An Intelligent Model for Residual life Prediction of Thyristor

Cherry Bhargava, Jagdeep Singh, Pardeep Kumar Sharma*

Abstract*: *Modern age is the age of integration, where millions of electronic components are integrated and installed on a single chip, to minimize the size of device and automatically increases the speed. But, as a greater number of components are placed on a single device, reliability becomes a concern issue, as failure of one component can degrade the complete device. From dimmer to high voltage power transmission, thyristors are widely used. The failure of thyristor can be proven dangerous for mankind, so the reliability prediction of thyristor is highly desirable. This paper is based on the accelerated life testing based experimental technique for reliability assessment. An intelligent model is designed using artificial intelligence techniques i.e. ANN, Fuzzy and ANFIS and comparative analysis is conducted to estimate the most accurate technique. Fuzzy based Graphical User Interface (GUI) is framed which informs the user about the live status of thyristor under various environmental conditions. The intelligent techniques are validated using experimental technique. An error analysis is conducted to predict the most accurate and reliable system for residual life prediction of thyristor. Out of all prediction techniques, ANFIS has the highest accuracy i.e. 95.3%, whereas ANN and Fuzzy inference system has accuracy range 86.1% and 89.2% respectively.

Index Terms*: *Artificial Intelligence, Accelerated life testing, Graphical user interface, Reliability Prediction, Thyristor

I. INTRODUCTION

The world is facing the fastest growing problem of electronic and electrical waste. It has hazardous material which is dangerous of human being. It is expected that by year 2020, the waste of electrical and electronics equipment (WEEE) will grow up-to 12 million tones. The reliability prediction is the key parameter for successful operation of the device or equipment. When a manufacturer releases a product in market, a datasheet is provided along with the component, which states the life of the component. If the component fails within warranty period, manufacturer has to bear the replacement cost or repairing charges. Moreover, failure before time, degrades the market reputation of the manufacturer. So, the reliability estimation is the crucial issue for the manufacturers. On the other side, the failure of the component may cause the financial as well as professional loss to the consumer. 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. If the remaining useful life (RUL) is calculated, it can save the user from complete shutdown or system failure [1]. The predicted life can direct the user for re-use of the component, that in-turns decreases the waste of electrical and electronics equipment (WEEE) problem to a great extent[2].

Many researchers are working on the untimely failure and fault analysis of electrical and electronic components and equipment. Various experimental, statistical as well as standard methods are deployed for failure prediction. For live health monitoring of the components, artificial intelligence techniques are used, which has capability to predict the end of life status of the component at various operating conditions and input parameters[3]. So, failure and fault prediction of the component becomes an important parameter for lucrative performance.

Thyristor

The Thyristor is semiconductor device. It is four layered device which acts as a switch. Thyristor word is composed of two words (the thyratron and the transistor). A thyristor works on the similar principle as a transistor. It is constructed of three electrodes: the gate, the anode and the cathode. The gate work as the controlling. It is mostly used in ac circuits. P type material and N type material used in thyristor[4]. SCR (Silicon-controlled rectifier) is like a thyristor. It behaves like a rectifying diode. Four layers of thyristors.

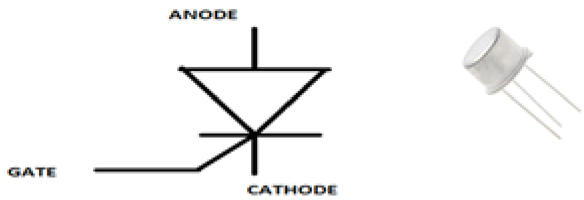

Figure 1. Symbol of thyristor 2N-2324

II. METHODS & RESULTS

Compact size and high speed are the prime need of the users. So, millions of components are integrated on a small size chip, which is known as integrated chip. The performance of the equipment depends on the reliability of the components inserted inside. A failure of single component can accelerate the failure of whole device. Thyristor is used in majority of power electronic devices and high-speed electronic devices, so its reliability prediction is a challenging issue[5].

There are various methods for reliability assessment of thyristor, which is summarized in below mentioned flow chart. Although standard methods are there, to predict the residual life of the component i.e. military handbook, but such method is not accurate as it does-not covers all aspects.

