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Condition Monitoring of Three Phase Induction Motor using Current Signature Analysis

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Abstract: In this paper we are going to see how Gabor transform is used to analyze the signal and to determine the inner and outer race of bearing faults by monitoring the condition of Induction motor using Motor Current Signature Analysis.
Among the various faults bearing faults is the major problem, which cause a huge damage to induction motor, when unnoticed at developing stage. So, monitoring of bearing faults is very important and it can done by several conditions monitoring methods like thermal monitoring, vibration monitoring and more but these methods require expensive sensors or specified tools, whereas current monitoring methods doesn't require any additional tools. Usually, this condition monitoring is used to detect the various faults like bearing faults, load faults by MCSA. If the fault is present in the motor, the frequency spectrum of the line current is different from healthy ones, the Gabor analysis detects the fault signature generated in the induction motor, by using mathematical expressions and calculate the RMS and Standard deviation values, these fault values are different from healthy ones. Through this we can identify faults.
Keywords: Gabor transform, Motor Current Signature Analysis (MCSA), Condition Monitoring, Inner race, Outer race.

I. INTRODUCTION

Industries play a vital role in any country in terms of that economy and it offers a wide variety of opportunities for people with and without technical skills. So, Industries should work every minute without any disturbances then only the efficiency of its production, energy and time increases. We should properly maintain the industrial equipment as much as possible.

Now-a-days, the use of induction motor in industries is increased a lot because of its wide variety of features like
1) Available in different sizes
2) Simple in construction
3) Requires less maintenance
4) Robust in nature
5) Low cost
6) High Durability
7) High starting torque

We have to operate the induction motor properly otherwise we will face various faults in the induction motor and we must provide the motor with correct inputs such as current and voltage at the standard frequencies then only it performs efficiently otherwise the motor may stop working. So, we have to check the inputs frequently so that we come to know about changes that are going to occur. Generally, if fault occurs in Induction motor take a lot of time to identify and rectify it during that time motor will stop working so it leads to decrease its production which brings loss to industry. So, if we check for the faults prior they occur then we can try to avoid it if not we can rectify it as soon as possible. This can be achieved by monitoring the three phase induction motor using current signature analysis.

A. Objective

The basic objective is to monitor the condition of 3-phase induction motor and to successfully implement the current signature analysis by using the Gabor transform. We have to analyse the signal with the help of Gabor transform code and get the output.

B. Types of Induction Motors and their Faults

There are two types of Induction motors:
1) Types of Single –Phase Induction Motors
a) Split-Phase Induction Motors.
b) Capacitor Start and Capacitor Run Induction Motors.
c) Shaded Pole Induction Motor.

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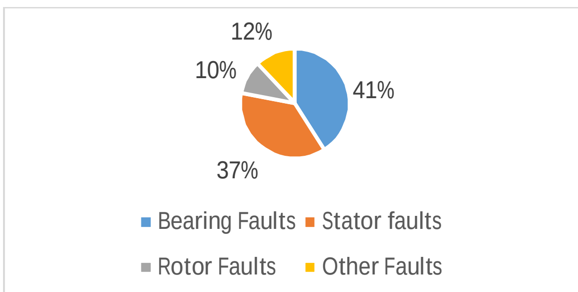
2) Types of Three-Phase Induction Motor.
a) Squirrel Cage Induction Motor.
b) Slip-ring or Wound Rotor Induction Motor.

C. *Types of Faults*
1) Electrical Faults.
a) Single Phasing Fault
b) Reverse Phase Sequencing Fault
c) Under or Over Voltage Faults
d) Over Load Fault
e) Earth Fault
f) Inter Turn Short Circuit Fault
g) Crawling Fault

2) Mechanical Faults.
a) Broken Rotor Bar Fault
b) Rotor Mass Unbalance Fault

3) Environmental Faults.
4) General Faults
5) Bearing Faults



Types of faults and their percentage of occurrence in induction motor is shown in above figure.

