Implementation of Reliability Centered Maintenance For Transformer

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Abstract : *The transformer's reliability is of so much importance because the failure of it can lead to several economic losses. The RCM methodology provides a framework for developing optimally scheduled maintenance programs. The aim of RCM is to optimize the maintenance achievements in a systematic way. This method requires maintenance plans and leads to a systematic maintenance effort. The aim is to achieve cost effec- tiveness by controlling the maintenance performance and increasing the reliability. The RCM gives us the principle of understanding that the vast majority of failures are not necessarily linked to the age of the asset, changing from efforts to predict life expectancies to trying to manage the process of failure and also gives us the understanding of the difference between the requirements of assets from a user perspective and the design reliability of the asset.*

Key Words: Preventive Maintenance, Corrective Maintenance, Reliability Centered Maintenance, Failure Mode and effect Analysis, Failure Mode and critical Analysis, Blocksim.

1.INTRODUCTION

Customers are nowadays becoming sensitive to critical disturbances and are demanding higher level of good power quality and service reliability. Deregulation is one of the forcing improvements in efficiency and it enables reductions in power cost. The transformer is lifeline of AC power system, whose failure affects the reliability of the system. So it is important part of electrical industry where reliability becomes a mandatory and a significant need. One primitive technique of replacing defective devices works by replacing that part of system which is prone to failure. All devices in a given class are replaced at pre-determined intervals or when they fail. In most electrical utility applications, maintenance resulting in limited improvement is an established practice and replacement Models have a secondary role. Maintenance programs range from the very simple to the quite sophisticated.

The Simplest plan is to adopt a rigid maintenance schedule where in a given time schedule, the activities are carried out. Component is repaired or replaced whenever it fails. In comparison to single maintenance job both repair and replacement are considered as much more costly.

Reliability Centered Maintenance (RCM) approach is based on regular assessments of equipment condition which does not apply rigid maintenance schedules. The RCM identifies the role of focusing maintenance activities on reliability aspects. The RCM methodology provides a framework for developing optimally scheduled maintenance programs. The aim of RCM is to optimize the maintenance achievements in a systematic way. This operation needs maintenance plans which lead to an effective & programmed maintenance effort. The aim is to achieve cost effectiveness by controlling the maintenance performance & increasing reliability. RCM gives the principle of understanding that the most of the failures are not linked to the requirements or unavailability of assets from a user perspective and the design reliability manage the process of failure and also gives us the understanding of the difference of the asset. Types of maintenance are graphically represented in Fig. 1.

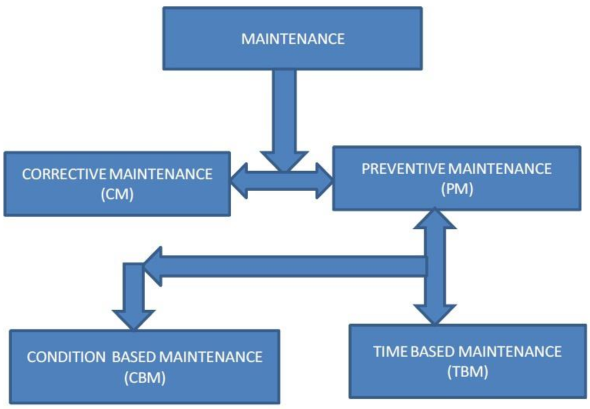

Fig. 1 Types of Maintenance

Literature Review

Much work has been done in the view of giving this important field of maintenance and reliability, some parameters on which improvement can be worked on further. J. Carneiro proposed an approach, in which maintenance was a function of reliability, and maintenance activities are scheduled as per reliability parameters. Greater importance is given to the failure of a transformer which may affect the transmission line heavily. RCM based transformer risk management is designed to improve the overall reliability. Preventive Maintenance, Corrective Maintenance and maintenance policy is briefly discussed in [1].

Transformer incipient fault detection including short circuit can be analyzed on time domain as well as frequency domain. The incipient faults due to internal winding faults are briefly discussed in [2].The analysis of maintenance strategies, RCM and risk management scenarios related to predictive techniques, taking into account the same weight for all systems corresponding to the components, functions failures, failure modes and criticality level has been discussed in [3].

