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Automatic Classification of Transmission Line Faults Using Probabilistic Neural Network and Discrete Wavelet Transform

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Abstract: ***The largest physical length of transmission network is the most critical part of the power system. The fast recognition of faults and events in transmission line has a significant role in order to prevent equipment damage and suddenly collapse of power system. The signal-processing and computational-intelligence based techniques have been proposed in literature for automatic classification of faults and events in transmission network. In this paper, discrete wavelet transform based probabilistic neural network have been proposed for the identification and classification of faults in transmission network. The short circuit faults are created at various fault resistances and fault locations. The wavelet transform is used to extract the features in order to distinguish the type of faults. The probabilistic neural network is used to automatically classify the type of faults. A real-time transmission network is used for simulation of faults. The simulation results show that the proposed algorithm is efficient and reliable for automatic classification of faults in electrical power system.***
Keywords: Transmission line faults, discrete wavelet transforms, feature extraction, probabilistic neural network

I. INTRODUCTION

There are various types of faults in transmission lines, occurring due to short circuit, high impedance, transients, harmonics, lightning stroke, flash over, fire, snow and wind. These faults directly affect the power system. For the safety of the power system, it is important to detect and localize these faults accurately and classify them as soon as possible [1]. There are many sources of faults in transmission line. There are two types of load linear loads and non-linear loads. The huge applications of power electronics, semiconductor devices, inverter and AC regulators are the main sources of non-linear loads due to occurrence of non-linear loads power quality can gradually diminished. Transient are produced due to instantaneous variation in current and voltage. Spike or surges produced in voltage and current which causes disturbance and also the usage of electromagnetic which causes transient when fault occurred spike created so the fault information is included in the transient. Mostly these transient used for the prediction of faults when transient are created the voltage can be swing above or below

High Impedance Fault (HIF) occurs when conductor come in contact with birds, tree, lighting strike or other equipment strike to conductor or two conductor come in contact or conductor fall in ground so the impedance becomes abruptly high so it can't detected by traditional protection. HIFs occur due to various causes such as humidity, voltage up and down, load condition. HIF harm the whole system and also endanger risk for human safety it is also important to detect these types of faults using algorithm [2].

Transmission line faults which are further classified as

A. Single Line-to-Ground faults (SLG)
B. Line-to-Line faults (LL)
C. Double Line-to-Ground (LLG)
D. Three Phase faults (LLL)
E. Three Phase-to-Ground faults (LLLG)[3]

Researchers have proposed many techniques for fault detection and classification. The conventional protection methods are based on the particular or limited measurement [4-6]. These methods are inadequate when there is large fault, in the perspective of the accuracy, reliability and quickness [7] The complexity and meddling of harmonics and transient must be necessary that our alternative weapon must rely on computational technique to counter the threat of complex type fault [8-10], conventional approaches show poor performance due to many factors involved such as fault resistance, noise, fault location, fault inception angle

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Fourier transform actually break down the signal into smaller frequencies of different sinusoids or break the signal into alternative sine wave or it can transform the signal from frequency base to time base or vice versa. This technique is very beneficial and simplified in nature if the signal is in the static condition. But this technique possess some limitation if we transform the signal from one domain to another domain or from frequency domain to time domain so time information is lost or in other words if the signal is non-stationary or transient it does not inform the accurate location q[11].

Dennis Gabor (1946) presents the idea of Short Time Fourier Transform (STFT) to predict only a small section of the signal at a particular time. To overcome the limitation of Fourier transform STFT prove more attractive and draw a signal into two dimensions of frequency as well as time, this is possible only a small portion of the signal being window. This technique will solve the problem of FT for some specific cases but there is still hurdle. Some of its drawbacks which are listed below, for the time window once you chose the specific size window that window is same for all the frequencies. Also short pulses can only poorly be localized in time with long window, low frequencies can hardly be illustrated with short window these limitations are in time-frequency resolution[12]. Due to all of these complications resulted the innovation of Wavelet Transform (WT) which emerge as a new technique which can solve the difficulties of FT and STFT, wavelet transform allow the use of long time intervals where we need more error-free low frequency data and smaller section where we need high-frequency data [13].