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For realistic estimation of residual life, experimental approach is adopted. An expert model is designed using artificial intelligence technique which guides the user to estimate the remaining useful life of the thyristor at different temperature and operational time[6].

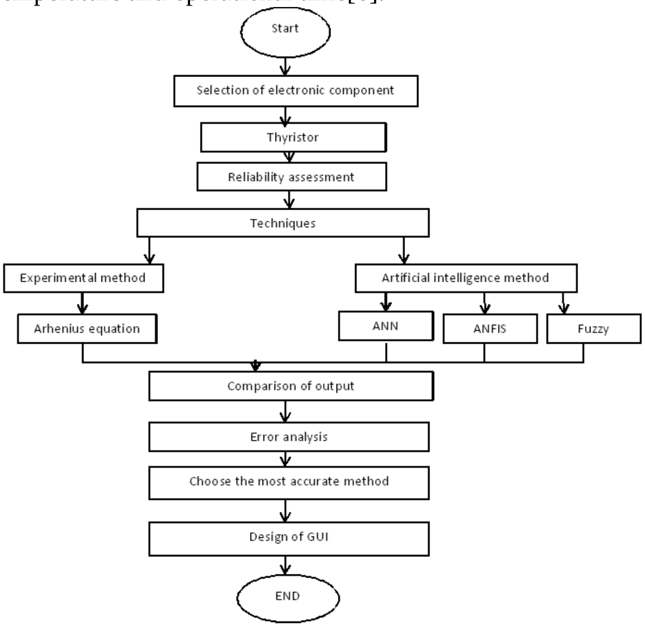

Figure 2. Flowchart for life estimation techniques

A. Failure estimation using experimental method (ALT)

Accelerated life testing is an experimental technique for failure prediction of components. This type of test is highly recommended by big production units because, it has an advantage of time saving. It is based on the fact of increase the stress level and decrease the test duration. The actual parameters of the components are specified in datasheet. The accelerated life testing suggests the experiment at the maximum stress level. The specified components are placed on the testing machine, for the maximum range of stressors[7].

Figure 3. Experiment setup of thyristor testing

The specified working parameters of Thyristor 2N-2324, have been analyzed. The specification of 2N-2324 is:

Table 1. Specification of 2N-2324

Parameter	Value
Voltage (Forward)	100V
Voltage (Gate)	6V
Current (On-state)	1.6A
Gate Threshold Current	200uA

The process of accelerated life testing consists of following steps [8]:

a) Regular check the component using digital multimeter and inspect for physical damage.

b) Place the 20 thyristors on the hot plate. Cover the thyristors using sand, so that all the components get uniform heat.

c) Set the temperature of the hotplate and note the readings from initial to maximum temperature.

d) The experiment is specified for a fix duration of time. There is variation in time corresponding to temperature. At higher temperature, time duration is lesser.

e) Measure the value and check the functioning of all components after specified time duration.

f) Collect the functional data of components and calculate the residual life of thyristor using:

$$Residual\ Life = \frac{Acceleration\ Factors}{Test\ duration\ (hours) \times Number of\ devices} \quad (1)$$

Where, failure rate is specified by acceleration factor, which is calculated as:

$$Acceleration\ Factors = e^{\frac{Ea}{K}\left[\frac{T1-T2}{T1\times T2}\right]} \quad (2)$$

T1 is the temperature during test and T2 is maximum temperature, as mentioned in datasheet. Boltzmann's constant 'K' and Activation energy is specified as Ea.

Using accelerated life testing (ALT), remaining useful lifetime of thyristor is calculated at various set of temperature and time, as shown in following table.

Table 2. Estimated life using experimental technique

Run	Temperature (C)	Time (hours)	Estimated Life (hours)
1	110	20	29601.2
2	115	17	21701.4
3	120	16	18881.1
4	125	14	18007.6
5	130	13	16782.2
6	135	10	15632.4
7	140	09	13214.5
8	145	07	11014.8
9	150	05	9265.1
10	155	03	7372.9
Mean estimated life			16147.3

The mean life estimated using accelerated life testing is 16147.3 hours.

