ADAPTIVE APPROACH FOR FAULT DETECTION IN POWER TRANSFORMER BASED ON OIL TESTING

Ankush Chander*

Nishant*

ABSTRACT

Transformers are an integral part of power systems and their reliable operation directly impacts on the whole network. Statistics about failures of power transformers constitute an important basis for asset management of a fleet of transformers. Periodic review of these statistics becomes necessary where they can be used to influence transformer design and technology. Recent utility survey shows that a large proportion of transformers has attained their designed life and is operating close to their nameplate rating or beyond. The load growth is compounding this problem on the existing transformers due to fewer extension projects. To enhance utility reliability, it is pertinent to identify problems that normally encountered in the past on a particular class of transformers, Identify Manufacturer, type of fault, frequency of occurrence, failure analysis, failure origin and causes of probable physical damage leading to catastrophic failure & hence interruption in supply of electric energy in a given locality. This paper describes case studies of failure of power transformers and failure reports, effect of aging and loading conditions on the life of Power Transformer and test reports of various categories of power transformers belonging to several electric utilities.

Keywords: *Power Transformer, Dissolved Gas analysis, Faults, Transformer Oil.*

* Arni University Indora Himachal Pradesh

1. Introduction

Power transformers are important equipments in power system. Smooth functioning is the key of ensuring hassle free operation of entire power system**[1].** Once power transformer develops abnormality, the power supply will be interrupted and huge economic loss will occur. Therefore, it is very significant to detect and identify incipient failures of power transformer as early as possible. Power transformers, which are often the most valuable asset in a substation or plant, are indispensable components of high-voltage equipment for power generation plants, transmission systems and large industrial plants. Unexpected failures cause major disturbances to operating systems, resulting in unscheduled outages and power delivery problems. Such failures can be the result of poor maintenance, poor operation, poor protection, undetected faults, or even severe lightning or short circuits [11].

Power transformer failure could result in huge economic loss and unplanned outage of the power system, which may affect a large number of industries and commercial customers **[2].** In order to keep power transformers in health condition and reduce probability of transformer failures or abnormalities while simultaneously cutting the maintenance cost, a variety of factors that affect transformer performance should be analyzed carefully, including electrical, mechanical, and chemical properties. Some new techniques can play a key role to reach this objective, such as condition monitoring, predictive maintenance, and artificial intelligence (AI) based diagnostic techniques.

2. Problem statement

Transformers have limited life. However, unlike other machines, it does not have any moving parts, except tap changers or cooling fan or pump motors. The outages, therefore, is not due to wear out. Unexpected failure is always a major disturbance in the system operation, resulting in unscheduled outages with power delivery problems. To reduce the risk of unexpected failure and the ensuing unscheduled outage, on -line monitoring has become the common practice **[4].**

3. Proposed Technique.

The methods used to evaluate transformer internal condition is described below.

i. Dissolve Gas Analysis Method

To measure Dissolve Gasses in the transformer oil we can use gas Extraction method. In this process extraction involves separating the gases from oil. The oil sample is introduced into an inert gas filled viol which is heated and agitated for a period of time (15 to 30 minutes) and total gas content in percentage is measured **[7].**

ii. Measurement of Winding Resistance Method

The measurement of the winding resistance has to be carried out with the help of Kelvin Double bridge/transformer ohm meter. Resistance should be measured between the line and the natural terminal and average of 3 set of reading shall be taken as tested value for star connected winding with natural brought out. The resistance of the HV side is measured between HV terminal and LV terminal then between LV terminal and the neutral for star connected auto transformers **[3].** For transformer provided with delta connected winding such as tertiary winding of auto transformer, measurement shall be made between pairs of line terminals and resistance per winding shell be calculated per formula as given below

Resistance per winding = 1.5 x Measured Value

iii. Dielectric Test Method

A sample of the oil to be tested is placed in a clean "standard" cup so that it covers the two disc electrodes that are one inch in diameter and have their faces apart by one-tenth of an inch. Voltage is applied across the electrodes and increased gradually until a flash-over occurs. It is an accepted practice to run a minimum of three tests and the average of the three being considered as the actual dielectric strength of the oil. The minimum acceptable value is 22KV for mineral oil, and 25KV for Askarel **[13].**

4. Power Transformer Testing And Failure Reports with proposed technique

The transformer, being a key element in the transmission and distribution of electrical energy, improving its reliability is of utmost importance. System abnormalities, loading, switching and ambient condition normally contributes towards accelerated aging and sudden failure, hence, it is, all the more essential, to employ continuous monitoring techniques and on-site diagnostics followed by quality maintenance for having trouble-free and reliable operation with minimum outages. This paper includes case studies as available from Himachal Pradesh State Electricity

Board Limited (HPSEBL), Himachal Pradesh and Haryana and from some Private Firms. The data has been collected from various substations/Hydro projects of H.P. and based on it; it is tried out to analyses the major reasons for Transformers failures. This data includes testing results of particular transformers [12].

