IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

THREE PHASE INDUCTION MOTOR FAULT DIAGNOSIS USING WAVELET & ANN

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Abstract: The efficient operation of three-phase induction motors is crucial for various industrial applications. However, the occurrence of faults can lead to unexpected downtime and costly repairs. This project proposes a novel approach for fault diagnosis in three-phase induction motors by integrating wavelet analysis and artificial neural networks (ANN).

Wavelet analysis is employed for feature extraction from motor current signals, allowing for the detection of subtle changes indicative of different fault types. The extracted features are then fed into an ANN model, trained to classify various fault conditions accurately.

The effectiveness of the proposed methodology is demonstrated through simulation data of three phase induction motor under different fault scenarios. Results indicate that the combined approach of wavelet analysis and ANN yields high accuracy in fault detection and classification, enabling proactive maintenance and minimizing downtime in industrial systems.

This project contributes to advancing the field of condition monitoring and predictive maintenance for three-phase induction motors, offering a robust solution for early fault detection and diagnosis, thereby enhancing reliability and efficiency in industrial operations.

Keywords:- ANN, Three phase Induction Motor, Quality Disturbances, Wavelet Transform ,Faults etc.

I. INTRODUCTION

Three-phase induction motors are ubiquitous in industrial applications due to their reliability, simplicity, and cost-effectiveness. However, the occurrence of faults in these motors can lead to significant downtime, production losses, and maintenance expenses. Timely detection and diagnosis of faults are crucial for ensuring uninterrupted operation and maximizing productivity.

Traditional methods of fault diagnosis in induction motors often rely on manual inspection or rudimentary techniques, which may not be sufficiently sensitive to detect incipient faults or provide accurate diagnostics. As a result, there is a growing need for advanced and automated fault diagnosis techniques that can detect faults early and precisely identify their nature.

In recent years, the integration of signal processing techniques with machine learning algorithms has emerged as a promising approach for fault diagnosis in electrical systems. Among these techniques, wavelet analysis has gained popularity for its ability to extract meaningful features from non-stationary signals, such as motor current signals, which are indicative of underlying fault conditions.

Additionally, artificial neural networks (ANNs) have shown remarkable capability in learning complex patterns and relationships from data, making them well-suited for classification tasks in fault diagnosis applications.

This project aims to leverage the complementary strengths of wavelet analysis and ANN to develop a robust and accurate fault diagnosis system for three-phase induction motors. By analyzing motor current signals using wavelet transforms and employing ANN models for fault classification, the proposed approach offers the potential for early detection and precise identification of various fault types.

Through simulation data of three phase induction motor, this project seeks to demonstrate the effectiveness of the proposed methodology in detecting and diagnosing faults in three-phase induction motors. Ultimately, the development of an advanced fault diagnosis system holds the promise of improving the reliability, efficiency, and maintenance practices of industrial motor-driven systems.

II. PROBLEM STATEMENTS

The report aims to develop a fault diagnosis system for three-phase induction motors using wavelet analysis and artificial neural networks (ANNs). The goal is to improve the reliability and efficiency of fault detection and classification, thereby minimizing downtime and maintenance costs in industrial applications.

III. WAVELET TRANSFORM

Wavelet analysis is a powerful mathematical tool used for analyzing signals in both time and frequency domains simultaneously. Unlike traditional Fourier analysis, which represents a signal as a sum of sinusoids of different frequencies, wavelet analysis employs wavelets, which are small wave-like functions localized in both time and frequency. This localization property makes wavelets particularly adept at capturing both short-duration transient features and long-duration trends in signals Mathematical transformations are applied to signals to obtain further information from that signal that is not readily available in the raw signal. The number of transformations is available which can be applied, among which the wavelet transform is most popular. When the time localization of the frequency components are required, a transform giving the time frequency representation of the signal is needed i.e. the Wavelet Transform. Wavelet Transform is capable of providing the time and frequency information simultaneously, hence giving a time frequency representation of the signal. In case of Wavelet Transform, higher frequencies are better resolved in time and lower frequencies are better resolved in frequency. This means that, a certain high frequency component can be located better in time. On the contrary, low frequency components can be located better in frequency compared to high frequency components. The frequency and time information of a signal at some certain point in the time frequency plane cannot be known i.e. we cannot know, what frequency components exists at any given time instead, we can investigate what frequency components exists at any given interval of time. This is a problem of resolution and it is the main reason why researchers have switched to wavelet transform.

IV. ARTIFICAL NEURAL NETWORK

ANN is defined as a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs. An Artificial Neural Network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. Why would be necessary the implementation of artificial neural networks? Although computing these days is truly advanced, there are certain tasks that a program made for a common microprocessor is unable to perform; even so a software implementation of a neural network can be made with their advantages and disadvantages.

V. METHODOLOGY

In this work the three phase 3HP, 440V, 50Hz, 1440 RPM Squirrel Cage Induction Motor under study is simulated using the MATLAB Simulink environment. Total five cases are simulated namely normal case, overload case, single phasing case, phase reversal and unbalance voltage case. The phase voltages and stator currents are captured from the simulation to create the dataset for further analysis. Figure 1 shows the flowchart of the first algorithm developed for detecting the occurrence of fault/abnormal conditions. Once the occurrence of fault/abnormal condition is detected then the second algorithm will classify the exact type/cause of fault/abnormal condition. Figure 2 shows the flowchart of second algorithm developed for classifying the type/cause of fault/abnormal condition.