II. GABOR TRANSFORM

Gabor transform is a special case of short-term Fourier Transform. It is used to determine the Sinusoidal signal in terms of both frequency and time as it changes over time. Gabor transform uses Gaussian Window to analyse the signal. Therefore, the signal to be converted must be multiplied by the Gaussian function, which is considered to be the Gaussian window, and must be transformed with the help of the Fourier transform to obtain the result of the time-frequency analysis.
The Gaussian Window means that the specific signal near the time that is going to be analysed has a higher weight. For the signal x (t), the Gabor transform is defined by this formula.

$$Gx(T,\omega) = \int_{-\infty}^{\infty} x(t)e^{-\pi(t-T)^{\wedge}2}\, e^{-j\omega t}dt$$

In General, the range of Gaussian function is infinite. So, it is difficult to implement. However, it is possible to select a specific level of significance (for instance, 0.00001), for the Gaussian function distribution.

$$e^{-\pi a^2} \geq 0.00001;\ |a| \leq 1.9143$$

$$e^{-\pi a^2} < 0.00001;\ |a| > 1.9143$$

The Limits of integration are beyond these

|a|>1.9143

It is ok to ignore the Gaussian function short enough. Thus, the Gabor transform can be assessed satisfactorily as

$$Gx(T,\omega) = \int_{-1.9143+T}^{1.9143+T} x(t)e^{-\pi(t-T)^{\wedge}2}\, e^{-j\omega t}\, dt$$

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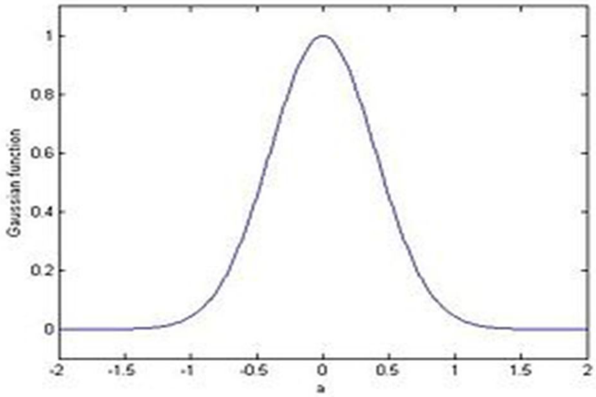
This makes the Gabor transform realizable and practical.



To get an optimized time-frequency resolution trade, we can vary the width of a window function for a specific application by replacing the

$-\pi$ (t-T)^2 with $-\pi\alpha$(t-T)^2 for some chosen alpha.

III. CONDITION MONITORING

The need for condition monitoring is for evaluation of health of plant and equipment throughout its survey life. Incipient failure detection is the must and should, that is to detect the fault while they are still developing. Which is produces a safe operating environment in the system. Which is why condition monitoring of electrical equipment and electrical machines is necessary. By using the condition monitoring, we can provide advocate warning an imminent failure. It also helps in scheduling future prevention maintenance and repair works, which results in less downtime. By maintaining the spare parts of motor, in such that for repairing immediately there by its reducers outage time. Which improves in reliability safety and productivity.

In this project, we focus on the monitoring and fault diagnosis of electric machines. In which fault diagnosis process helps to identify the false that they occurred in the system.

The process of condition monitoring and fault diagnosis takes in different steps, in which they had great significance in the business environment, because of the following reasons,

A. To reduce the cost of maintenance.
B. To identify the equipment failure.
C. To improve the reliability of equipment and components.
D. To improve the accuracy in failure prediction.

The process of fault diagnosis involves in different steps they are,

1) Data acquisition
2) Future extraction
3) Fault progression and trending analysis
4) Decision making

Where condition monitoring of electrical and mechanical devices has been in practice for some time. Which most permanent technical are developed over time in which current signature analysis is one of them.

IV. CURRENT SIGNATURE ANALYSIS

The motor current signature analysis is a monitoring method, this have been published among several industries. In this method we study the monitoring of stator current for diagnosis of different faults in the induction motor.

In which rolling element bearing damage in induction motor is an application of MCSA. This study helps us to find out the efficiency of current monitoring for bearing faults, bike correlating the relation between vibration and current frequencies caused by incipient bearing failures. In this, construction of bearing is defined by reviewing and characterizing the bearing frequencies. In this we conduct an experiment on bearing faults that by monitoring the stator current side, which spectrums are described and related frequencies are determined.