III. LIFE PREDICTION OF USING EXPERT ARTIFICIAL INTELLIGENCE MODELLING

After assessment of thyristor life using experimental approach, an intelligent model is designed which predicts the end of life status of thyristor using artificial intelligence techniques. Artificial neural network, fuzzy logic and adaptive neuro fuzzy inference system techniques are deployed for life time estimation.

A. Artificial neural network model for life estimation of thyristor

Artificial neural network is a type of artificial intelligence technique which is similar to brain neuron. For natural neural processing, ANN is the computational unit. Several processes are trained and tested in parallel manner[9]. For thyristor life estimation, the number of input layers are two i.e. temperature and time, whereas the output layer is one which is residual life estimation.

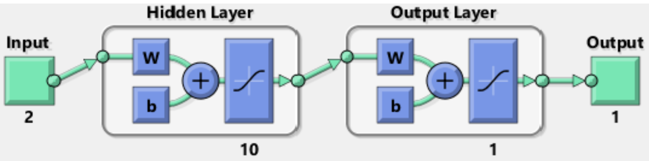

Figure 4. ANN model for residual life of thyristor

The best result is obtained by the method of training and testing at different epochs[10].

B. Fuzzy inference model for life estimation of thyristor

It is acceptable but definite output in response to unfinished, dual meaning, distorted, or not accurate input. It is a method of reasoning that like human reasoning[11]. Fuzzy logic has a lot of real time applications. The system selects the inputs and then through the process of fuzzification the inputs are converted into language quantities (L- low, M – medium, H – high)[12]. Therefore, defuzzification a fuzzy quantity represented by a membership function is converted in to a precise or crisp quantity[13].

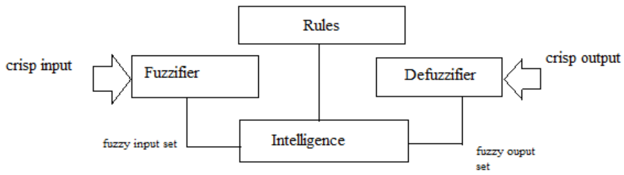

Figure 5. Flow chart of fuzzy inference system

The flow process of fuzzy inference system is depicted as in figure 6. For residual life assessment of thyristor, Mamdani type inference is used.

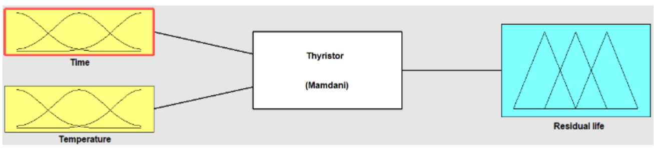

Figure 6. Fuzzy inference model for residual life of thyristor

The gaussian membership is used for input parameters i.e. temperature and time as well as output parameter i.e. residual life.

C. Adaptive Neuro-fuzzy Inference System (ANFIS)

ANFIS is a hybrid type of prediction technique which comprises of both ANN as well as fuzzy tool[14]. It has advantage of both the techniques, as ANN has this self-learning mechanism but it doesn't know how the hidden process is following to reach the particular target and the disadvantage is that the output is not that user understandable, precise and accurate[15]. It can't handle ambiguity. On the other hand, the advantage with fuzzy logic is that it can handle uncertain data and also, linguistic variable to have better understanding but no self-learning is there. Hence, to omit each other advantages, these two techniques have been combined to formed third technique that is ANFIS (Adaptive neuro-fuzzy Inference system). Here the rules needed by fuzzy get self-updated through the self-learning mechanism possessed by ANN[16]. So, lesser number of errors is shown by the predicted data of ANFIS.

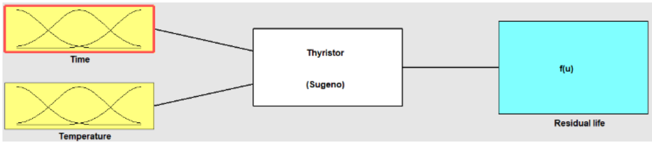

Figure 7. ANFIS model for residual life of thyristor

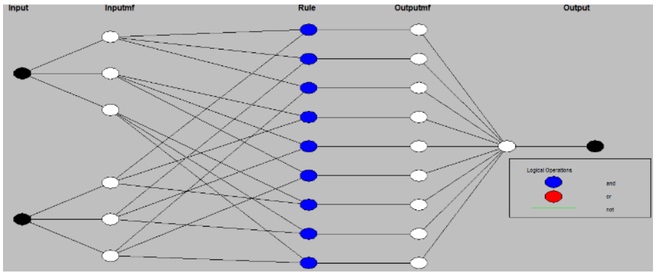

Figure 8. ANFIS structure

IV. DESIGN OF DECISION SUPPORT SYSTEM

The graphical user interface has been created using different life estimation techniques. This is based on fuzzy logic and results have been interpreted to choose the most accurate method[17].