Another emergence technique is wavelet singular entropy (WSE).So finally demerits of all these techniques is that they are all rest on specified measurement and it's hard to find peak or heavy loading condition [14].

For feature extraction mostly method used are Fourier Transform (FT) and Wavelet Transform (WT). And further these feature extraction carried as input and classified by the most intelligence methods Artificial Neural Network (ANN) and Fuzzy Logic (FL) [15-17].

Exploiting some algorithms which generally well-regarded for fault detection and even we remind nowadays how could we forget ANN which stands fast and accurate and widely express [18-21].. Neuro-Fuzzy systems require massive numbers of training patterns in succeeding a valid relay function. And frequently retraining must be mandatory in different power systems[22]. It must be essential to adopts algorithm which can localize and classify fault in expert's way. Speed, accuracy, short time must be essential.

The rest of the paper is organized as follows. Section 2 describes the wavelet transform and probabilistic neural network. Section 3 discusses the proposed methodology. The results and discussion are provided in section 4. The conclusion of the paper is given in section 5.

II. PROPOSED METHODS

A. Transmission Line Model

The single line diagram of the proposed transmission line is shown in Fig.1. If the fault is occurred in the line, the variations occurred in the current and voltage waveforms. The transients are generated and the fault information is included in the transient component so it is necessary to predict the fault and analyze the reason of faults. It is necessary to detect fault with in short time and accurately. The change in values occurred in those phases in which fault is occurred. The changes may be large according to the type of fault so it will be easier to detect the fault and classify that type of faults. A 220kV, 50Hz and 100km transmission line is proposed. The values of resistance, inductance and capacitance and the values included with positive, negative and zero sequence component.

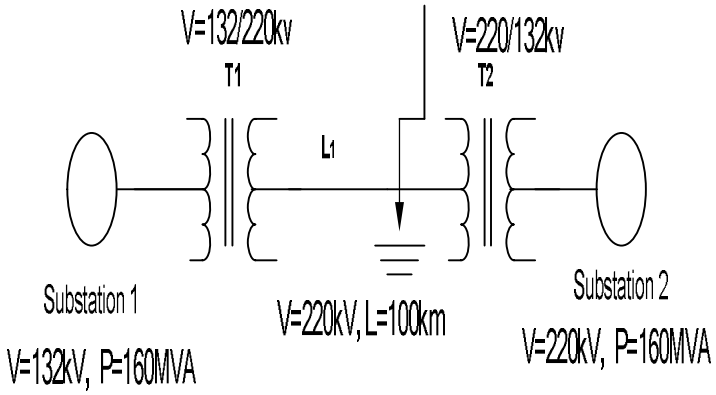

Fig. 1 Single line diagram

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B. Wavelet Transform

Signal mostly exist slowly change in trends or oscillation interrupted with transients. Fourier transform is an important technique for data calculation. Fourier Transform (FT) represents data in the sum of sine and cosine wave or breaking signal in smaller infinite sine wave. If there is stationary signal then FT performing best mostly in power system increasing usage of electronic devices these are the main creator of transient and harmonics. If there is non-stationary signal then in FT if the signal is in frequency domain the time information is lost and vice versa. So it's better to use those techniques which localize the signal in time and frequency domain accurately so innovation brings to the new topic of Wavelet Transform (WT).A wavelet is a small wave which has zero mean that are located the signal in different time and scale wavelet exhibits in time as well as frequency base. As compared to FT which exist in infinite period wavelet occur for finite period wavelet have many types that have different shapes and sizes some family of wavelet are described here

1) Morlet
2) Daubechies
3) Coiflets
4) Biorthogonal

To pick out the accurate wavelet family you need to look at the application, usage, suitability then carried that family forward. The wavelet equations which are shown as under. Continuous wavelet transform (CWT)

$$W_\Psi(a,b) = \frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} x(t)\Psi^*\left(\frac{t-b}{a}\right)dt \qquad (1.1)$$

Where $W_\Psi(a,b)$ are wavelet coefficients, a and b are scale and translation real parameters. Discrete wavelet transforms (DWT)

$$W_\Psi(m,n) = \frac{1}{\sqrt{a_0^m}}\sum_{k=-\infty}^{+\infty} x(k)\left(\frac{k - a_0^m nb_0}{a_0^m}\right) \qquad (1.2)$$

Where $a=a_0^m$, $b=a_0^m nb_0$, m and n are the integer numbers provided $a_0>1$ and $b_0\neq 0$.