4.2 Transformer Failures

A typical power transformer has a life expectancy of more than 30 years. During this time it is obvious that such a device has several failures, thus needing maintenance to ensure that the expectancy is fulfilled. Because transformer failures are responsible for a very high amount of costs, this section is based on different studies about transformer failures **[10].** William H. Bartley P.E, The Hartford Steam Boiler Inspection & Insurance Co., has done a research on 94 different cases of failures and their losses. In this study, he figured out, that in the period of 1997 to 2001 the total loss in 94 cases was over US$280,000,000[8] in the US only. This makes it clear why compensation of transformer failures is important. Apart from that, the different application types are researched and it is shown that most of the failures occur in the utility substations cases). Anyway, only 6% of the loss is generated in this area **[15].** In total 36 failure cases 8 in the step up generator area generate 70% of the total losses. Most of the total failures are insulation faults (24 failures generate a loss of about US$150,000,000).

More detailed information about the Hartford Steam Boiler (HSB) research is available in **[9].** Another study which was published by the CIGRE Working Group 05 took another approach. In that study the failure source was attributed to the different parts in a transformer. The result was that 40% of the failures were caused by the on-load tap-changers. The problem with investigating different studies about this topic is that their definition and characterization of the failure groups are often different. A common denominator has therefore been sought in these studies. Apart from that, information provided by the German RWE AG (German Power Company) is integrated in this section. The failures are therefore separated to: winding, core, isolation, tank, bushing, oil, cooling and the load tap-changer. In this subsection, information is provided about the failures, their impacts on the transformer and typical reasons why these failures could occur. Moreover, fault trees for the different transformer parts can be found in the work of Anna Franzén and Sabina Karlsson from the Royal Institute of Technology, Stockholm. The life cycle curve of Power

Transformer **[14]** is shown below in Fig. 4.1.

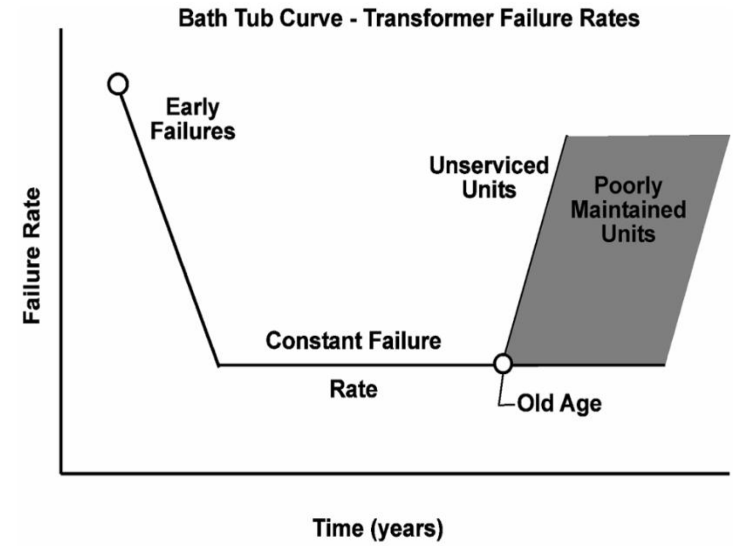

Fig 1:

4.3 CASE STUDY 1: DAMAGE REPORT OF TRANSFORMER.

The damage report of Transformer at subdivision Tissa, Chamba is studied in order to find out the major cause of fault in the transformer. In the investigation of the damaged transformer it is found that the major reason of failure is Defective mechanism of Incoming no-II ACB of Jhajja /Kothi, Tarek and Himgiri outgoing ACB. The 11 KV incoming and outgoing breakers were malfunctioning. The detailed investigation report of the damaged transformer is shown below in the Table 4.1.