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V. BEARING FAULTS ANALYSES

It is important to detect the mechanical falls in the induction motor. In which bearing plays an important role in the induction motor. For that reason we use the advanced signal processing technique for the detection of bearing fault.

According to the survey, the various induction motors in industries, most faults happened to bearing and winding. A study by the electric power research institute (EPRI) provide similar reasons.

In the induction motor the fault percentages are of Bearing (41%), stator (37%), rotor (10%) and other (12%).

The purpose of bearing in an electric motor is to support and locate the rotor. To keep the air gap small and consistent and transfer the load from the shaft to the motor. The bearing should be we able to operate at low and high speed whilst minimizing fractional losses. At the same time the bearing must be economic and require absolutely minimal maintenance.

In the bearing fault, they are two different types which are namely cyclic and noncyclic faults.

Cyclic faults are occurred by depending upon the location of fault.

A. Inner race fault
B. Outer race fault
C. Cage fault
D. Ball defect fault

These faults can be illustrated and identified, then the formed fault frequencies can be calculated by using the following expressions. Whereas the noncyclic faults which classify corrosion roughness and the deformation of the seal. Which does not produce the fault frequencies in the stator current.

1) *Inner Race:* It is a smaller ring that attached to the shaft. Which helps in holding the balls in the bearing held in place between outer and inner race.

$$f_i = \frac{N_b}{2} f_r \left(1 + \frac{d}{D} cos\emptyset \right)$$

2) *Outer Race:* The outer race and the inner race of bearing which helps to holds the ball in bearing rest. When it exposes to large forces it may cause to damage of the outer race. So, it is important to make sure to design outer race materials that are up to the task.

The relationship of stator current and the ball bearing vibration can be determined by, remembering that any air gap centricity produces anomalies in the air gap flux density. Due to the damage in the bearings that will produce radial motion between stator and the rotor of machine.

$$f_o = \frac{N_b}{2} f_r \left(1 - \frac{d}{D} cos\emptyset \right)$$

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VI. EXPERIMENTAL RESULTS

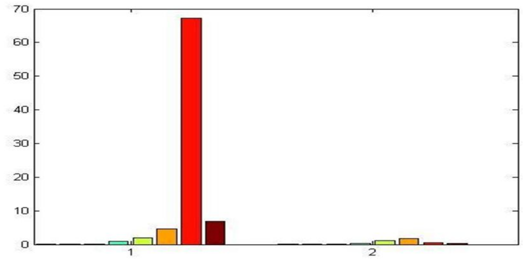
1) Experimental conditions for the detection of bearing faults

Cases	Experiments	Severity of bearing faults	Load condition
Case1	1	Inner race fault with one hole	No Load
	2	Inner race fault with one hole	Full Load
Case2	1	Outer race fault with two holes	No Load
	2	Outer race fault with two holes	Full Load

Experimental Setup

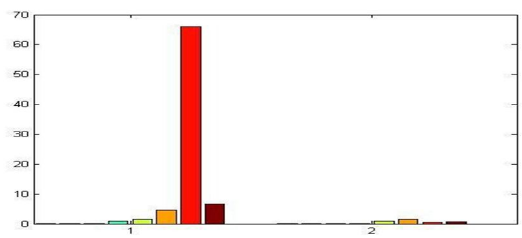
2) Inner race with one hole

Load Condition	Parameters	1	2	3	4	5	6	7	8
No-Load	RMS	0.043	0.0192	0.0553	0.9010	1.8791	4.5310	67.5077	6.7876
	Standard deviation	0.0038	0.0141	0.0292	0.2293	1.0980	1.6742	0.5584	0.3464
Full-Load	RMS	0.0162	0.0511	0.1358	0.9062	1.7240	4.0164	67.777	7.1048
	Standard deviation	0.016	0.0555	0.1272	0.3371	0.9703	1.6770	1.7461	0.6208