Then further we have to be describe the wavelet working principle how wavelet work actually wavelet describe by two coefficients scaling and detail, the coefficient scaling refers to the process of expand or compress the signal with respect to time by using equation, A larger scale factor results in a expanse wavelet which relates to a lower frequency, An expanded or stretched wavelet helps in capturing the little bit altering changes in the signal. A smaller scale factor result in a compressed wavelet which relates to a high frequency and the compressed wavelet helps in catching the sudden alteration. We will build distant scales that inversely corresponds to the equivalent frequency, while shifting means delaying or progressing insert of the wavelet beside, the size of the signal, moved wavelet represent using this sign Ø(t-k) means to shift the wavelet and centered at k, we must shift the wavelet to combine with a feature that are necessary in a signal. Main Transforms in wavelet are Discrete Wavelet Transform (DWT) and Continuous Wavelet Transform (CWT).

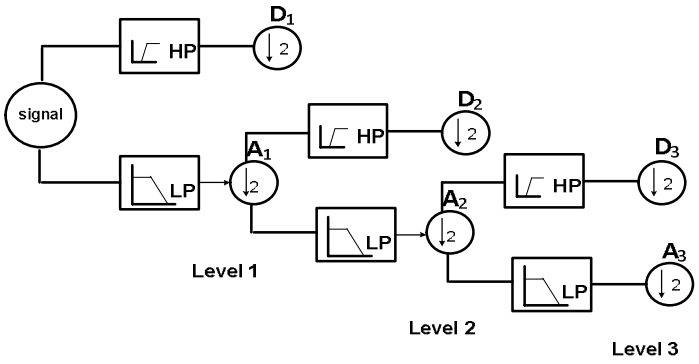

Fig. 2 Wavelet transform

C. Probabilistic Neural Networks

The term Artificial neural network (ANN) is inspired from the biological term Brain its operation principle may resemble with brain in some special condition but in real world Brain function is completely differ from the ANN it can't equated with brain but the idea which cause the development of ANN is triggered from the Brain. Let's took a shot to the brain. In Brain there is complex

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connection among the neurons of the brain, A neuron is the basis processing unit in a neural network, neuron inside the brain are connected through synaptic junction brain consist of 10 billion nerve cells or neurons, each neuron is connected to other neuron through about 10,000 synapses this may be an estimated figure but not an exact figure. The brain can be learnt from experience and also it performs massively parallel computations extremely efficiently for example if there is a huge database the brain work more easily and swiftly than computer or complex visual perception occur within less than 100 milliseconds while computer trying to recollect image it takes a long time, even we have the fast machine like Computers why do we need ANN, lets shed a light to comparison between Brain and Computer.

Table 1 Comparison between Brain and computer

	Processing Elements	Energy Use	Processing Speed	Learn
Brain	10^{14} synapses	30 Watt	100hz	Learn fastly
Computer	10^{8} transistor	30 Watt CPU	10^{8} hz	A little

Although it's clear that computer can solve the problems more speedy like Arithmetic calculation, multiplication, division and many other problems but when we talking about Intelligence operation likewise language understanding, pattern recognition, complex visual perception so once again Brain will solve within mille second and computer either fail or hardly solve these types of problem or take a long time for solving. So the learning process of brain is much faster than computer. Although from all of this discussion we understand some properties of the brain, during the last few centuries, scientists and researchers tried to develop an Artificial Neural Network (ANN) and it is observed that ANN is motivated by some features that exist in the brain, this ANN has three basic elements, nodes, weights and activation function.