Reliability centered maintenance is a technique which includes many intermediate techniques like Failure Mode-Effect Analysis (FMEA) and COFA which again needs for the development of the RCM software which helps to simulate the results for fault detection. Any software to support an RCM process should include documenting all its phases. A statistical model of equipment defects and failures, and an approach for optimization of maintenance frequency is used to define the software functionality. The needs for doing work on software requirements for reliability centered maintenance (RCM) application is discussed in a broad manner. [4]

On-line monitoring of power transformer can provide a clear indication of their status and ageing behavior. Analysis of the collected data allows avoidance of irreversible failures and preventive maintenance. The methods available for online monitoring is discussed in [5]

The concept of RCM was developed by the commercial airline industry Maintenance Steering Group and was endorsed by the Air Transport Association. RCM is based on the premise that reliability is a design characteristics to be released and preserved during operational life. The RCM process achieves these safety and reliability cost by using well defined approach. [6]

The RCM method is based on power interruption analysis, Maintenance activities, maintenance and system improvement budgets and appropriate selection of maintenance activities. RCM will optimize reliability based activities against budget limit. RCM also properly manages maintenance activities using Reliability Improvement Opportunity Graph [7].

Proposed Method

BlockSim Software is used for reliability analysis of Transformer, which is used for finding out the reliability of different kinds of models which may be a series model, parallel model or a combination of both. BlockSim provides an intensive platform for determining system reliability, availability values, maintainability status and many other related analysis.

A. Reliability Block Diagrams (RBDs)

Block diagrams are widely used in engineering to represent any system & its component connectivity. They can also be used to describe the interrelation between the components. When used for reliability analysis, it is referred to as a reliability block diagram (RBD). RBDs is constructed out of blocks. The blocks are connected with direction lines that represent the reliability relationship between the blocks. A RBD is a graphical representation of the various parts of the system which is under consideration as shown in Fig. 2. A block is usually represented in the diagram by a rectangle. In a reliability block diagram, such blocks represent the body of component, a complicated subsystem or an assembly of objects at its chosen black box level.