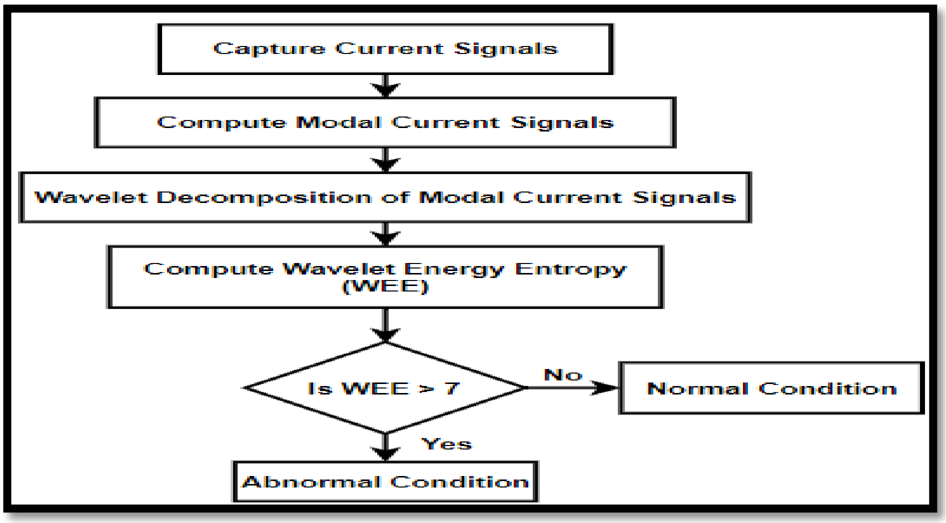

Figure 1:- Flowchart of Three Phase Induction Motor Fault Detection Algorithm

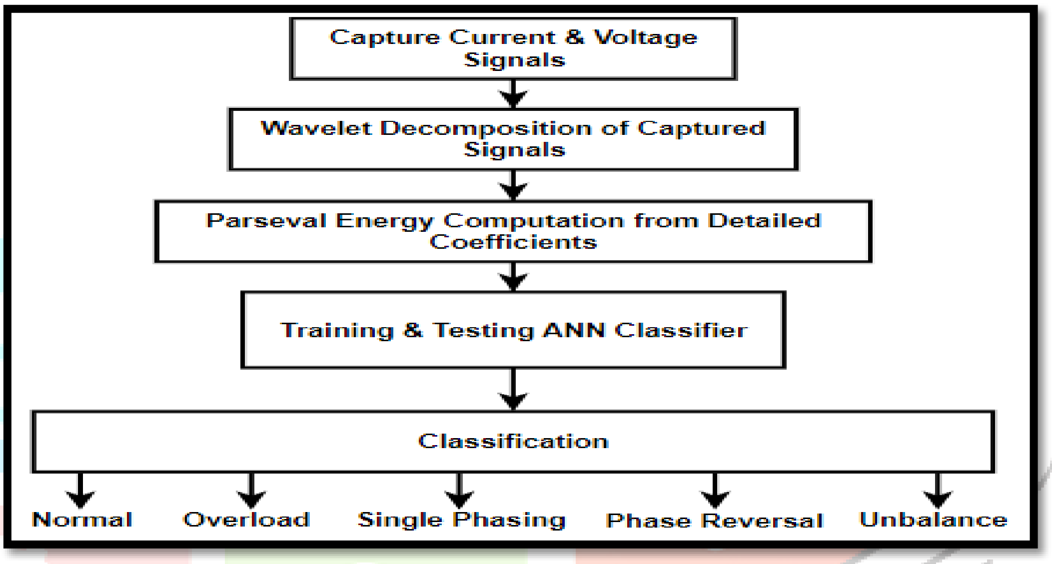

Figure 2:- Flowchart of Three Phase Induction Motor Fault Classification Algorithm

VI. SIMULATION MODELS OF THREE PHASE INDUCTION MOTOR

In this work the 3 phase, 3 HP, 440 Volts, 50 Hz, 1440 RPM squirrel cage induction motor is used for staging different faults on the motor. This motor is simulated in MATLAB Simulink environment. In the simulation we have created different cases on induction motor namely normal case, overload case, single phasing case, phase reversal and unbalance voltage case. The normal and various fault/abnormal simulation cases of induction motor are described below.

CASE 1: Simulation Model of Induction Motor for Normal Condition

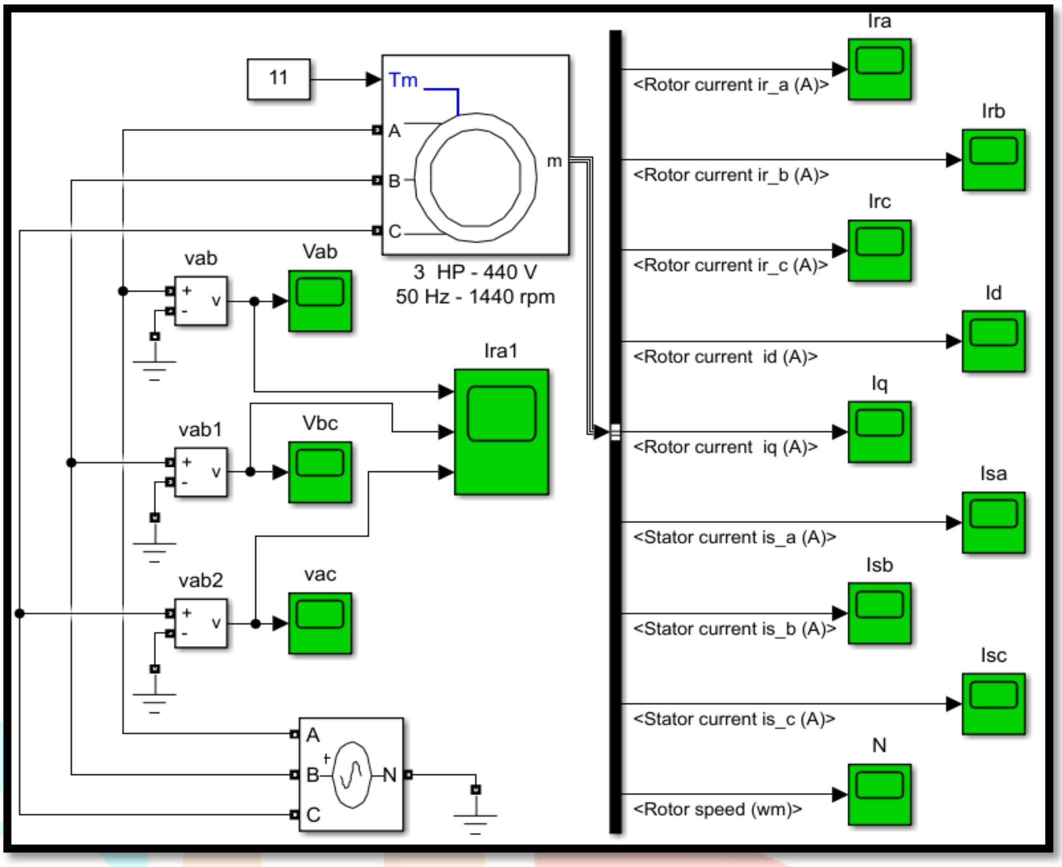

Figure 3:- Simulation model of Induction motor for Normal condition

Similar to normal condition we have created simulation model for overload case, single phasing case, phase reversal and unbalance voltage cases..

VII. SIMULATION RESULT OF ALL CASES

Simulation Result of Normal Condition:-

In this case the induction motor under study is working in its normal condition with a supply voltage of 440V and stator current drawn from the source is 8A. Figure 4 shows the waveform of three phase instantaneous voltage applied to the induction motor operating in its normal state. Figure 5 shows the waveform ofthree phase instantaneous stator current when the motor is operating under normal condition. In this waveform the magnitude of current is initially high due to inrush and latter on the magnitude of current is steady which indicates the normal rated current of motor under the operating condition.