3) Outer race with two holes

Load Condition	Parameters	1	2	3	4	5	6	7	8
No-Load	RMS	0.0060	0.0248	0.0713	0.9498	1.5516	4.5255	66.0597	6.6983
	Standard deviation	0.0057	0.0215	0.0548	0.1865	0.8958	1.5989	0.5948	0.6917
Full-Load	RMS	0.0083	0.0299	0.0774	0.8958	1.4442	3.9950	68.2537	6.9543
	Standard deviation	0.0081	0.0277	0.0632	0.1800	0.7626	1.3380	0.8794	0.6208



A. Case-1

1) *Inner race Fault with one hole at No-Load:* The inner race fault of the induction motor is subjected to test under No-Load and Full-Load conditions by using the Gabor transformation code. The faulty induction motor with one hole in inner race of bearing under No-Load condition is shown in the figure-1.3.

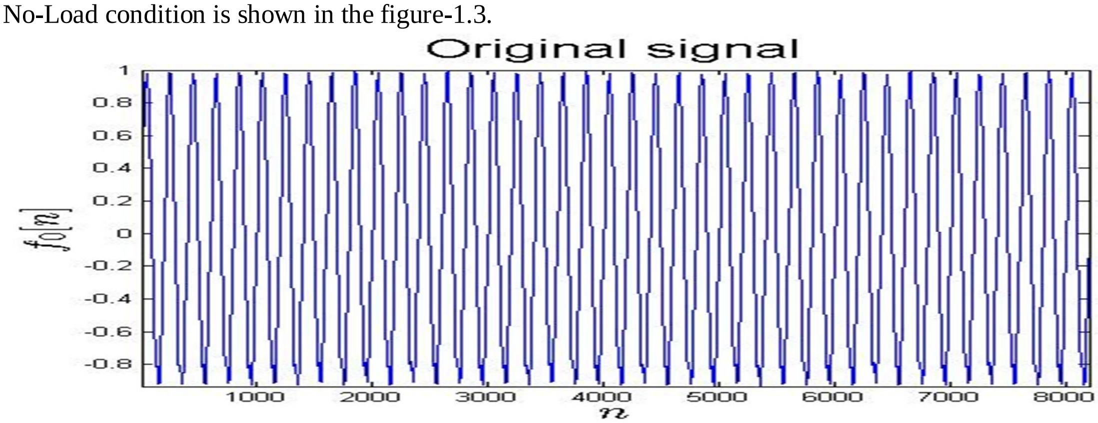


Figure 1.1-Orginal signal of one hole inner race fault at the No-Load

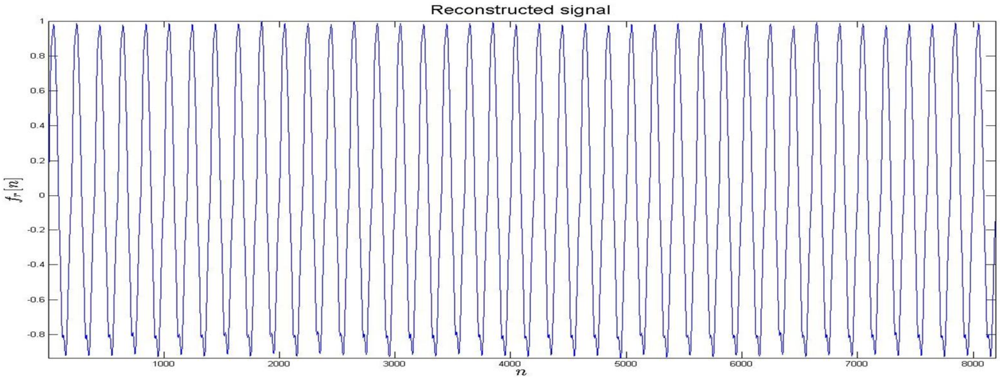


Figure 1.2-Reconstructed signal of one hole inner race fault at the No-Load

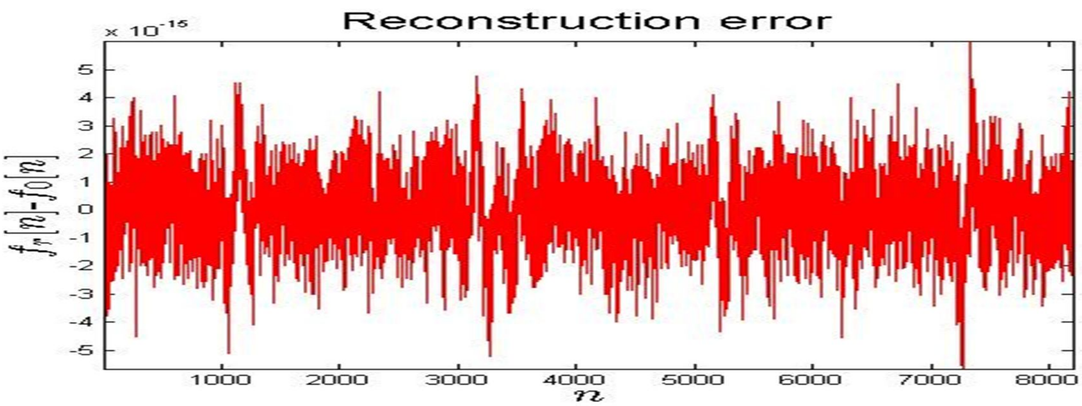


Fig-1.3 Reconstruction error signal with one hole in the inner race at the No-Load

2) *Inner race Fault with one hole at Full-Load:* When the motor is tested again with the same bearing under Full-Load condition, it is observed that the magnitude of fault frequencies are increased in the spectrum, as shown in the figure-1.6.