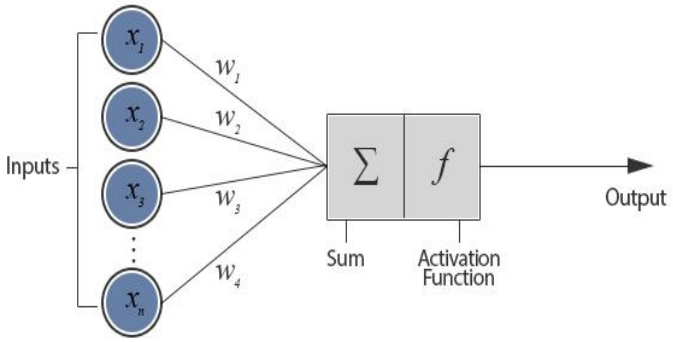

Fig. 3 ANN Activation Function

This figure show the input which are x_1, x_2, x_3 up to goes on to x_n and which are connected through weight w_1,w_2,w_3, and w_n and these weights are multiplied with the signal as they reach to the output signal, the output is simply the sum of the signals multiplied with the weights and then this output goes to an activation function.

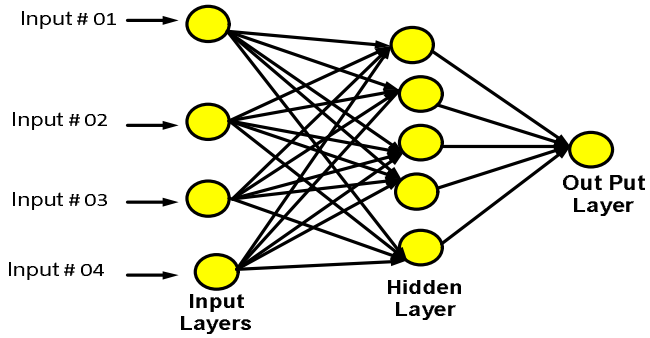

Fig. 4 Artificial Neural Network

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Table 2 Targets values for training of ANN

FAULT TYPE	A	B	C	G
A-G	0	0	0	1
B-G	0	0	1	0
C-G	0	0	1	1
A-B	0	1	0	0
B-C	0	1	1	0
A-C	0	1	1	1
AB-G	1	0	0	0
BC-G	1	0	1	0
AC-G	1	0	1	1
ABC	1	1	0	0
ABC-G	1	1	1	0

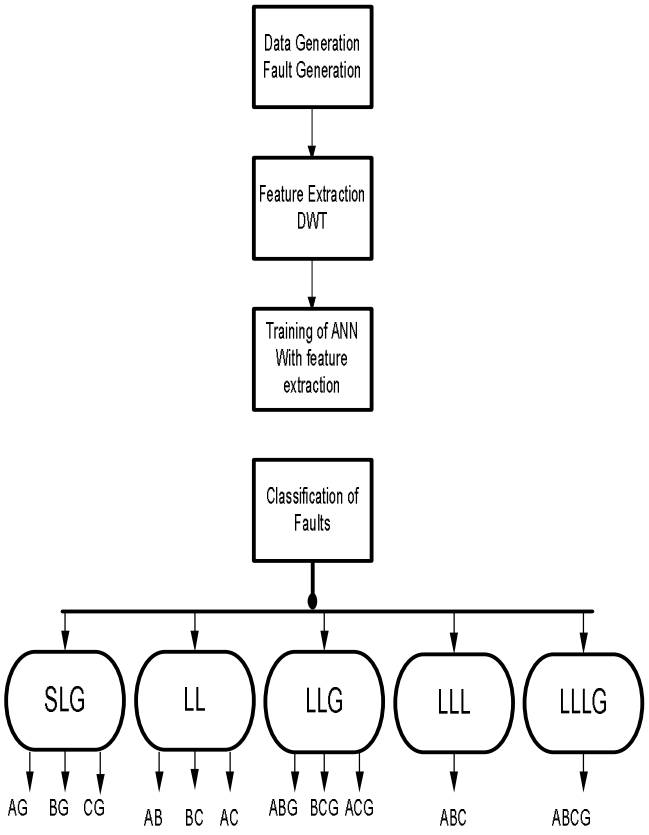

Fig. 5 Flow chart of the Proposed Methodology

III. METHODOLOGY

Single line diagram of power system is clearly represented in to figure 1. The system consist of two generators and transformer and the transmission line parameters can be illustrated as follows, Gird station of Hyderabad T M KHAN HYDERABAD with 220kv transmission line with two generator of 160MVA.