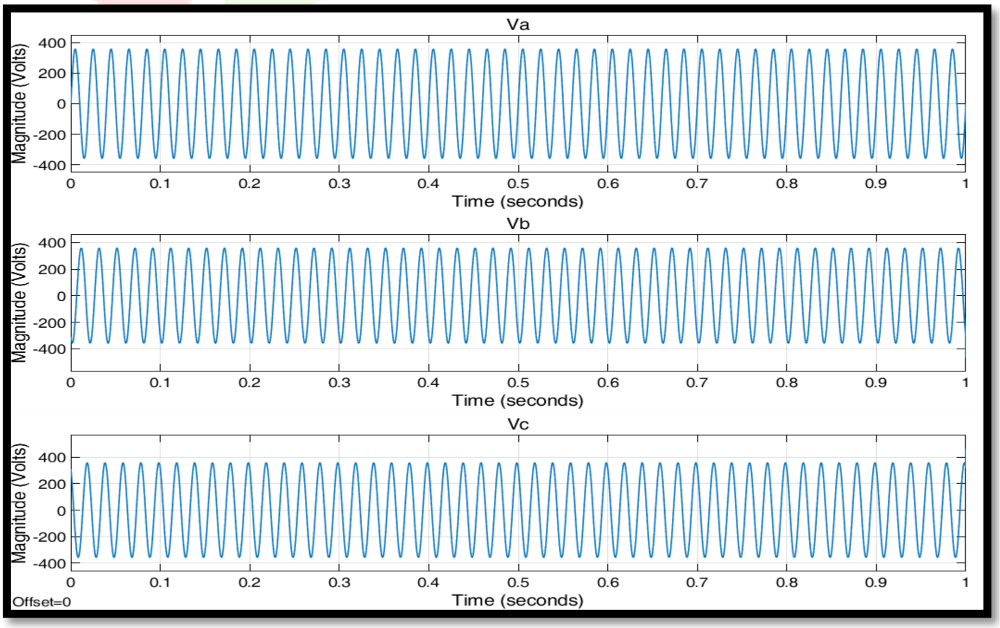

Figure 4:- Waveform of Three Phase Voltage Applied to IM under Normal Condition

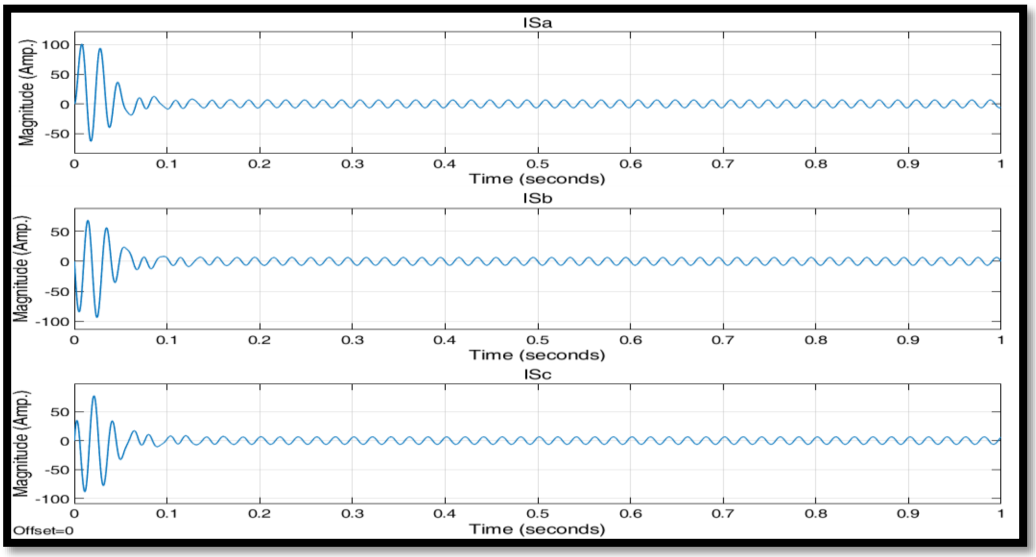

Figure 5:- Waveform of Induction Motor Stator Current under Normal Condition

Simulation Result of Overload Condition:-

In this case the induction motor under study is working under overload condition with a supply voltage of 440V and stator current drawn from the source is 12A. Figure 6 shows the waveform of three phase instantaneous voltage applied to the induction motor operating in overload state. Figure 7 shows the waveform of three phase instantaneous stator current when the motor is operating under overload condition. In this waveform the magnitude of current is initially high due to inrush and latter on the magnitude of current is steady at 12Awhich indicates the overload current of motor under the operating condition. Under overload condition the current drawn by the motor is more than normal rated current. The magnitude of current is initially high due to inrush.

