Reliability state space model of Power Transformer

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Abstract

In electrical power network, transformer is one of the most important electrical equipment in power system, which running status is directly concerned with the reliability of power system. Reliability of a power system is considerably influenced by its equipments. Power transformers are one of the most critical and expensive equipments of a power system and their proper functions are vital for the substations and utilities .Therefore, reliability model of power transformer is very important in the risk assessment of the engineering systems. In this paper the reliability model of the power transformer is obtained. The transformer is dividing into different part. State space model of model of each equipment is achieved. The state space model of different component either divide into three states and two state space models. Combining these three state & two state model of power transformer is obtained. The proposed model contains five states that can be use evaluating reliability.

Keywords: Power Transformer, Reliability, State Space Model.

1. Introduction-

Transformer is one of the most important electrical equipment in power system, therefore research on the reliability of the transformer has becomes an important research topic. In [1] Markov model for component and protective system has been proposed. The protected component is assumed to be a transmission line. Using the Markov model, optimum routine test and self checking intervals are determined. In [2] improved Markov model for protective system has been proposed. This structure is capable of modeling redundant protective systems. Therefore unlike most proposed models in the literature, back up protection is not assumed to be 100% reliable .In [3] novel techniques for life assessment of the transformer insulation have been presented and estimated by using of load and ambient temping feature. In [4] method to determine the reliability of integrated protection and control system of a transmission line has been proposed .In [5] reliability model for power transformer protection is proposed. The model is an extension of a previously proposed Markov model for transmission line protection. In [6]Considering the fact that transformer is void of reliability data, Fault Tree Analysis (FTA) and Monte Carlo algorithm are combined in this paper to analyze the reliability of transformer. In [7] components of the power system can be divided in smaller units, sub-components. The components can also be divided to passive and active units and they can be modeled both physically and operationally. In [8] describes a case study of the reliability of sub-transmission transformers (63/20 KV) installed in Mazandaran province, operated in sub-transmission system. The information obtained from Meandering Regional Electric Company. The results of study and analysis on 60 substation including more than 110 transformers installed in sub-transmission system show that the failure modes of transformers can be represented by Weibull distribution.

The paper is organized as follows. In section 2 structure of power transformer is discussed. In section 3 study basic of reliability and section 4 state space model of each component has been obtained. In section 5 presented complete state space model of transformer and section 6 presents result and section7 finally paper is conclude.

2. Power Transformer-

Power transformer consists of different parts winding, core, and bushing, tank, dielectric and cooler. In transformer core and winding are active part and this are very important .The winding wound the core and each one is covered with insulation paper. The function of the winding is the carry current and core also play important role in transformer. Core carries magnetic flux. There are two type of core first is core type and second is shell type. This two active part place inside the tank and tank provide the protection .Transformer oil fill inside of transformer for insulation purpose and cooling purpose [3]. In transformer cooler are used for cooling of transformer .Bushing one of the important components of the transformer. This connects the winding and the power system. The transformer is dividing into different part. State space model of model of each equipment is achieved. The state space model of different component either divide into three states and two state space models. The combining these three state & two state model of power transformer is obtained. The proposed model contains five states that can be use evaluating reliability.

3. Basic Concepts of Reliability Analysis

In general, a bathtub curve may be used as an adequate representation of a transformer failure mode with varying life time[14]. Accelerated life testing has shown that transformer have a bathtub curved failure rate. It can be divided in to three failure modes as shown in figure [1] .The first parts of curve, known as failure period. Early failures are those which occur in early life of a system operation. The concept of "warranty is based on the concept of early failures. These failures are primarily due to manufacturing defects, such as weak parts, poor insulation, bad assembly, poor fit etc. Since the defective units are eliminated during the initial failure period, this period is known as debugging or burn-in period. After initial failures, for a long period of time of operation fewer failures are reported but it is difficult to determine their cause. They occur due to the sharp change in parameters determining the performance of the units, either as a result of the change in the working stresses or environment conditions. But in either case, it is difficult to predict the amplitude of stress variations and their time of occurrence; thus the failure during this period are often called random failure or catastrophic failures. This is the period of normal operation and is characterized by (approximately) constant number of failure per unit time. The final part of the curve, where the failure rate is increasing, is known as the wear out failure. Wear–out failures are caused due to aging or wearing out of components. These failures occur if the system is not maintained properly or not maintained at all and the frequency of such failure increases rapidly with time.

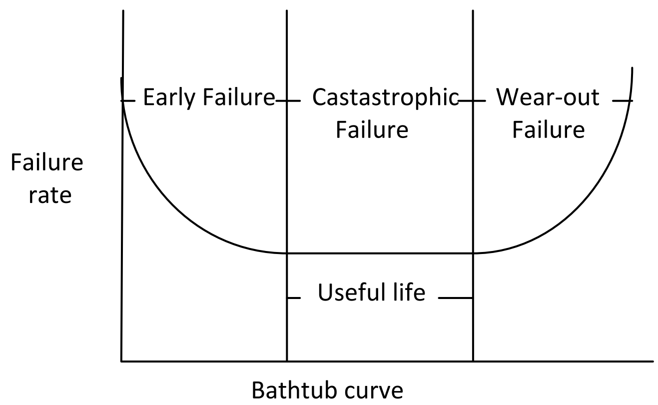


FIG .1 BATHTUB CURVE

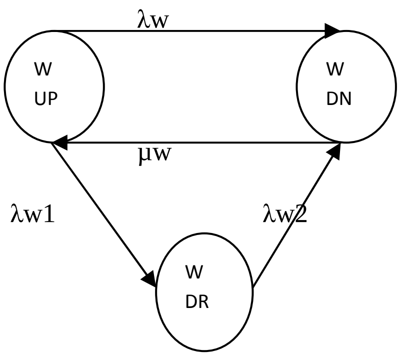
4. Reliability Model of Transformer

In this section state space model of transformer component winding, core, tank, bushing dielectric material and cooler is discuss.