Table 4.1:-

1	Devision	Chamba no-1
2	Sub-Division	Tissa
3	Capacity Voltage	1 MVA 33/11 kv
4	Transformer	GEC NO. 4913
5	Year of Manufacture	1986

6	Date of Installation	14.08.2003
7	Date of Damage	14.08.2003
8	Area Effected	Jhajja Koti, Himgiri
9	Detailed reason for damage of Transformer	Defective mechanism of Incoming no. II ACB of Jhajja/ Kothi, Tarek and Himgiri outgoing ACB.
10	Whether reason for damage of Transformer	Yes
11	D.O. fuses	Yes
12	G.O Fuses	Yes
13	Oil insulation result last taken before damage	46 kv/min
14	Detail of latest dehydration result	46 kv/min
15	Earth Resistance	0.9 ohm
16	Max. Load during peak load hours	34 Amperes
17	Whether transformer over loaded	No
18	Megger Result- H.V to Earth L.V to Earth H.V to L.T	 130 Mega ohm 250 Mega Ohm 200 Mega Ohm
19	Whether burnt during warranty period	No

The IR value test results with effect to the above referred transformer are shown below in Table4.2.

Table 4.2: Meggar insulation results of the damaged transformer

HT to Earth	LT to Earth	HT to LT	HT to Neutral	LT to Neutral

R- Phase HT to Earth	130 M-Ohm	R- Phase HT to Earth	250 M-Ohm	R- Phase HT to Earth	200 M-Ohm	R- Phase HT to Earth	Short	R- Phase HT to Earth	200 M-Ohm (Open)
Y- Phase HT to Earth	130 M-Ohm	Y- Phase HT to Earth	250 M-Ohm	Y- Phase HT to Earth	200 M-Ohm	Y- Phase HT to Earth	Short	Y- Phase HT to Earth	200 M-Ohm (Open)
B- Phase HT to Earth	130 M-Ohm	B- Phase HT to Earth	250 M-Ohm	B- Phase HT to Earth	200 M-Ohm	B- Phase HT to Earth	Short	B- Phase HT to Earth	200 M-Ohm (Open)

- Transformer oil level:

The transformer oil level was reported to be okay.

- Breather provision:

The breather provision existed in the transformer and the Silica gel was checked and found okay.

- Position of lightening Arrestors:

i. The lightening arrestors were existing on the structure and were found to be in sound condition.

ii Four pedestals of the Geo-Switches were found punctured/damaged

iii The lightening arrestors were found existing on the HT line's emanating from the switchyard within 2 KMS radius.

- Weather conditions

The weather condition on the day of damage was rainy, Windy and with intermittent lightening i.e. it was not clear on the day of damage.

- Susceptible cause of damage:

Keeping in view the facts as mentioned above, the possible cause of damage in view of the investigation committee appears to be due to:

i. Atmospheric Lightening.

ii. Some internal defect: the dead fault on the 11 kV Himgiri feeder causing internal fault in the 1 MVA Transformer.

iii. Some manufacturing defect.

iv. Due to aging factor: the transformer has almost outlived its life as it is 1976 make.

v. Due to oil maintenance.

- Recommendations:

i. The 11 KV incoming and outgoing breakers were malfunctioning. These should be got repaired and if are beyond repairs, these should be replaced.

ii. The battery system should be got checked and if it is beyond repairs, these should be replaced as it is the back-bone of the substation.

iii. The transformer oil results through dehydration should be improved if required it is suggested that the dehydration set should be very near to the yard. should be got repaired.

iv. Earthing results should be got improved by recharging/providing fresh earthing electrode.

v. Each 11 KV outgoing feeder should have the separate breaker panel in the sub-station.

In this case, it can be seen that the major reason of transformer failure is aging and lack of proper condition monitoring with advanced techniques.

Conclusion

Power Transformers belong to the most expensive and strategically important components of any power generation and transmission system and thus, their reliability is of key importance for the availability and profitable operation of such systems to ensure quality electric power for the consumers in national endeavor. By adopting a disciplined monitoring and testing schedule for Power Transformer, the life of Power Transformer can be enhanced leading to reduction in revenue loss on account of damaged Transformer. Through relentless efforts of eminent researchers & Technologists including utility engineers, It has been established that better monitoring and awareness leads to more revenue/profit and also in case of transformer it enhances the consumer satisfaction.

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