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Remaining Useful Life (RUL) Prediction of electrolytic Capacitor using Artificial Intelligence

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CHAPTER
INTRODUCTION

Residual life prediction is the technique which demonstrates how reliable a particular electronic system or component works under in specific operating conditions. The remaining useful life relies on the failure rate of a component and on the operating conditions of a device. This failure rate drifts for the duration of the life of the item with time. Life is an important aspect while choosing the electronic hardware. Residual life estimation and life prediction are two distinct terms [1] [2]. The importance of life estimation is to evaluate the remaining useful life (RUL) of a specific component under the different stress parameters.

As an increasing number of components are integrated on to a chip, the chances of failure increase, as the different parts have their own stress factors and different working conditions. So the condition monitoring strategies are utilized which enhances the reliability of a component and a suitable move to be made before any harmful breakdown happens. The electronic circuits need a failure estimation technique to protect the system from unavoidable failures [3].

RESIDUAL LIFE PREDICTIONOFELECTRONIC COMPONENTS

Residual life estimation of electronic components is an important fact these days as electronic components and devices becomes a great need of society. Residual life prediction is predicting the remaining useful life of a component or device based on various failure factors of any component and it also depends on the operating conditions. Many methods for predicting the life of electronic components have been developed. The life of electronic components can be predicted by creating an intelligent system for the failure analysis [4] [5]. The capability to predict the life of electronic components is a key to prevent the sudden costly failure and it will increase the overall performance and reliability of a system [6]. So, remaining useful life prediction is an important factor for every active and passive electronic component such as resistor, capacitor and diode etc.

RESIDUAL LIFE PREDICTION OF ELECTROLYTIC CAPACITOR

One of the major aspects for electronic engineers regarding capacitor is to predict its remaining useful life in order to protect it from sudden failures and prevent the complete system breakdown. The life of electrolytic capacitors is mostly relies on various environmental and electrical factors where environmental factors are temperature, humidity, atmospheric pressure and vibration and electrical factors are operating voltage, ripple current and dissipation factor. Out of these factors, temperature (ambient temperature) is the critical factor while estimating the life of aluminum electrolytic capacitors whereas; conditions such as vibration, shock and humidity have little impact on the actual life of the capacitor [7-8].

Lifetime Acceleration Factors

Electrolytic capacitors are by assessed by accelerated life tests. The accelerated life tests contain four components (one for temperature, voltage and ripple current) which are given by the accompanying equation [9-10]:

$$L_P = L_T * L_V * L_R * L_{VIB} * L_H$$

Where:

L_P = Predicted lifetime

L_T = Temperature acceleration factor

L_V = Voltage acceleration factor

L_R = Ripple current acceleration factor

L_V = Voltage acceleration factor

L_R = Ripple current acceleration factor

1.2.1.1 Temperature factor

A capacitor is basically an electro-chemical gadget in which increased temperatures ranges maximize the chemical reaction rates inside the capacitor (normally with a 10°C rise in temperature, the chemical reaction rate become twice). The higher temperature ranges cause maximum changes in value of capacitance and dissipation factor because of the continuous dissipation of the electrolyte through the capacitor seal and the equivalent series resistance that is a measure of electrolyte loss also changes with change in temperature. So, the higher temperature changes affects the lifetime of a capacitor to a great extent [11].

1.2.1.2 Voltage factor

The electrolytic capacitor have a specified rated voltage and while operation if the voltage more than the rated value is applied then it leads to more heat dissipation and degrades the life of electrolytic capacitor. The life of electrolytic capacitor is affected less by applied voltage than by operating temperature. Constant application of excessive voltage will quickly expand the ripple current and may cause instant damage to the capacitor [12].

1.2.1.3 Ripple Current factor

Electrolytic capacitors have higher heat dissipation due to ripple current. To guarantee the capacitor's life, the greatest ripple current of the capacitor is specified [13]. At the point when ripple current flows through the capacitor and the internal heat is produced inside the capacitor with a rise in temperature. Internal heat dissipation produced by ripple current can be given by:

$$W = I_R^2 * R_{ESR} + V * I_L$$

Where:

W = Internal heat dissipation

I_R = Ripple current

R_{ESR} = Internal resistance (Equivalent Series Resistance)

V = Applied voltage

I_L = Leakage current

1.2.1.4 Humidity

Humidity is an important factor affecting the life of capacitor. If moisture absorbed by the sealing of the capacitor case then it leads to parametric changes (especially in the ripple current) and results in reduced lifetime and sometimes serious failure occurs due to more moisture penetration [14].

RESIDUAL LIFE PREDICTION OF FIXED RESISTOR

The carbon film resistor is a kind of fixed resistor that uses carbon film to limit the electric current to flow through it. These resistors are generally utilized as a part of large electronic circuits. One of the significant worry for electronic specialists with respect to fixed resistor is to forecast their remaining useful life so as to preserve it from unpredictable failures and system shutdown [15]. The life of fixed resistor is relied on various environmental and electrical factors. Environmental element is temperature whereas electrical elements are working voltage and

power dissipation. Out of these components, temperature is the most affected to the life of fixed resistor [16]. So, the conditions such as voltage and humidity have little impact on the resistor.

Effects of Temperature on Life

With the rise in operating temperature of resistor the performance of resistor starts degrading and after a specified temperature resistor stops working and may harm the complete circuit. Maximum temperature limit is defined in terms of maximum power called power rating and at highest temperature rate a resistor dissipates maximum power.

Effects of operating voltage on Life

The operating voltage also have a significant effect on life of a fixed resistor, When the operating voltage rise up more than the specified value, amount of power dissipation through the resistor increases and it will results in failure of resistor.

RESIDUAL LIFE PREDICTION OF DIODE

The diode is a type of electrical component that is used to rectify the electric voltage to certain level. The diodes are used in many electronic circuits. One of the important aspect of diode for electronic industries is to predict their remaining useful life in order to save it from sudden failures and complete circuit shutdown [17]. The life of a diode is generally dependent on environmental and electrical parameters. Environmental parameters are temperature and humidity whereas electrical parameters are voltage and current.

Effect of temperature on life

As the ambient temperature of a diode increases the working performance of diode starts degrading and after a specified temperature diode fails and may harm the complete circuit.

Effect of voltage on life

The life of diode is affected less by applied voltage. When during operation at voltages above the rated voltage of a diode is applied, the internal current of diodes starts rising and more heat dissipation takes place through the diode and if the current rises to a great extent it will degrade the performance of diode completely and sometimes leads to failure of diode ct [18].

ARTIFICIAL INTELLIGENCE TECHNIQUES USED FOR RESIDUAL LIFE PREDICTION

The actual operating life of every product depends on its real operating conditions. Hence these operating conditions must be taken into account while determining the total life and consumed