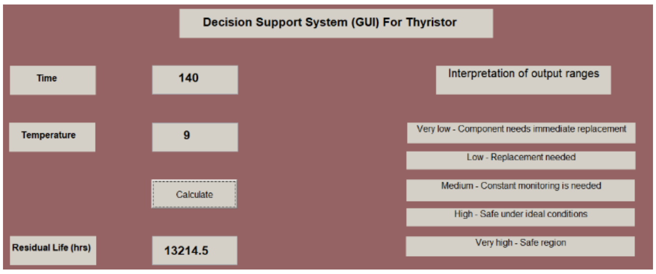

Figure 9. Decision support system for thyristor

Using decision support system using graphical user interface (GUI), the consumer can directly interact with the system and calculate the remaining useful lifetime of thyristor. It also displays the warning, if the estimated life is less than threshold value for immediate replacement.

A. Comparative analysis of prediction techniques

Different techniques have been used for calculating the useful life of thyristor in this paper. The comparison has been summarised in table 3. This shows that ANFIS has the least error and estimated lifetime using ANFIS is the most accurate one. The graphical user interface has been created as a decision support system which calculates the life, based on different techniques[18].

Table 3. Comparison of different artificial intelligence techniques

Parameter	Residual lifetime using artificial intelligence techniques		
	ANFIS	ANN	Fuzzy
Estimated lifetime(hours)	15372.28	13934.12	14566.56
Average error %	4.7	13.9	10.8
Accuracy %	95.3	86.1	89.2

The residual life of thyristor is calculated using experimental approach i.e. accelerated life testing and it shows an average life of 16147.3 hours. The residual life predicted by ANN, fuzzy and ANFIS are compared with experimental lifetime and error analysis is conducted, which shows that ANFIS has the least error i.e.4.7%.

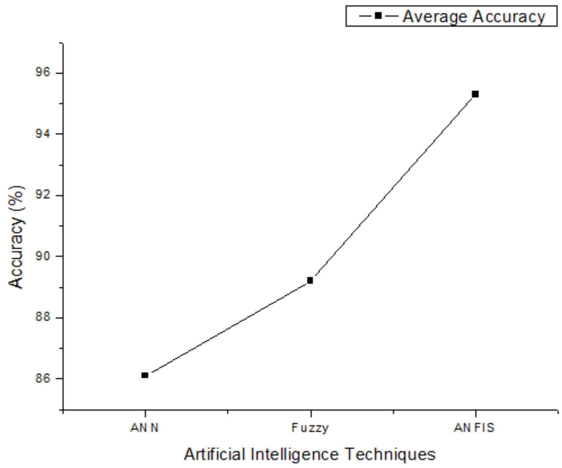

Figure 10: Accuracy comparison of prediction techniques

The figure 10 depicts the graphical comparison of all the intelligent prediction models with respect to the residual life calculated using experimental technique.

V. CONCLUSION

The electronic component such as thyristor is used widely. But this component has limited time period for useful operation. For successful operation of thyristor, it is necessary to predict its health condition for various set of input parameters. Accelerated life testing is used as an experimental approach for calculating the useful time. The residual life is calculated by assessing the acceleration factors at stressed values. An expert system is designed using various artificial intelligence techniques, which predicts the end of life status of thyristor well before, it actually occurs. The predicted models are validated using experimental technique and comparison is made in between all the intelligent techniques in terms of error and accuracy. After analysing all the techniques and their output, ANFIS is proven as the most accurate technique, which has 95.3% accuracy, as compare to ANN which has 86.1% and fuzzy inference system has 89.2% accuracy.

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