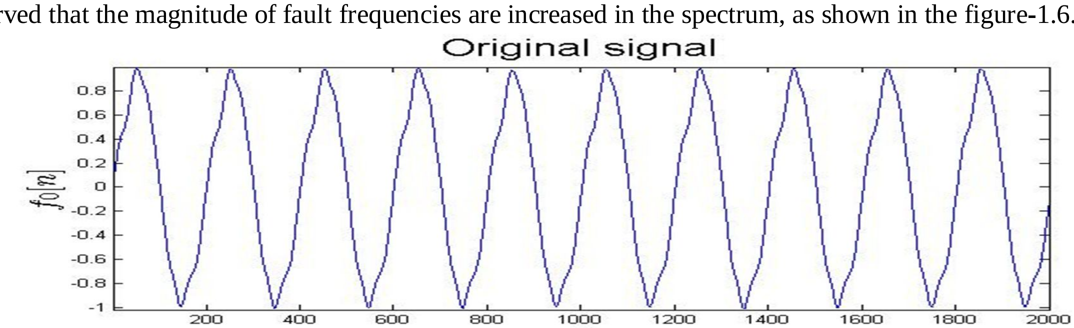


Figure 1.4-Orginal signal of one hole inner race fault at the Full-Load

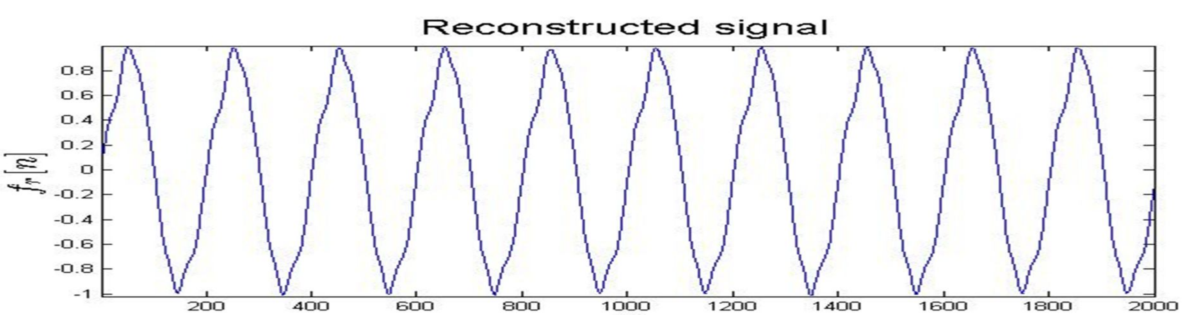


Figure 1.5-Reconstructed signal of one hole inner race fault at the Full-Load

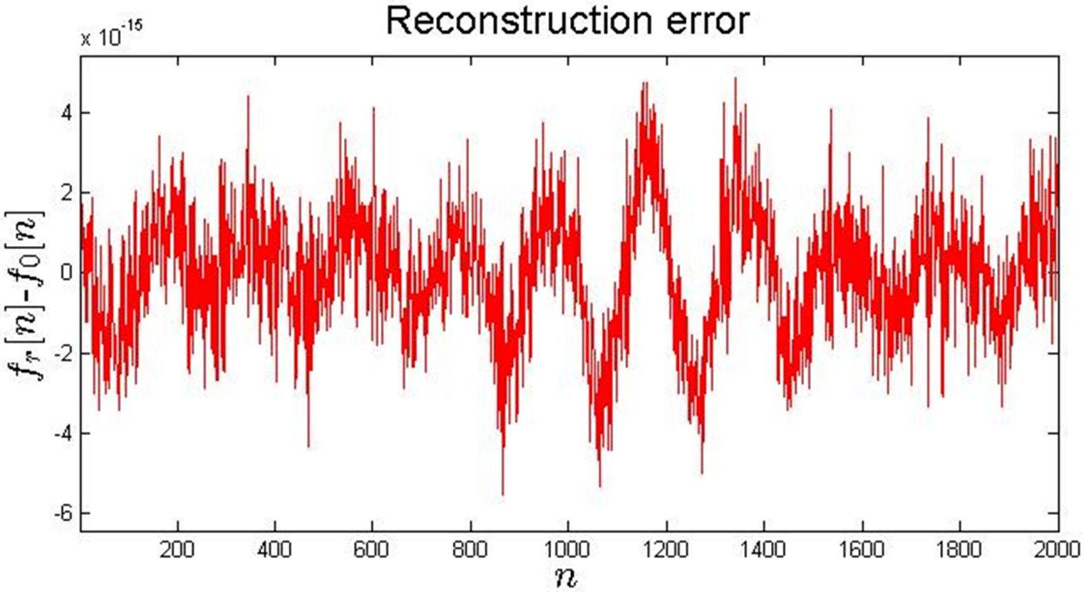


Figure 1.6- Reconstruction error signal with one hole in inner race at the Full-Load

B. *Case-2*

1) *Outer race Fault with two hole at No-Load:* The outer race fault of the induction motor is subjected to test under No-Load and Full-Load conditions by using the Gabor transformation code. Initially, two holes was drilled in the outer race of the bearing and then it was installed in the motor. The spectrum of a faulty motor with two hole in the outer race of bearing under No-Load condition is shown in figure 2.3.