4.1Winding State Space Model-

The winding belong to the active part of a transformer and their function is to carry current [16]. the winding are arranged as cylindrical shells around the core limbs, where each strand is wrapped with insulation paper. Copper is today Copper is today the primary choice as winding material. In addition to dielectric stresses an thermal requirements the windings have to withstand mechanical forces that may cause windings replacement. Such forces can appear during short circuits, lightning, and short circuits in the net or during a movement of the transformer. A fault in the windings can occur due to material faults in the cellulose isolation, lighting, short circuits in the net, ageing of cellulose low oil quality [12]. There are various type of method use for fault detection like partial discharge, hot spot temperature, DGA etc [15]. Large amount of failures occur in winding, the most prevalent one is short circuit. If short circuit is severe, it will damage the transformer. In this situation, the system fails or it must be immediately removed from service .Some faults do not cause the outage of the transformer and just disturb the normal operation of the system. Preventive tests and on-line monitoring help us to diagnose these types of faults. The most successful technique for on-line fault diagnosis is dissolved gas-in oil analysis (DGA).According to above statements, state-space reliability model of windings contain three state is shown in Fig. shown. State 1 is related to the condition in which no fault occurs in windings. State 2 shows the status that windings failure leads to removal of the transformer from service. State 3 demonstrates the condition that windings have fault but by reducing the load, transformer will remain in service. In Fig. 1 are as follows:

λw : winding failure rate,
$\lambda w1$: winding fault rate that does not cause removal of the transformer from the service,
$\lambda w2$: faulty winding failure rate ,
μw : winding repair rate.



UP: Up , DR: Derated , DN: Down

Fig.2 State Space Model of Transformer Winding

4.2 State Space Model of Core, Bushing, Tank, Dielectric Material, and Cooler

The core's function is to carry magnetic flux. The failure mode of this function is a reduction of the transformer's efficiency. The cause can be a mechanical fault in the core, due to DC magnetism or displacement of the core steel during the construction, i.e. a construction fault. The tank is primarily the container of the oil and a physical protection for the active part of the transformer. It also serves as support structure for accessories and control equipment. The tank has to withstand environmental stresses, such as corrosive atmosphere, high humidity and sun radiation. Bushing may damage because of several reasons. Other part of this transformer is the cooling system. Transformer cooling used for transformer protection. The state space model of core, tank ,oil, cooler, bushing and dielectric material is two state because two state available up and down and failure rate of core , tank ,bushing , cooler, dielectric is λc,λt,λb,λco,λd and repair rate is μc, μt ,μb, μco ,μd respectively. Combine failure rate of core, tank, bushing, cooler and, dielectric material is λ and repair rate is μ and two state is A UP and B DOWN.

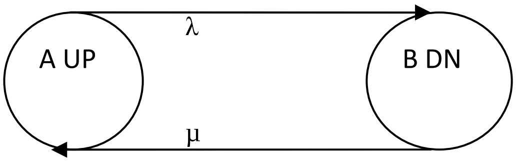


Fig.3 Combine State Space Model of Core, Tank, Bushing, Cooler and Dielectric Material.

5. Combine Three and Two State Space Model of Transformer.

Combining the three state model of winding and other two state model of core, Bushing, tank, cooler and finally establish the reliability five state model of transformer[5] .In five state model shown A,B,C,D and E. State A shown winding are working condition and other component are also working condition . State C shown in winding fault has been occurred in winding but still works. However due to winding are derated condition and other component are up. In state B winding are down because of same fault occurs in winding and other component are up. In state D all component are down condition. State E shown winding are operating condition and other component are down condition.

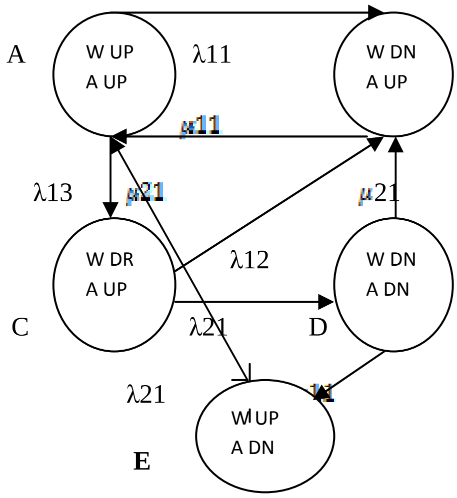


Fig.4 Complete Five State Model of Transformer

6. Result

In this section numerical analysis and calculated the reliability of power transformer using source failure data of transformer component .Where p1, p2 and p3 is full, half and derated probability.

Probability (full capacity)P1 = PA
Probability (half capacity)P2= PB+ PE+PD
Probability (zero capacity)P3=PC

Table1 .Result – probability of transformer

Probability	Value (%)
P1	99.27
P2	0.22
P3	0.50

7. Conclusion

This paper presents on state space model for reliability of power transformer. Multi state markov models and approximate methods wear used to model the transformer component. Ultimately 3 state and 2 state space models was developed. By combining three state and two state space model five state model achieved that can be use to calculate the reliability of power transformer using failure parameter and repair rate.

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