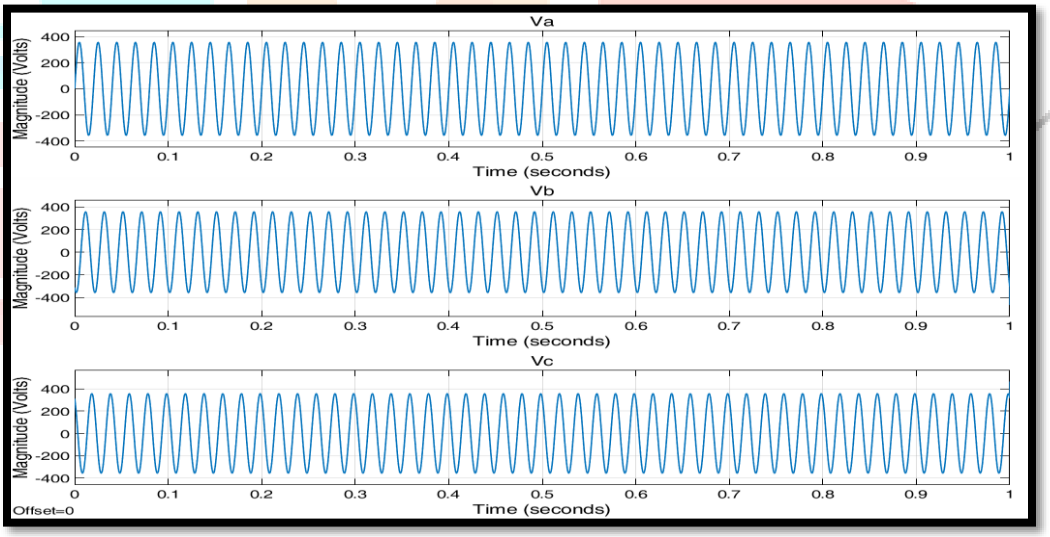

Figure 6:-Waveform of Three Phase Voltage Applied to IM under Overload Condition

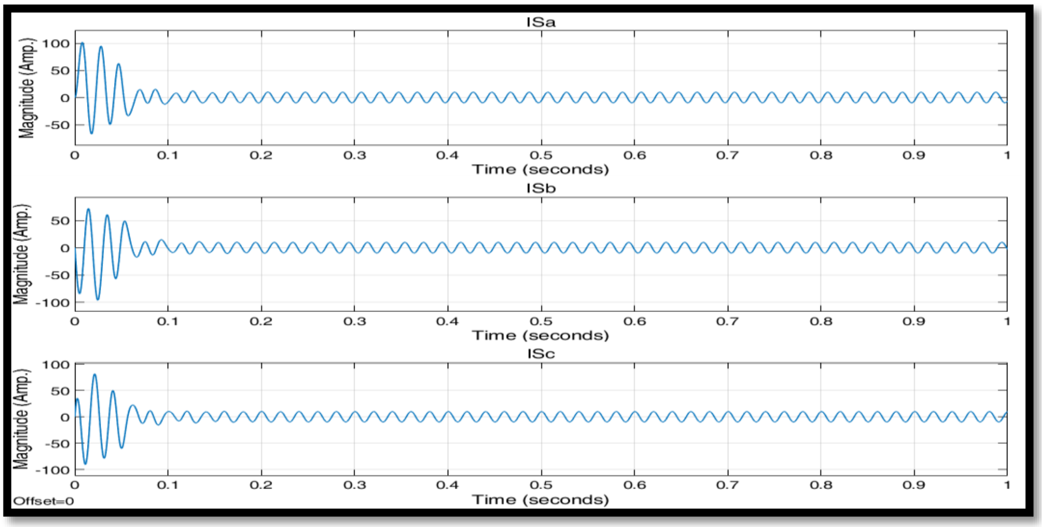

Figure 7:- Waveform of Induction Motor Stator Current under Overload Condition

Simulation Result of Single Phasing

In this case the induction motor under study is initially working under normal condition with a supply voltage of 440V and stator current drawn from the source is 8A later on a single phasing is created by opening the phase A at 0.4 seconds. During single phasing the phase A is open circuited and the load is carried by the other two healthy phases. As the load on the other two phases increases, the current of those two phases will rise to 13.75A and the current of the phase on which single phasing occurred will get down to 0A. The results of single phasing are shown in figure 8 and 9. The magnitude of current is initially high due to inrush.

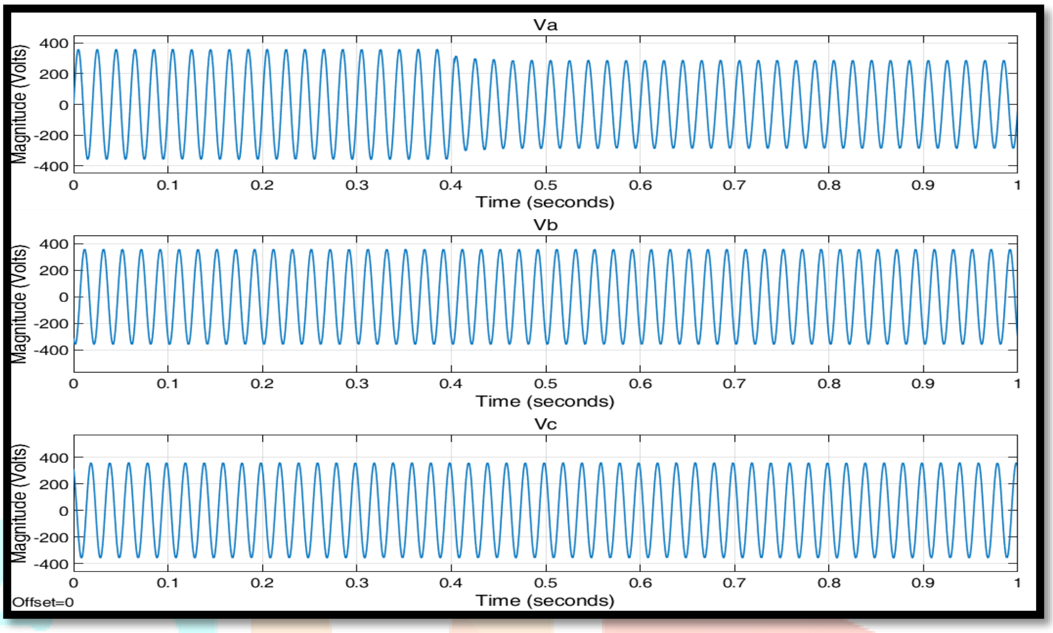

Figure 8:- Waveform of Three Phase Voltage under Single Phasing Condition

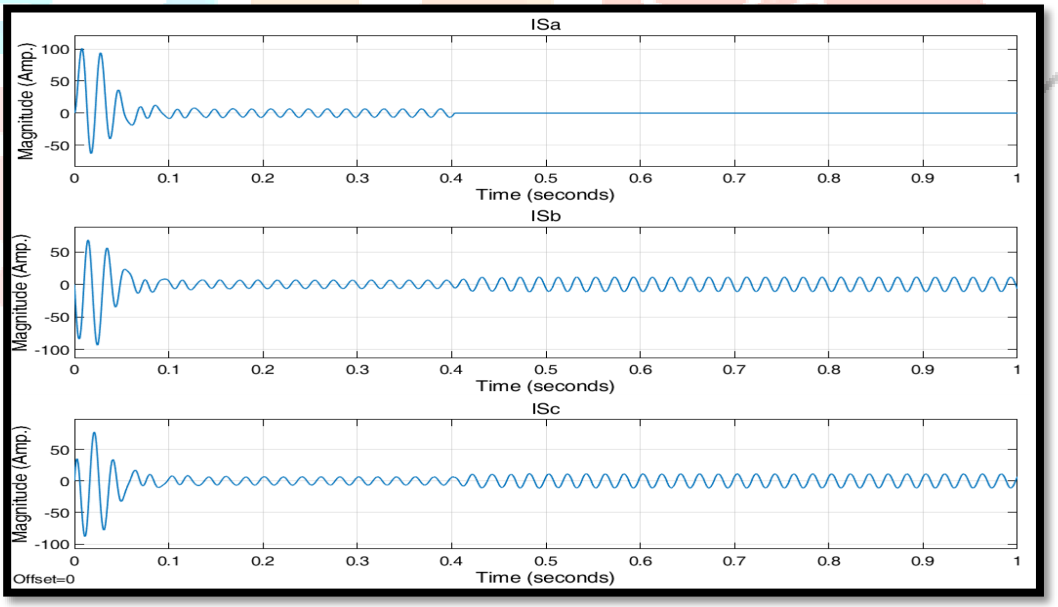

Figure 9:- Waveform of Induction Motor Stator Current under Single Phasing Condition

Simulation Result of Phase Reversal

In this case the induction motor under study is initially running in clockwise direction with the supply phase sequence ABC, at t=0.4 second the supply phase sequence is reversed to BAC then motor starts rotating in anticlockwise direction again at t=0.8 seconds the phase sequence is restored to ABC. Due to the phase reversal the transients are obtained in both voltage and current signals at the instant of changeover which is shown in figure 10 and 11.The magnitude of current is initially high due to inrush.