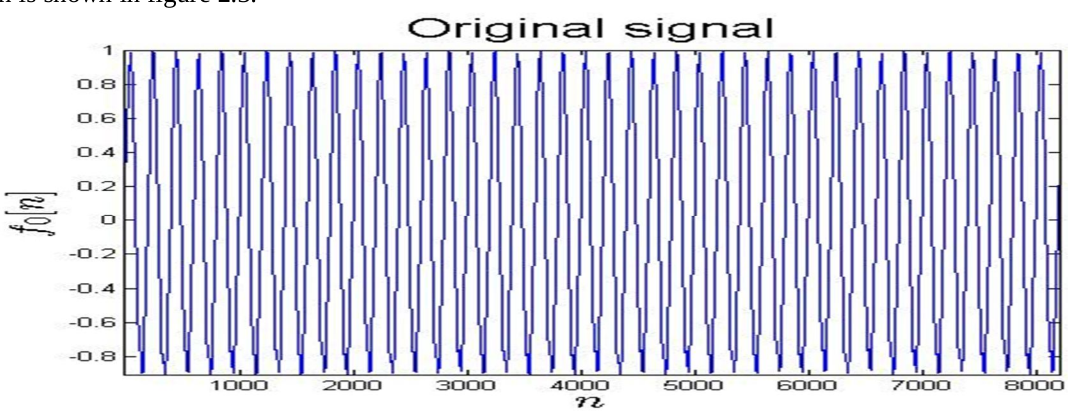


Figure 2.1-Orginal signal of two hole outer race fault at the No-Load

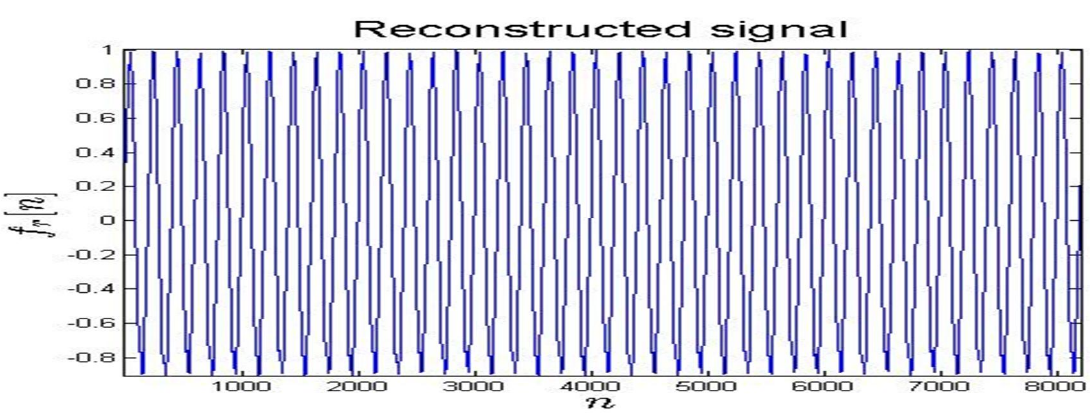


Figure 2.2-Reconstructed signal of two hole outer race fault at the No-Load

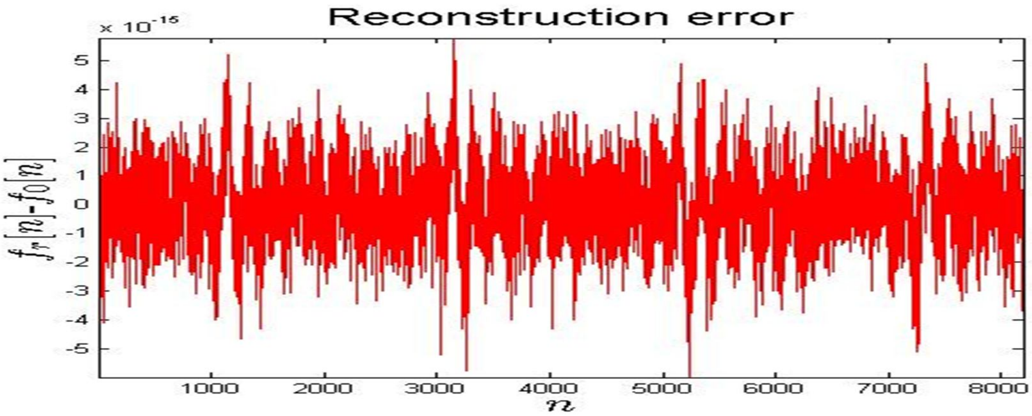


Figure 2.3-Reconstructed error signal of two hole outer race fault at the No-Load

2) *Outer race Fault with two hole at Full-Load:* When the motor is tested again with the same bearing under Full-Load condition, it is observed that the magnitude of fault frequencies are increased in the spectrum, as shown in the figure-2.6.

