

**Cherry Bhargava / Shivani Gulati**

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

**Master's Thesis**

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# Inhalt

CHAPTER.....	4
INTRODUCTION .....	4
RESIDUAL LIFE PREDICTION OF ELECTRONIC COMPONENTS .....	4
RESIDUAL LIFE PREDICTION OF ELECTROLYTIC CAPACITOR .....	5
Lifetime Acceleration Factors .....	5
RESIDUAL LIFE PREDICTION OF FIXED RESISTOR .....	6
Effects of Temperature on Life .....	7
Effects of operating voltage on Life .....	7
RESIDUAL LIFE PREDICTION OF DIODE .....	7
Effect of temperature on life .....	7
Effect of voltage on life .....	7
ARTIFICIAL INTELLIGENCE TECHNIQUES USED FOR RESIDUAL LIFE PREDICTION .....	7
Artificial neural network technique .....	8
Fuzzy Inference System .....	8
Adaptive Neuro-fuzzy Inference System (ANFIS).....	10
CHAPTER.....	12
LITERATURE REVIEW.....	12
Salah-Al-Zubaidi, et.al: .....	12
Cherry Bhargava, et.al: .....	12
Salah Al-Zubaidi, et.al: .....	13
PrakashHPatil, et.al:.....	13
Zhigang Tian :.....	13
Seung Wu Lee, et.al: .....	14
Adithya Thaduri, et.al: .....	14
Garron K Morris, et.al:.....	15
Ajith Abraham, et.al:.....	15
Youmin Rong, et.al:.....	16
Prabhakar VVarde, et.al:.....	16
Vishu Madaan, et.al:.....	16
CHAPTER.....	17
REVIEW OF BASIC CONCEPTS AND DEVELOPMENT OF .....	17
Introduction.....	17
Outline of proposed work.....	18
Selection of components for life estimation .....	19
Methods for estimating the remaining useful life of electronic components.....	21
Experimental method (Using ALT) .....	21

Analytical method.....	22
Residual life estimation using artificial intelligence techniques.....	25
Artificial neural network technique.....	25
Fuzzy Inference System.....	25
Adaptive Neuro-fuzzy Inference System (ANFIS).....	25
Design of decision support system.....	26
Tools Used:.....	26
MATLAB tool.....	26
Scope of the study.....	27
Residual life estimation using artificial intelligence techniques.....	27
Artificial neural network model.....	27
Fuzzy Inference System.....	28
Adaptive Neuro-fuzzy Inference System (ANFIS).....	35
Design of fuzzy based decision support system.....	39
Modeling of fuzzy based decision support system.....	40
CHAPTER.....	43
WORK DONE.....	43
Residual life estimation of capacitor.....	43
Life estimation of electrolytic capacitor using analytical method.....	44
Residual life estimation of capacitor using ALT (acceleration life testing) approach.....	45
Residual life estimation of resistor.....	46
Residual life estimation of resistor using Acceleration life testing.....	47
Residual life estimation of resistor using artificial intelligence modeling.....	48
Residual life estimation of Diode.....	51
Residual life estimation of diode using ALT (acceleration life testing) method.....	52
Life prediction of diode using expert artificial intelligence modeling.....	53
Design of decision support system.....	56
CHAPTER.....	57
RESULTS AND DISCUSSION.....	57
Residual life estimation of capacitor using analytical method.....	57
Residual life of electrolytic capacitor obtained using artificial intelligence modeling.....	60
Residual life of electrolytic capacitor obtained using artificial neural network model.....	60
Residual life of electrolytic capacitor obtained using fuzzy model.....	64
Residual life of electrolytic capacitor obtained using ANFIS model.....	68
Comparison of output life obtained using various techniques.....	72
Life estimation of electrolytic capacitor using experimental method (using ALT).....	76
Fuzzy based decision support system interfaces for electrolytic capacitor.....	78

Fuzzy based decision support system interfaces for resistor .....	90
Residual life estimation of diode using experimental method (ALT).....	91
Fuzzy based decision support system interface for diode.....	100
CHAPTER.....	101
CONCLUSION & FUTURE SCOPE .....	101
CHAPTER.....	102
CONCLUSION & FUTURE SCOPE .....	102
CHAPTER.....	103
REFERENCES.....	103
ANNEXURE.....	108



# **CHAPTER**

## **INTRODUCTION**

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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 PREDICTION OF ELECTRONIC 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