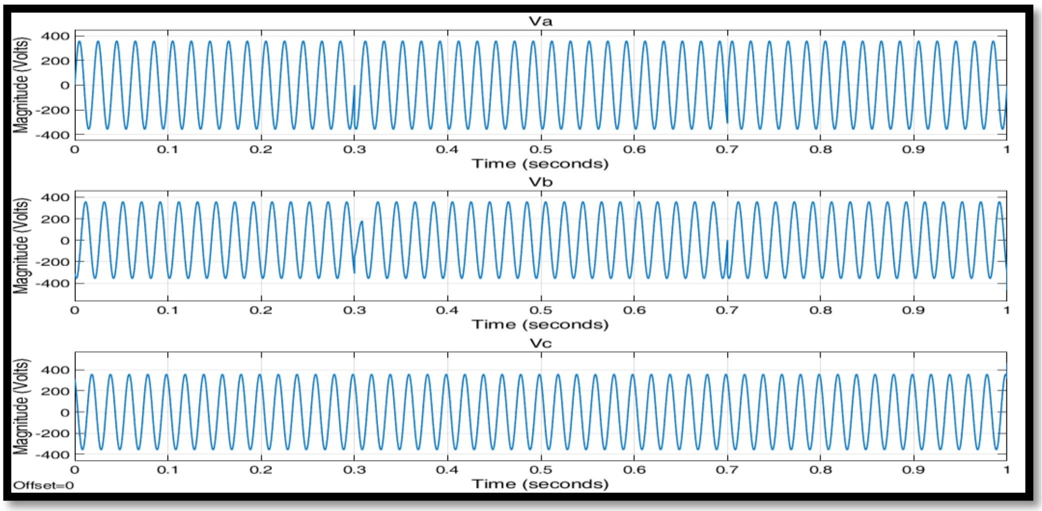

Figure 10:- Waveform of Three Phase Voltage under Phase Reversal Condition

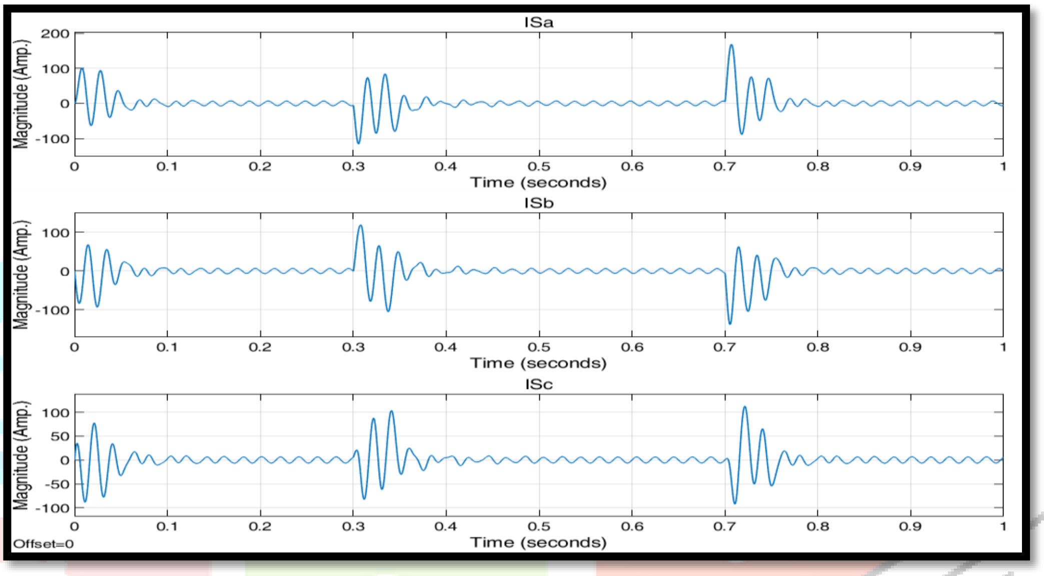

Figure 11:- Waveform of Induction Motor Stator Current under Phase Reversal Condition

Simulation Result of Unbalance Supply Voltage

In this case the induction motor under study is fed with unbalance supply voltage where the magnitude of voltage varies from 330V to 520V. Figure 12 shows the waveform of three phase instantaneous voltage applied to the induction motor operating on unbalance voltage. Figure 13 shows the waveform of three phase instantaneous stator current when the motor is operating on unbalance supply voltage. The magnitude of current is initially high due to inrush.