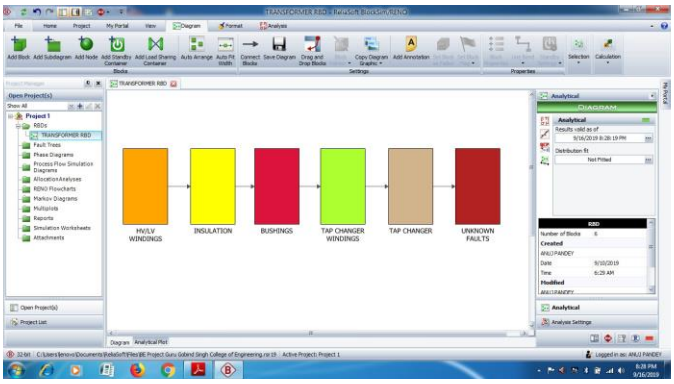

Fig. 2. Figure showing the RBD of a Transformer

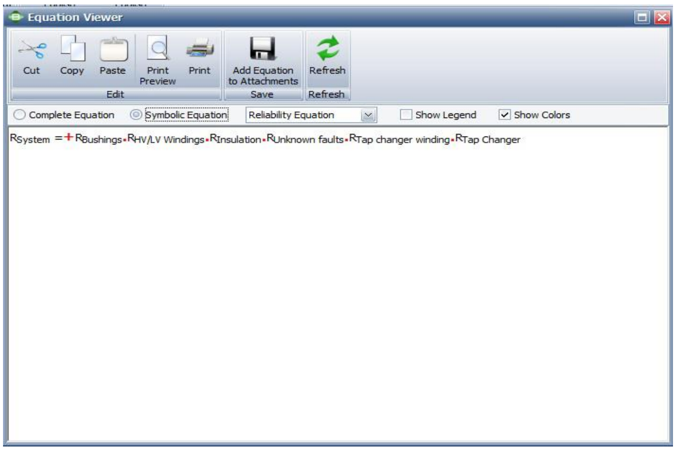

Fig. 3. Equation viewer wizard

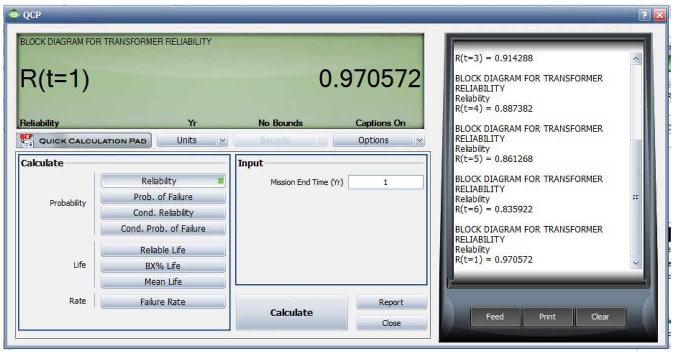

Fig. 4. Quick Pad Calculator (QPC) in Blocksim Analytic Calculations

1.1 Block Failure Models

The first step in evaluating the reliability of a system is to obtain life/event data related to each component of system or each subsystem in the circuit, in simple words, for each of the blocks in RBD. This information will allow the reliability engineer to determine the characteristics of the product or component life distribution. Data can be obtained from different sources such as from In-house tests for reliability indices, accelerated life ageing tests, test data from field equipment's, Warranty data, Engineering knowledge, Similarity to prior designs another reference sources. Once the data set has been obtained, the life distribution of a component/subsystem can be estimated depending upon the component. For example, consider a HV/LV Winding that is part of a transformer system to be analysed. Failure data for this HV/LV can be obtained by observing the failures or through the failure data in history.

1.2 Result

The study of reliability of a transformer is done using Reliability block diagram in BlockSim. The reliability analysis is performed using failure data considered from year 2006 to 2013 as shown in table 1.The figure 2 shows a typical reliability model under consideration. The series path contains Bushings, HV/LV winding, Insulation, Tap-changer winding and Tap-changer .Failure of any series component will result in a transformer failure. An unknown component is added for failures that could not be traced to a known component. A series model has a dependency from one component to another for the transformer to perform its desired output. The undesirable event being modeled is the ability of the transformer to transform voltage from one level to another at a constant frequency. If this does not occur, then the transformer has failed to perform its function and the undesirable event has occurred. There are no parallel paths in the model. The only parallel path in the model will be an identical parallel power transformer to prevent the undesirable event in-case one transformer fails. The reliability of the transformer is the series product of the components. With the help of failure rate reliability can be calculated with the help of

$$R(t) = 1 - F(t) \qquad (1)$$

Where,
F= Failure rate

The calculation for transformer reliability is given below:

Transformer Reliability
=(HVILV Winding)(Bushing)(Unknown) (Tapping Winding)(Insulation)(Tapchanger)
=(0.98567)(0.99512)(0.99665)(0.99695)(0.99787)(0.9981)
= 0.970734
= 97.07%

The RBD consist of 6 separate blocks representing individual components of the transformer model. The components are connected in series. So it is a series RBD model. The failure rates of these components are fed into the model. So while considering reliability, the analytical expression for the reliability of the system is given by:

$$R_{system} = R_A . R_B . R_C . R_D . R_E . R_F \qquad (2)$$

$$R_{system} = e^{-\lambda_1 t} . e^{-\lambda_2 t} . e^{-\lambda_3 t} . e^{-\lambda_4 t} . e^{-\lambda_5 t} . e^{-\lambda_6 t} \qquad (3)$$

$$R_{system=} e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t} \qquad (4)$$

At 1 year of operation the reliability of the system is:

$$R_{system} = e^{(0.0143+0.00488+0.00335+0.00213+0.00183).1}$$

$$= 0.9738577824 \text{ or } 97.3857 \ \%$$

In order to obtain the system's pdf, the derivative of the reliability equation is taken with respect to time, or:

$$f_s(t) = -\frac{d[R_s(t)]}{dt} \qquad (5)$$

$$f_s(t) = -\frac{d[e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t}]}{dt} \qquad (6)$$

$$f_s(t) = (\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t} \qquad (7)$$

