing	51	19.70%
4	Oil insulation	37	14.28%
5	Solid insulation	32	12.32%

Figure 1 shows failure percentage contribution of different components of power transformer T1 (160 MVA).

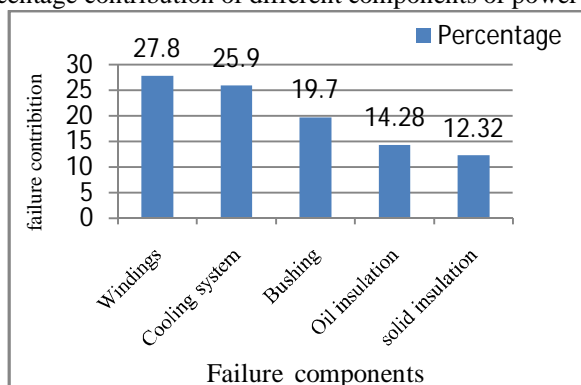


Fig. 1 failure percentage contribution of different components of power transformer T1 (160 MVA)

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Table 2 Failure data of windings of T1 (160MVA)

PRODUCT DETAIL	NAME T1	NUMBER 1	MAKE BHEL	RATING 160MVA
Sr. No.	Date of Failure	Failure Time (in hours)	Cause of Failure	
1	14.05.12	14	Faults in Windings	
2	07.01.13	12	..	
3	17.11.13	13	..	
4	03.04.14	10	..	
5	30.01.15	15	..	
6	09.05.16	08	..	

This table 2 shows the failure time of power transformer T1 (160MVA) due to windings faults in previous five years. Similarly, failure time of power transformer T1 (160MVA) due to bushing and oil insulation faults has been collected for previous five years.

V. FAULT TREE ANALYSIS FOR POWER TRANSFORMER

To completely analyze failures of a system it should be broken to subsystems, components and parts. In this paper, oil immersed power transformers are considered to study under FMEA technique.

Transformer fault trees are the result of discussion with experts on transformers and the study of literature. In order to analyze the transformer and the components of power transformer such as bushings, oil insulation, windings, tanks, core, tap changer, protection system, cooling system and oil insulation were analyzed to make a fault tree. Figure 2 components of power transformer and a small clarity for them are presented below.

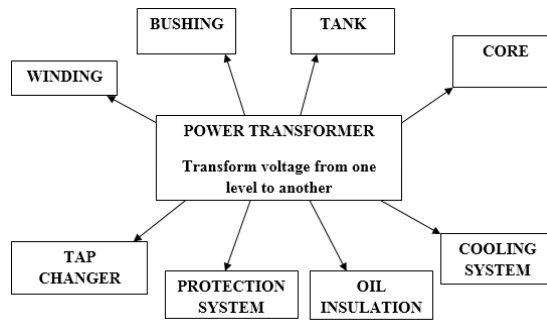


Fig. 2 Faults prone parts of power transformer

A. Windings

Related to the active part of the windings transformer and their function are to carry out current. The windings are kept as the cylinders around the core organ, where every stand is wrapped with protection paper.

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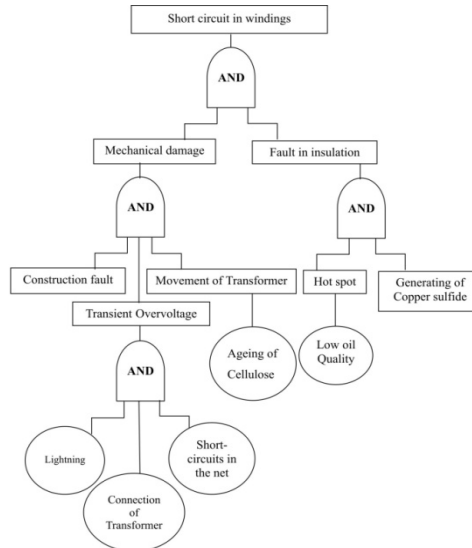


Fig. 3 Faults tree for windings

Copper is the main choice in terms of matured material now, in spite of the addition of dielectric stress and thermal requirements, the windings have to deal with mechanical forces which may change the look of heat. Such forces can show during, lightning, short circuits, short circuits in whole in transformer or during the transformers movement. There may be a flaw in the rotation due to physical faults in cellulose. Figure 3 shows fault tree for windings.

B. Bushings

The in the interior of the bushing may be full of paper insulation and Bushings are filled with oil to give more insulation to the transformer’s tank. Provide insulating high current through the tank wall (metal) to the curvature. Figure 4 shows fault tree for bushing.