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Substation
Voltage: 132kv
Frequency: 50Hz
Power: 160MVA
X/R: 10
Transformer
Voltage: 132/220kv
: 220/132kv
Transmission line
Positive and negative sequence arrangement inductance per unit length= 0.00092974
Zero sequence arrangement inductance per unit length= 0.0032829
Positive and negative sequence arrangement capacitance per unit length =1.2571e-8
Zero sequence arrangements capacitance per unit length = 7.8555e-9
Positive as well as negative sequence arrangement resistance per unit length = 0.01809
Zero sequence arrangement resistance per unit length =0.2188
Load
Power: 100MVA
Power factor: 0.8

IV. SIMULATION RESULTS

To study various faults of transmission line, a transmission network is framed in MATLAB/Simulink (version 2008). DWT is used for fault detection or extraction when surges occur current will go abruptly high and voltage diminish so DWT used for detection purpose and ANN is used for classifying the faults. System has 2 substation of 160MVA, 132kv. These substation are combined with the power transformer of 132/220kv, 160MVA and also the series load is connected of 100MVA with leading power factor of 0.8 and transmission line has voltage of 220kv with a length of 100km the Results are shown in figures. Different types of faults that are occurred on the transmission lines are detect with use of DWT. Alternative types of faults As shown in figures simultaneously.

Fault types	AG	BG	CG	AB	BC	CA	ABG	BCG	CAG	ABC	Success (%)
AG	99	0	1	0	0	0	0	0	0	0	99
BG	1	97	0	2	0	0	0	0	0	0	97
CG	0	0	98	0	0	2	0	0	0	0	98
AB	0	1	0	98	0	0	1	0	0	0	98
BC	0	0	0	0	99	0	0	0	1	0	99
CA	0	0	0	0	2	97	0	0	0	1	97
ABG	0	0	0	2	0	0	98	0	0	0	98
BCG	0	0	0	0	0	0	0	99	0	0	99
CAG	0	1	0	1	0	1	0	0	97	0	97
ABC	0	0	0	0	1	0	0	0	0	99	99
Overall accuracy											98.1

Table 3: Test result for the proposed fault classification scheme using test samples

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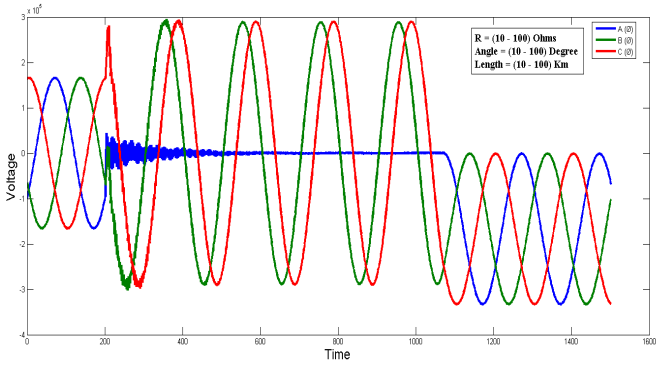