The system's failure rate can now be obtained simply by dividing the system's pdf given in the equation above by the system's reliability function given in the first equation above,

$$\lambda_s(t) = \frac{f_s(t)}{R_s(t)} \quad (8)$$

$$\lambda_s(t) = \frac{(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t}}{e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t}} \quad (9)$$

$$= (\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6$$

The MTTF can be calculated as,

$$MTTF = \int_0^\infty R_s(t)dt. \quad (10)$$

$$MTTF = \int_0^\infty e^{-(\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6).t}dt. \quad (11)$$

$$MTTF = \frac{1}{\lambda_1+\lambda_2+\lambda_3+\lambda_4+\lambda_5+\lambda_6} \quad (12)$$

$$MTTF = \frac{1}{0.01433+0.00488+0.00335+0.00305+0.00213} \quad (13)$$

$$MTTF = \frac{1}{0.02957} \quad (14)$$

$$MTTF = 33.81 \ Years \quad (15)$$

Reliability analysis using BlockSim software: The reliability of the series model of the transformer can be find out with the help of BlockSim Software. It has a Quick Pad Calculator which helps to find out the reliability of the transformer. The Quick Pad Calculator Wizard Window is shown in fig. 4.

TABLE I
TRANSFORMER COMPONENT FAILURE DATA

Component that failed	No. of failures	Percentage	Failure rate
HV/LV Winding	47	48	1.433
Bushing	16	16	0.488
Unknown	11	11	0.335
Tapping Winding	10	10	0.305
Insulation	7	7	0.213
Tapchanger	6	6	0.183

TABLE II
TRANSFORMER COMPONENT FAILURE & RELIABILITY

Component that failed	No of failures	Percentage	Failure rate	Reliability
HV/LV Winding	47	48	1.433	0.98567
Bushing	16	16	0.488	0.99512
Unknown	11	11	0.335	0.99665
Tapping Winding	10	10	0.305	0.99695
Insulation	7	7	0.213	0.99787
Tapchanger	6	6	0.183	0.99817

In the BlockSim software, we can generate different kinds of Plots required for the analysis such as Reliability vs. time plot, Unreliability vs. time plot, plot, failure rate vs. time plot and Reliability Importance plot. These graphs help us in studying the variation of radiabilities with ageing. The various plots have been shown below:

2. CONCLUSIONS

The BlockSim Software helps us to completely calculate the reliability analysis of transformer. The transformer is one of the most significant equipment whose unreliable operation can lead to outages and as well result in large economic losses. As we study the transformer data based on component level the RCM program can be implemented using this software. The theoretical reliability analysis calculation matches with the software results. The preventive and corrective maintenance taken is based on various criteria which will reduce the failure rates in future. The failures increases if proper maintenance strategies are not applied thereby increasing the outages and as well as economic losses.