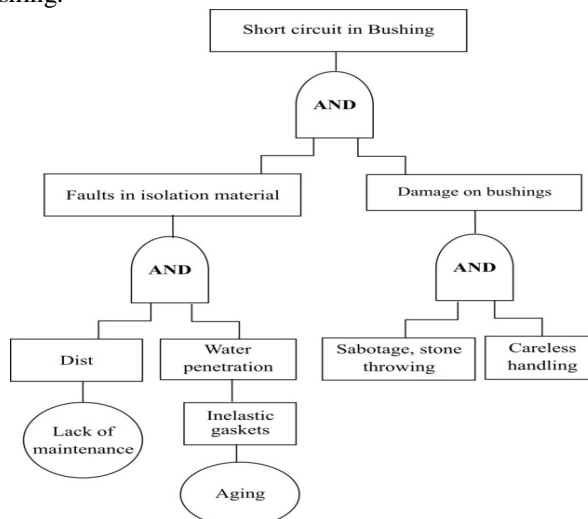


Fig. 4 Faults tree for bushing

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C. Oil insulation

Transformer oil is a highly sophisticated product with mineral crude oil, of which the most common are naphthenic, hydrocarbon and paraffin and aromatic oil structure.

Power transformers are outfitted with water-cooled or oil pumps, cooling fans heat exchangers planned to eliminate the high temperature caused by iron losses and copper. The main causes of oil fall are due to oxygen and moisture in combination with heat. Figure 5 shows fault tree for the oil insulation.

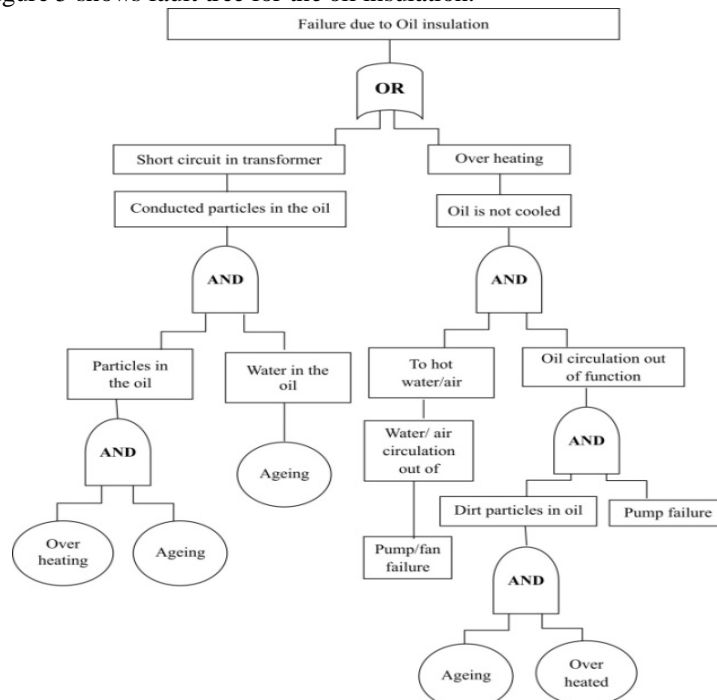


Fig. 5 Faults tree for oil insulation

VI. POWER TRANSFORMER FMEA

S.No.	Components	Remedies
1	Windings Failure	<ol style="list-style-type: none"> 1. Provide proper repair, good maintenance, insulation, remove vibration and decreases mechanical movement within the transformer. 2. Periodical checking of the soil resistivity. Renovation of earth pit or making a new earth pit. 3. Periodical checking of earth connections. Tightening of the terminal connections.
2	Bushing Failure	<ol style="list-style-type: none"> 1. Proper tightening of terminals and joints, and replacement of loose burnt out gaskets 2. Regular check of the insulation of cables and Periodical cleaning of substation. 3. Erection of intermediary poles where necessary. 4. Place spacers where necessary and maintain safety clearance between conductors. 5. Maintain sag of conductors as per standard. 6. The bushing of the transformer should be cleaned with soft cloth after years and cracks should be thoroughly examined in the bushing.
3	Oil Insulation Failure	<ol style="list-style-type: none"> 1. Augmentation of transformer or construction of a new substation. Proper tightening of terminals and joints.

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		<ol style="list-style-type: none"> 2. Replacement of deteriorated gaskets and cracked bushings. . Periodical testing of oil. 3. Prompt replacement of deteriorated silica gel & dirty oil in the breather. 4. Filtration/overhauling of transformer oil as & when required after testing. 5. Each sub-division should have mugger, tong tester, and earth tester and each division should have an oil filter machine and oil testing kit. 6. The transformer oil must be tested in six months, for dielectric strength, water content, acidity, sludge content, flash point, Inter 7. Facial Tension, resistivity for transformer oil.
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After looking at all the failure modes of the transformers, remedial measures are given in the table 3 above

VII. RESULTS

Allow viewing the FMEA tab in the analysis panel / currently editing the failure mode and effect analysis for 160 MVA power transformers.

Table 4 shows all failure components of 160 MVA power transformer and their failure modes, causes and effects. Calculate the value of risk priority number (RPN) with the help of severity, occurrence and detection. Also described revise rating of RPN with recommended action.

Click on FMEA tab to analysis FMEA for steering system. Now there are four tabs below the analysis panel. Every tab display analysis information in a special way to make easy information entry and management.