Fig. 6 Single Line-to-Ground Fault

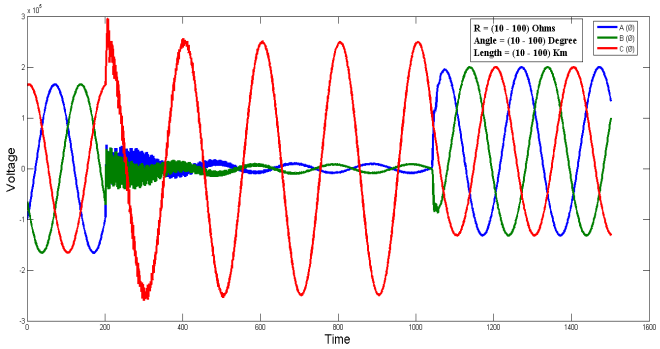

Fig. 7 Line-to-Line Fault

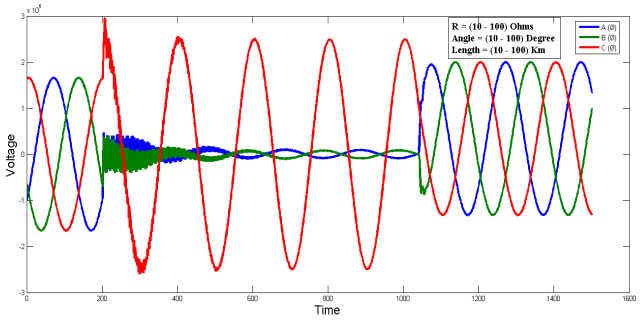

Fig. 8 Double-Phase-Ground Fault

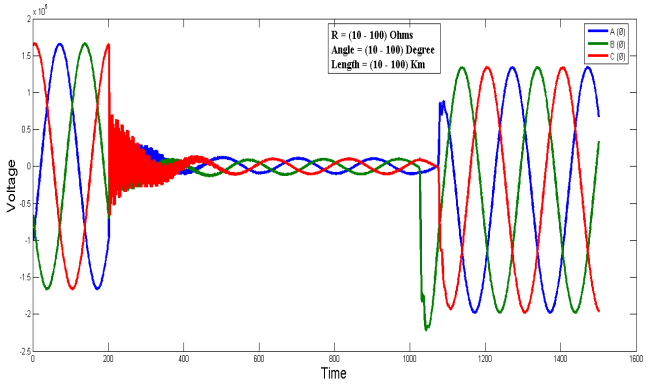

Fig. 9 Three-phase Faults

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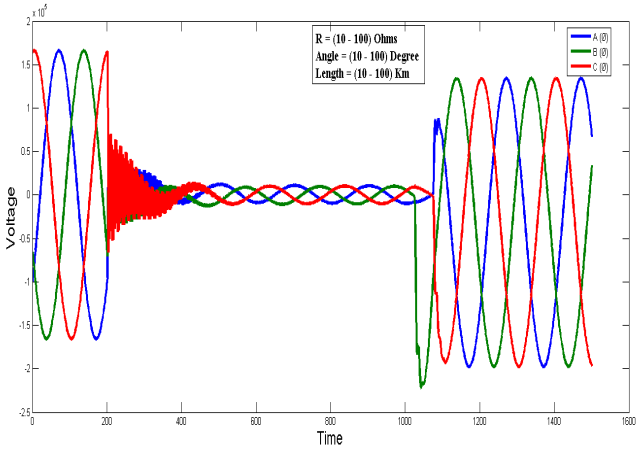

Fig. 10 Three-phase-Ground Fault

These simulation results are helpful for designing protection of transmission network especially in Pakistan.

Tab. 4 Results of fault classification for various fault types

Fault type	A	B	C
AG	8.793074	2.412454	1.781219
BG	2.241024	2.400959	2.972748
CG	2.746005	1.423488	3.324033
AB	4.067775	1.708913	2.136151
BC	3.139409	1.03598	3.015802
AC	3.945093	0.662414	2.750042
ABG	4.067775	1.708913	2.136151
BCG	2.166244	1.200211	3.426883
ACG	3.887197	0.315019	3.120889
ABC	3.787845	1.391539	3.150422
ABCG	3.787845	1.391539	3.150422

V. CONCLUSION

The adopted algorithm used the digitized samples of current signals (Ia, Ib, Ic), which are obtained using digital relay. Using wavelet toolbox the DWT is used for feature extraction of signals which are in the form of indices (A, B, C). which are shown in Tab. 4, All of these indices of 11 types of faults are further given as input to ANN, so the next step is to compare the indices of no fault which is at normal condition to abnormal condition which is at the occurrence of fault. If the values of indices at abnormal condition or occurrence of fault exceed to normal condition or no fault condition, then the whole process is taken to the next level which is classification of faults. For classification the coding of ANN is proposed which is shown in Tab. 2 according to the types of faults, ANN is being trained and classifies the fault accurately. To classify transmission line faults which are as SLG, LL, and LLG etc. The joint approach of DWT and ANN is used to classify faults. The approximation of this method is that it can accurately detect the fault and classify as fast as possible, the efficiency reliability and accuracy of this method is high. After shedding the light to the Results so consequence of this method is that Automatically detection of fault implementing DWT for feature extraction and choosing ANN for classification clearly explain that this technique accurately detect the fault and analyze as fast as possible. So if

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we implement this method as comparing to other traditional method which are ambivalent to fault classification. It will beneficial in the form of life saving of equipment and cost reduction. This method is more economical.