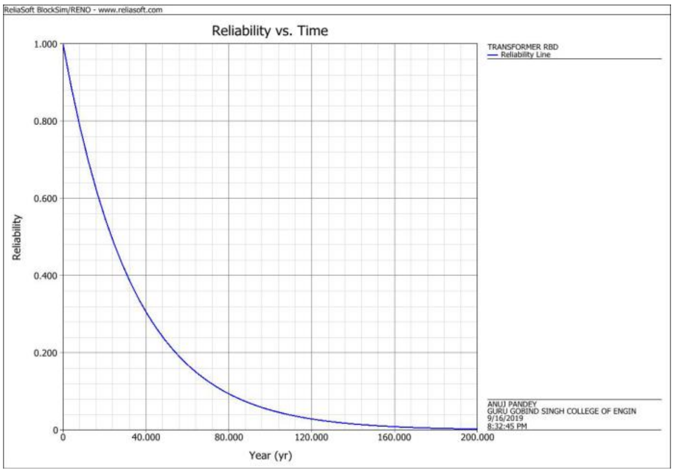

Fig. 5. Reliability Vs time plot

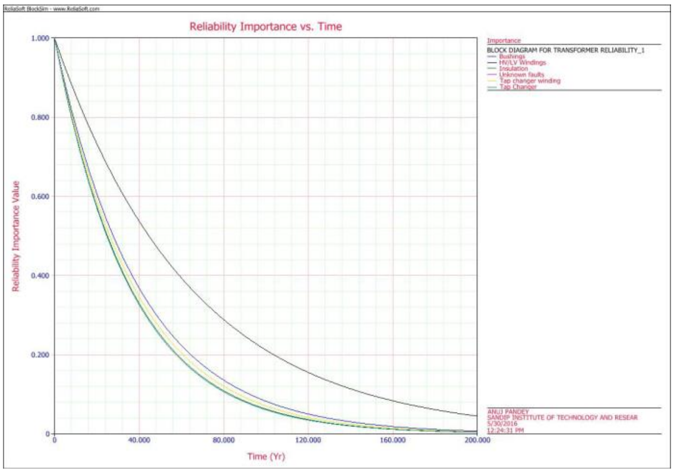

Fig. 8. RI Vs Time plot

Fig. 6. Unreliability Vs time plot

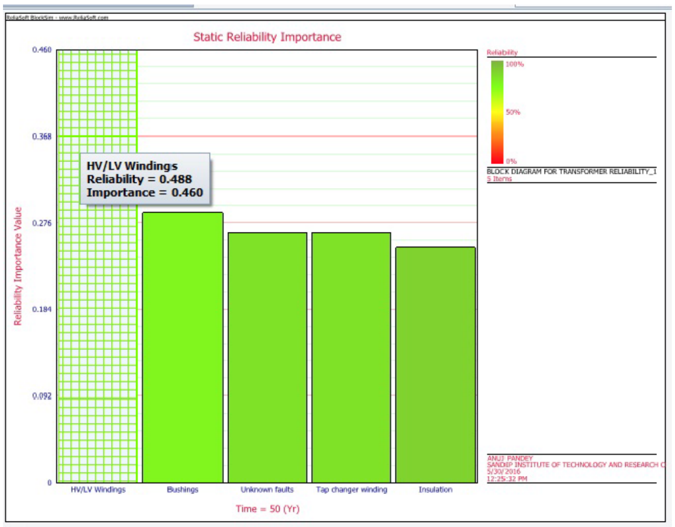

Fig. 9. Static RI plot for HV=LV winding

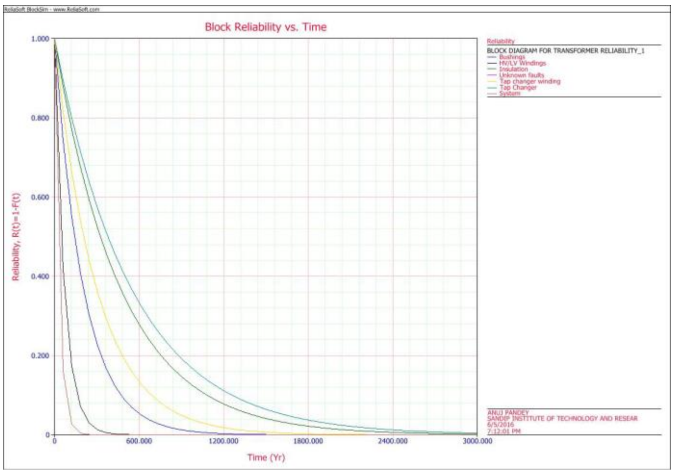

Fig. 7. Block reliability Vs time

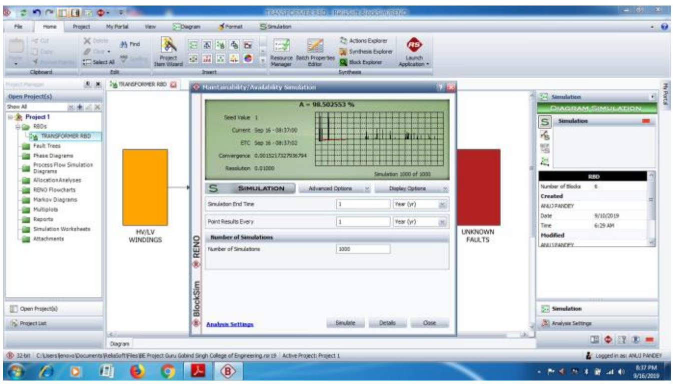

Fig. 10. Simulation Window

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