The hierarchy view can be particularly useful when searching for a specific section or scan the analysis to copy and paste data. XFMEA software also creates a worksheet similar to Microsoft Excel.

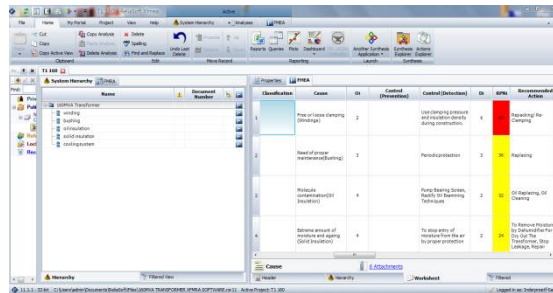


Fig 6 Initial RPN of 160 MVA power transformer (in worksheet view)

Fig. 6 represents the initial (highlighted) risk priority number (RPN) of 160 MVA Power Transformer. Risk priority number (RPN) divided into three parts such as red, yellow and green in which red color indicate critical condition of component.

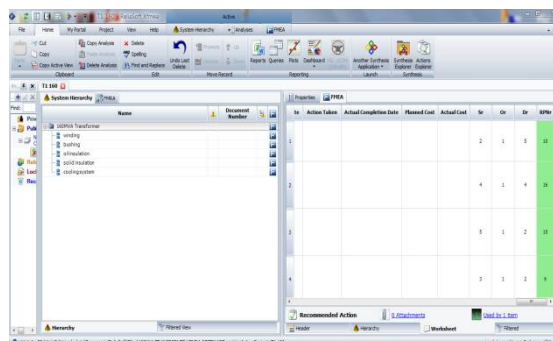


Fig 7 Reverse RPN of 160 MVA power transformer (in worksheet view)

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Fig. 7 shows revised rating (with remedial measures) of 160 MVA power transformers. Figure 8 shows Initial and revised ratings from the risk priority number Type drop-down list. In the event that the Auto Refresh choice is chosen, the show will refresh naturally

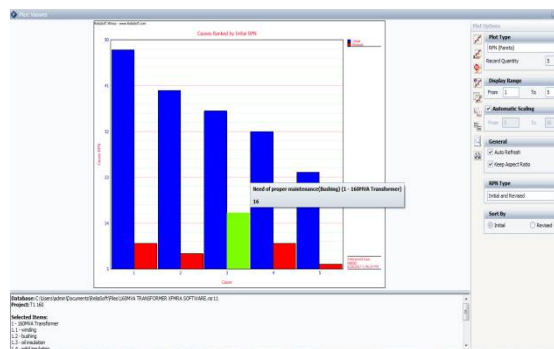


Fig 8 Initial and revised ratings of 160 MVA power transformer T1

VIII. CONCLUSION

The work on Condition Monitoring of Power Transformer using Failure Modes and Effects Analysis has been successfully completed. Data was collected from 220 kV substation Lalton Kalan , which is located in Ludhiana district. Three transformers one of 160 MVA and two of 100 MVA were considered in this work. The last 5 years data was collected and tables were created by dividing each component with fault time in hours. According to this analysis, fault trees and worksheets have been created. Faults of these transformers are analyzed using Failure Modes and Effect Analysis (FMEA) method and remedial measures are proposed to reduce the Risk Priority Number (RPN) so that faults can be decreased and reliability of power transformer can be increased. All the data of three transformers were fed to the software. ReliaSoft XFMEA software tool is used to automatically analyze the collected data in order to reduce failure, time consumption and cost.

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Table 5 Failure Modes and Effects Analysis for 160 MVA Power Transformer (T1) with recommended action at 220 KV Substation, Lalton Kalan, Ludhiana

I D	Components	Function(s)	Failure Mode	Failure Cause	Failure Effects		Controls		Risk Rating				Recommended Action	Revised Risk				
					Local Effects	End Effects	Obstacle Control(s)	Identifica tion Control	O	S	D	R P N		O	S	D	R P N	
1	Windings	Conduct Current	Mechanical	Free or loose clamping	Distortion of Windings	Go over the Current Flows, high Inrush Currents, protection/saf ety Relay failed	Use clamping pressure and insulation density during construction. Use of the coil clamping structure for spring dashpot assemblies.	Leakage Reactance		2	4	6	48	Repacking/ Re-Clamping	1	2	5	10
2	Bushing	Associate windings with network, separate amongst tank and windings	Physical Chemistry	Need of proper maintenance	Outside contamination, consumption/m ake release current on the outer surface of insulation	Personnel protection, short circuit	Periodic protection	Visual	3	4	3	36	Replacing	1	4	4	16	
3	Oil Insulation	Provide cooling and insulation of active parts of Transformer	Physical Science	Molecule contamination	decrease the electrical quality and breakdown voltage, raise the dielectric defeat of oil	Short circuit and raise temperature in the transformer	Pump Bearing Screen, Rectify Oil Examining Techniques	Molecule count	4	4	2	32	Oil Replacing, Oil Cleaning	1	5	2	10	