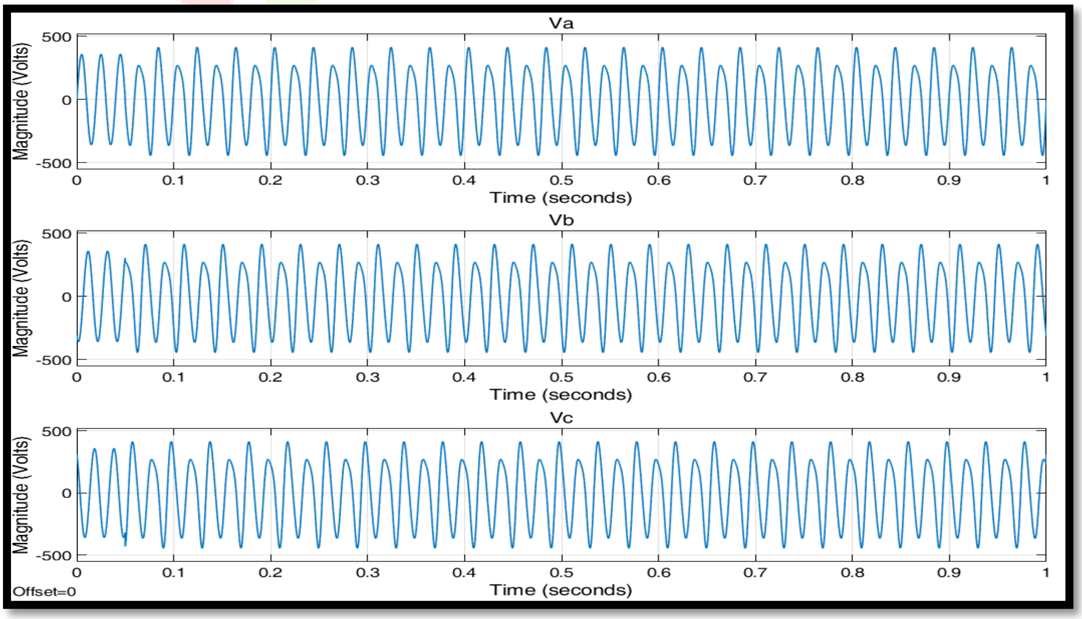

Figure 12:- Waveform of Three Phase Voltage under Voltage Unbalance Condition

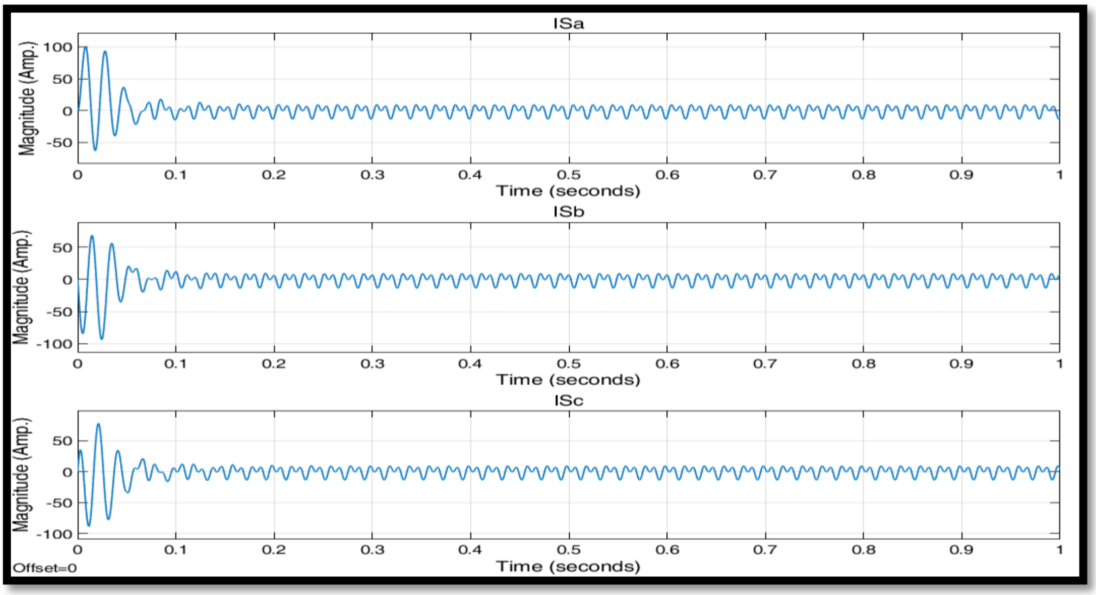

Figure 13:-Waveform of IM Stator Current under Voltage Unbalance Condition

VIII. Results of Wavelet Analysis for Stator Current Signals

The current and voltage signals thus obtained from the simulation are in time domain, these signals are transformed in frequency domain using Wavelet transform. In this project work we have used Db4 wavelet as a mother wavelet since it has many advantages over other wavelet in fault analysis. Based on sampling rate of 10kHz, the current signals are decomposed into approximate and detail coefficient up to six levels. The wavelet energy entropy is computed from the detail coefficients as a feature for detection and classification of induction motor faults. Figure 14 shows the wavelet decomposition of stator current signal of induction motor using db4 wavelet up to six levels.

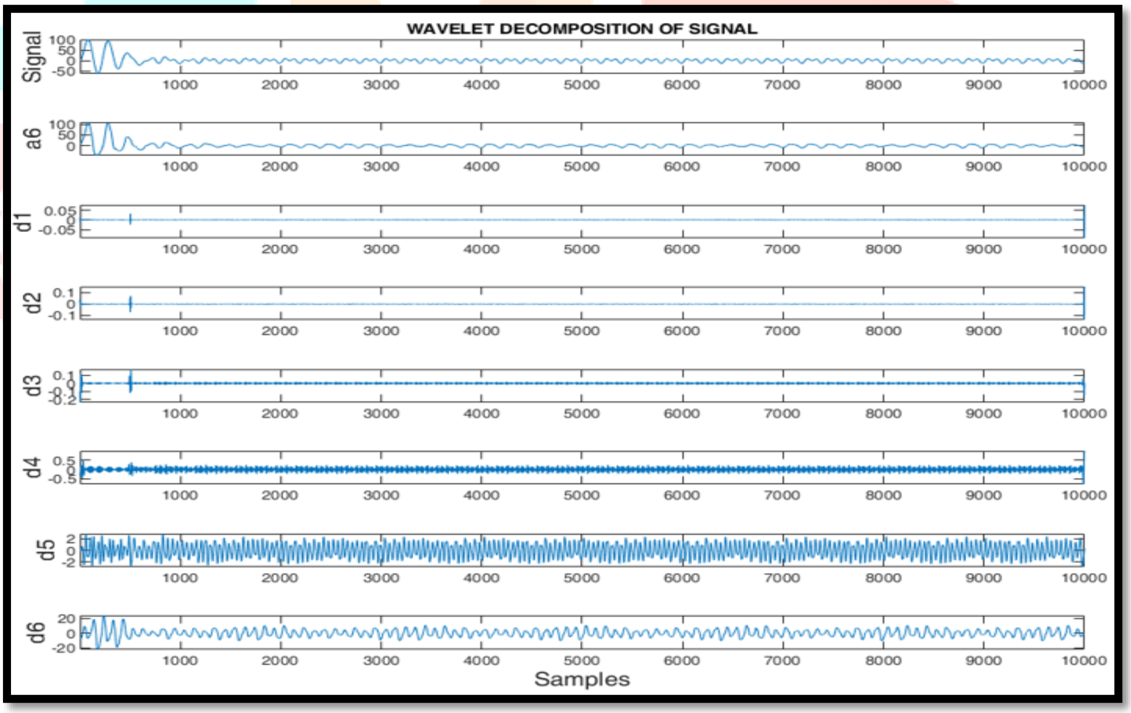

Figure 14:- Wavelet Decomposition of Stator Current Signal of Induction Motor

IX. Results of Induction Motor Fault Detection Algorithm

In this algorithm the wavelet energy entropy is computed from the wavelet analysis of current signals. Figure 15 shows the comparative bar graph of wavelet energy entropy values corresponds to normal and abnormal cases. It is clear from the figure that the value of wavelet energy entropy corresponding to normal operating condition is below 7 and that of other abnormal/fault conditions is above 7. Therefore, we have set the threshold value of 7 in the algorithm. If the wavelet energy entropy value corresponds to the current signal is below 7 then the detection algorithm will show "NO FAULT DETECTED" i.e. "NORMAL CONDITION" else it will show "FAULT DETECTED" i.e. "ABNORMAL CONDITION". These results of fault detection algorithm are shown in figure 16.