VI. AKNOWLEDGEMENT

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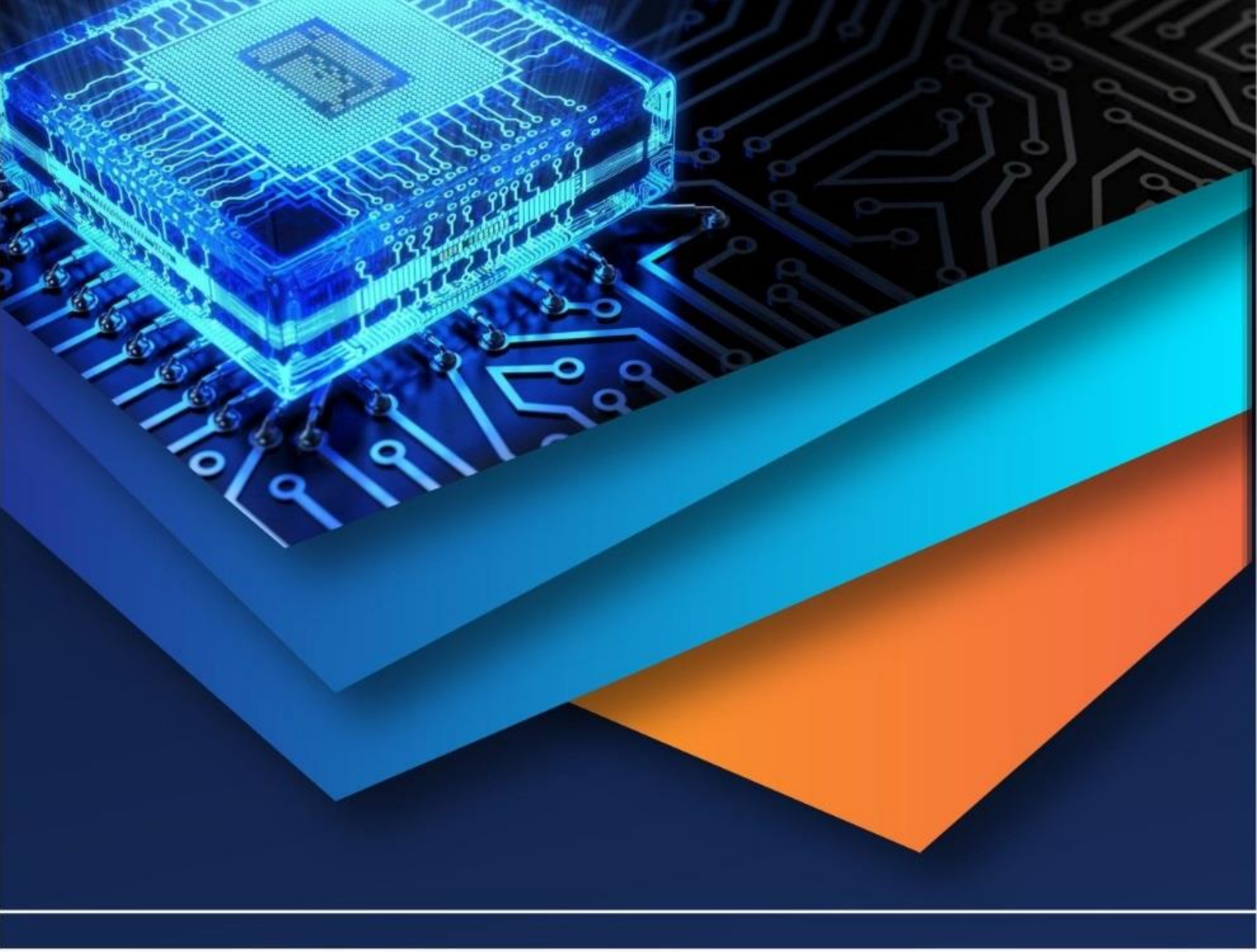

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