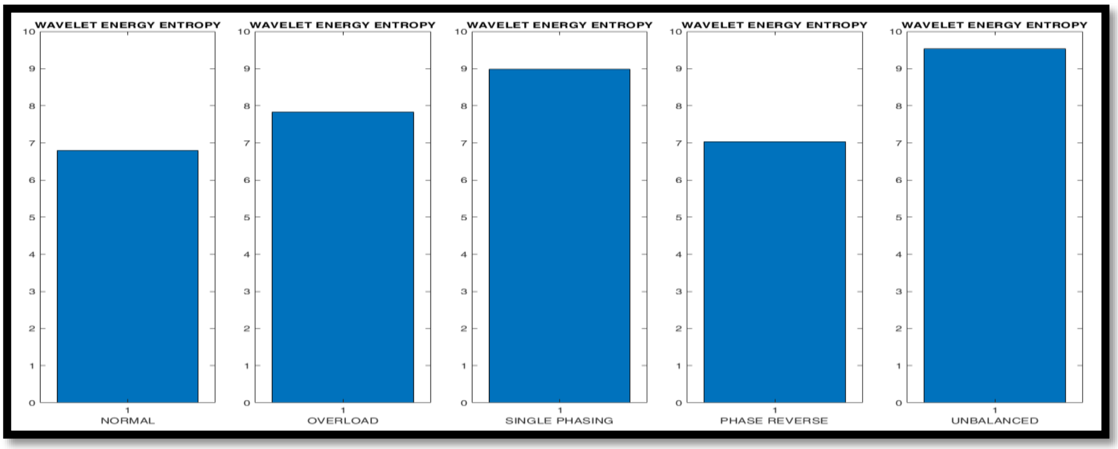

Figure 15:- Wavelet Energy Entropy Bar Graph

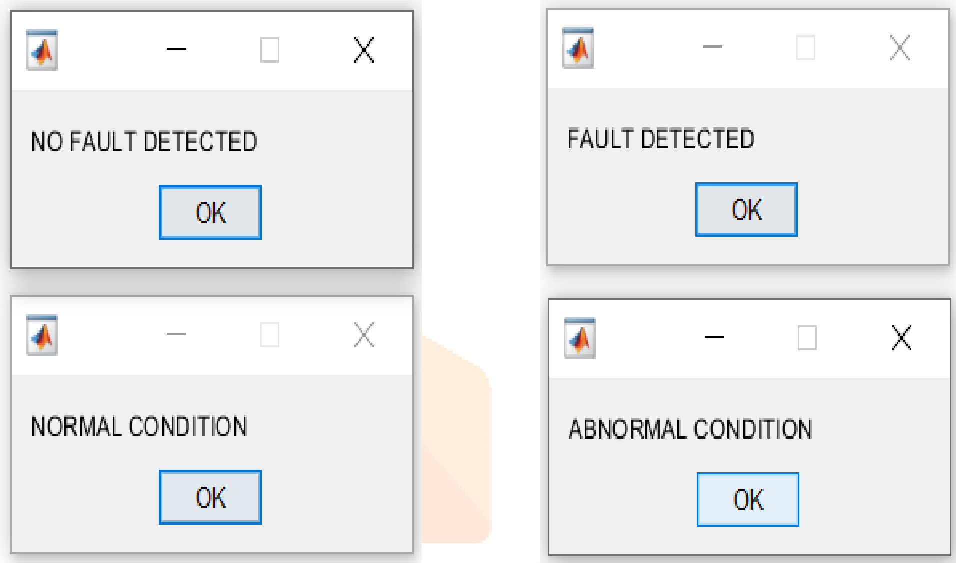

Figure 16:- Results of Fault Detection Algorithm

X. Results of Induction Motor Fault Classification Algorithm

ANN is used to classify the faults occurring in the induction motor. Table 1 shows the ANN architecture and figure 17 shows the ANN network configuration. A feature vector of features extracted from the wavelet analysis of current signal is created. This dataset is used to train and test the classifier. The performance of ANN classifier is represented in the form of confusion matrix. In confusion matrix each column represents the instances in a predicted class while each row represents the instances in an actual class. The diagonal elements represent correctly classified instances while the off-diagonal elements represent misclassified instances. In the first case 60% data is used for training purpose and 40% data is used for testing purpose. Figure 18 shows the training confusion matrix, figure 19 shows the testing confusion matrix and figure 20 shows the overall confusion matrix corresponding to first case. The overall accuracy for this case is 93.30%.

Table 1:- ANN Architecture

Number of Input	6
Number of Output	5
Number of Hidden Layers	2
Network	Multi-Layer Perceptron
Transfer function	Sigmoid Axon
Learning rule	Levenberg Marquard
Training Data	60% / 80%
Testing Data	40% / 20%
Max Epoch	1000

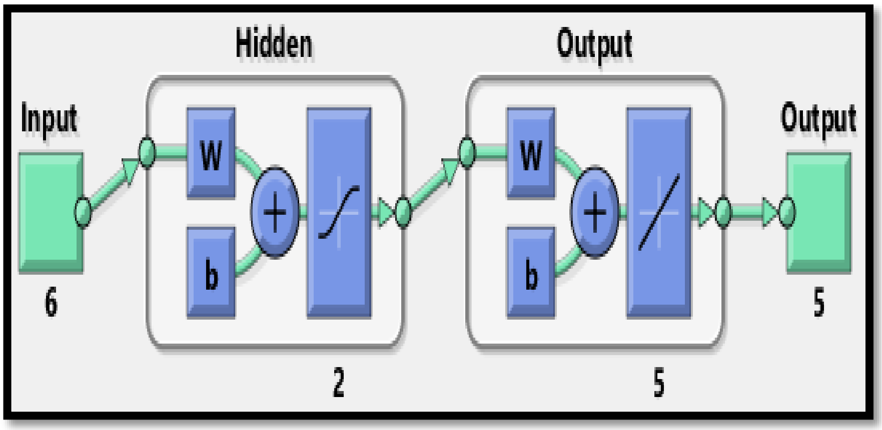

Figure 17:- ANN Network Configuration

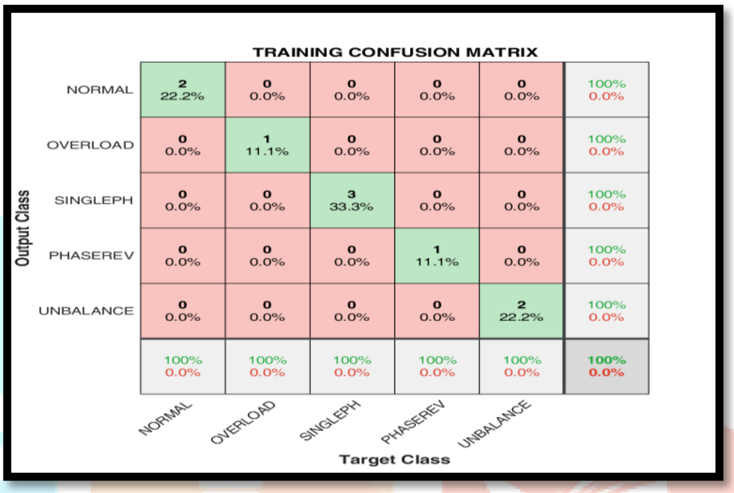

Figure 18 :- Training Confusion Matrix for First Case

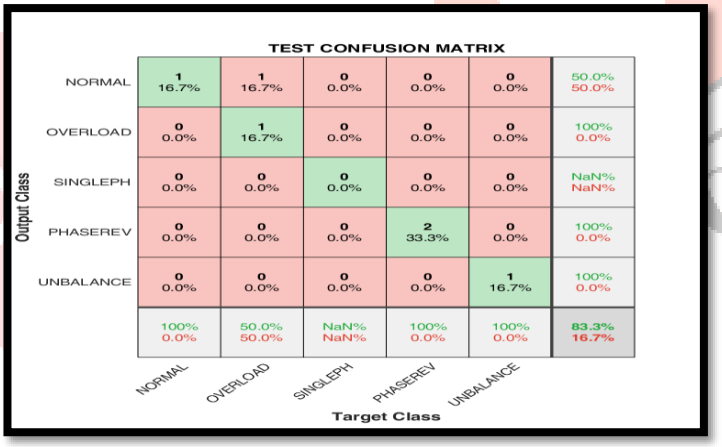

Figure 19:- Test Confusion Matrix for First Case

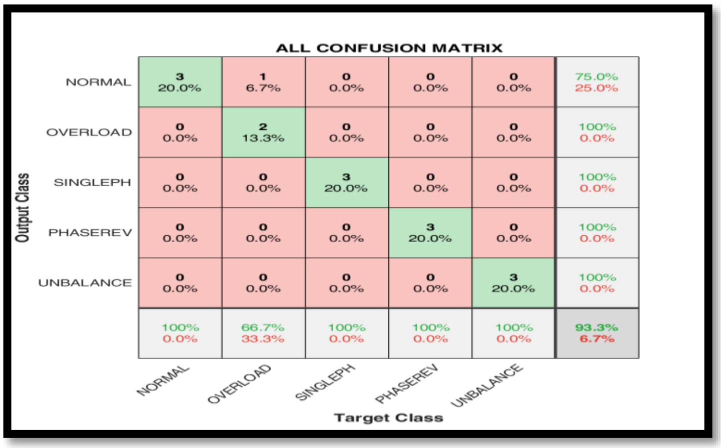

Figure 20:- All Confusion Matrix for First Case

In the second case 80% data is used for training purpose and 20% data is used for testing purpose. Figure 21 shows the training confusion matrix, figure 22 shows the testing confusion matrix and figure 23 shows the overall confusion matrix corresponding to first case. The overall accuracy for this case is 100%.

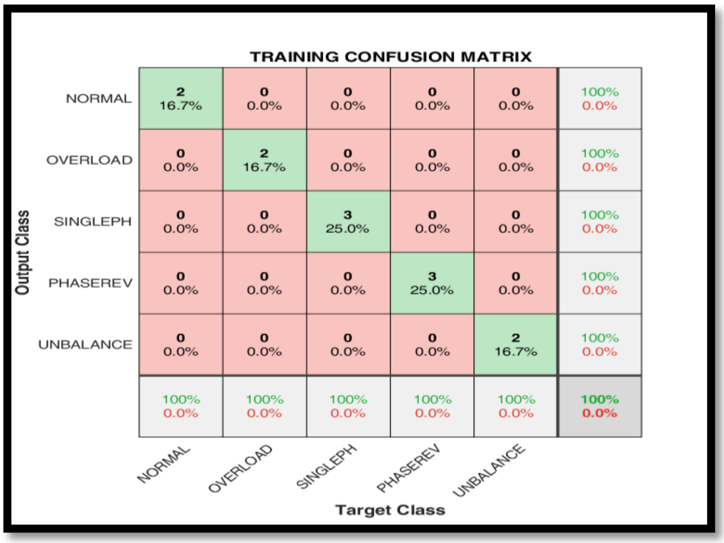

Figure 21:- Training Confusion Matrix for Second Case

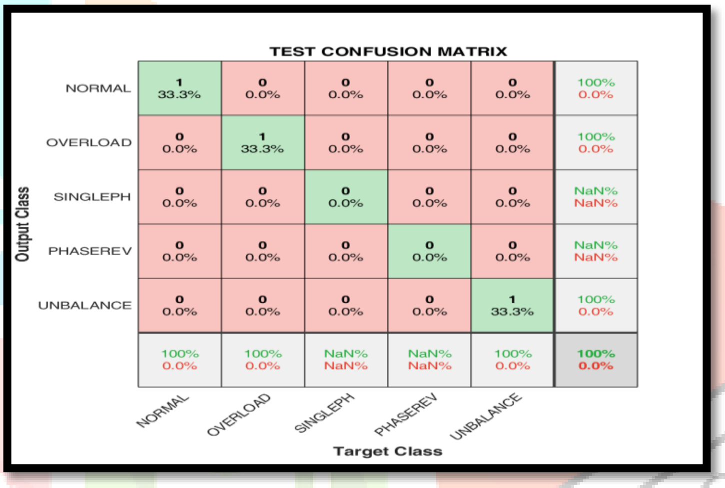

Figure 22:- Test Confusion Matrix for Second Case

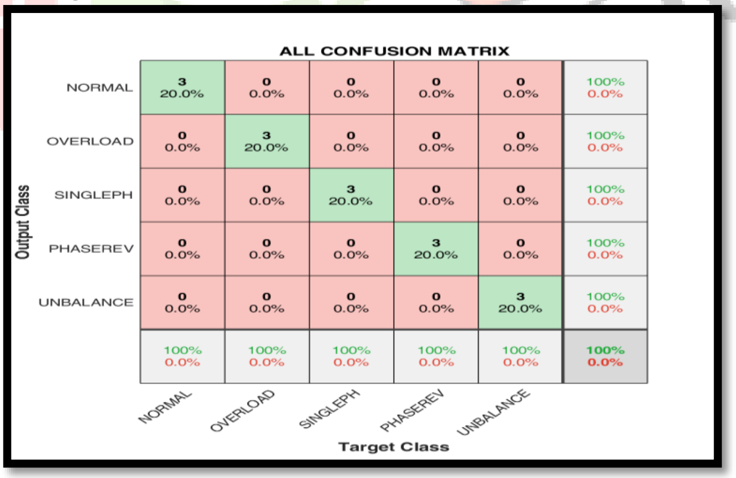

Figure 23:- All Confusion Matrix for Second Case

XI. Conclusion

In conclusion, the development of a fault diagnosis system for three-phase induction motors using Wavelet Analysis and Artificial Neural Network has shown promising results in enhancing the reliability and efficiency of fault detection and classification. By leveraging the complementary strengths of wavelet analysis for feature extraction and ANNs for fault classification, the project has achieved its aim of improving the accuracy and effectiveness of motor fault diagnosis.

The developed system has demonstrated its ability to accurately detect and classify various fault types, enabling proactive maintenance strategies to minimize downtime and optimize operational efficiency.

The integration of advanced signal processing techniques with artificial intelligence has enabled early fault detection and precise identification of fault conditions. The results discussed in this report clearly shows that the first algorithm effectively detects the occurrence of abnormal condition. Once the occurrence of abnormal condition is detected the second algorithm classifies the type of fault/disturbance with 100% accuracy.

In summary, the project outcomes contribute to advancing the field of motor fault diagnosis, offering a robust solution for enhancing operational resilience and minimizing downtime. As the demand for reliable and efficient fault diagnosis systems continues to grow, the developed methodology serves as a valuable tool for improving the performance of three-phase induction motors.

XII. Future Scope

The future scope of the project "Three Phase Induction Motor Fault Diagnosis Using Wavelet & ANN" includes:

- Deployed the algorithm in embedded systems for real-time fault diagnosis.
- Conducting field trials and validation studies in collaboration with industries.
- Further refinement of the fault diagnosis models to ensuring reliable performance across diverse operatingconditions.

By pursuing these future directions, the project aims to advance the state-of-the-art in induction motor fault diagnosis.

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