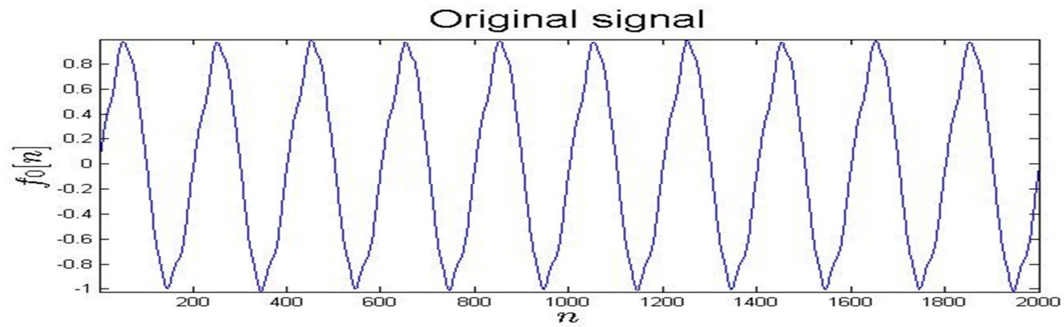


Figure 2.4-Orginal signal of two hole outer race fault at the Full-Load

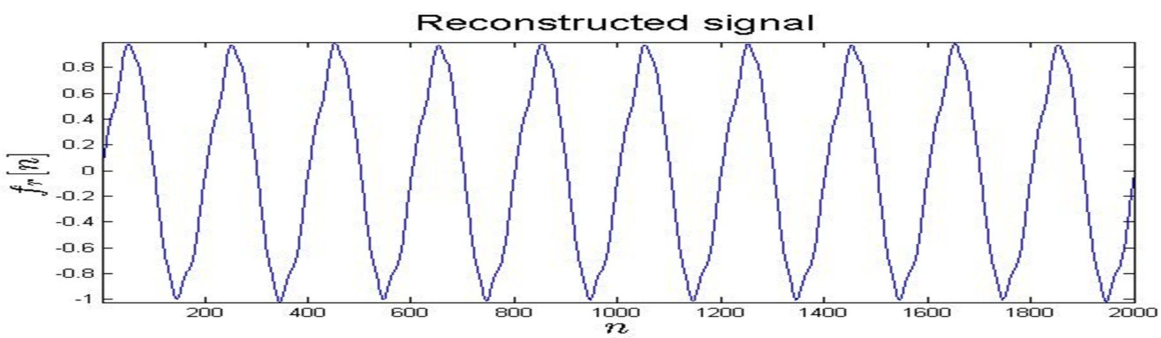


Figure 2.5-Reconstructed signal of two hole outer race fault at the Full-Load

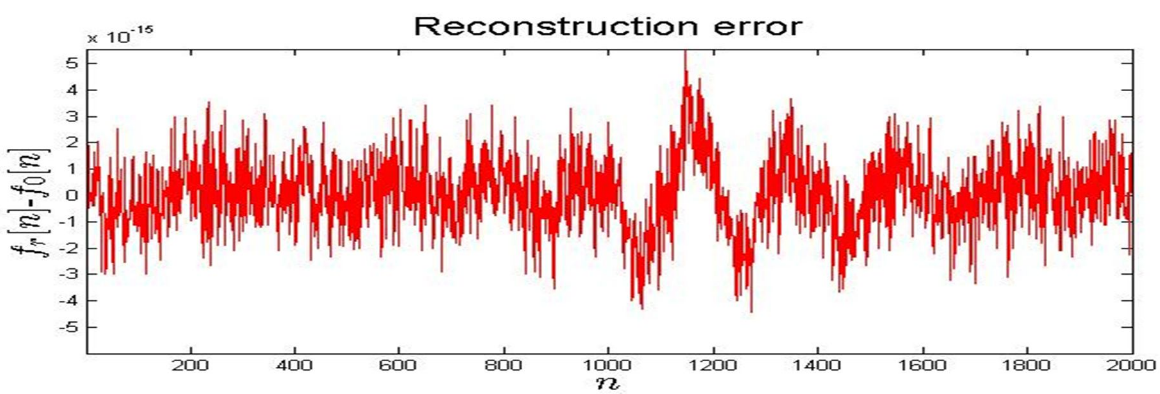


Figure 2.6-Reconstruction error signal of two hole outer race fault at the Full-Load

VII. CONCLUSION

In this we learned about analysis of the current signal using Gabor transform with help of motor current signature analysis and able to detect the cyclic faults of bearing faults like Inner race and outer race faults which are occurring in the induction motor. The ratio of faulty RMS and Standard Deviation parameters to the healthy parameters are proposed has fault indexing parameters. After a careful expermental process, we can say that the Gabor transform technique gives better results.

VIII. ACKNOWLEDGEMENT

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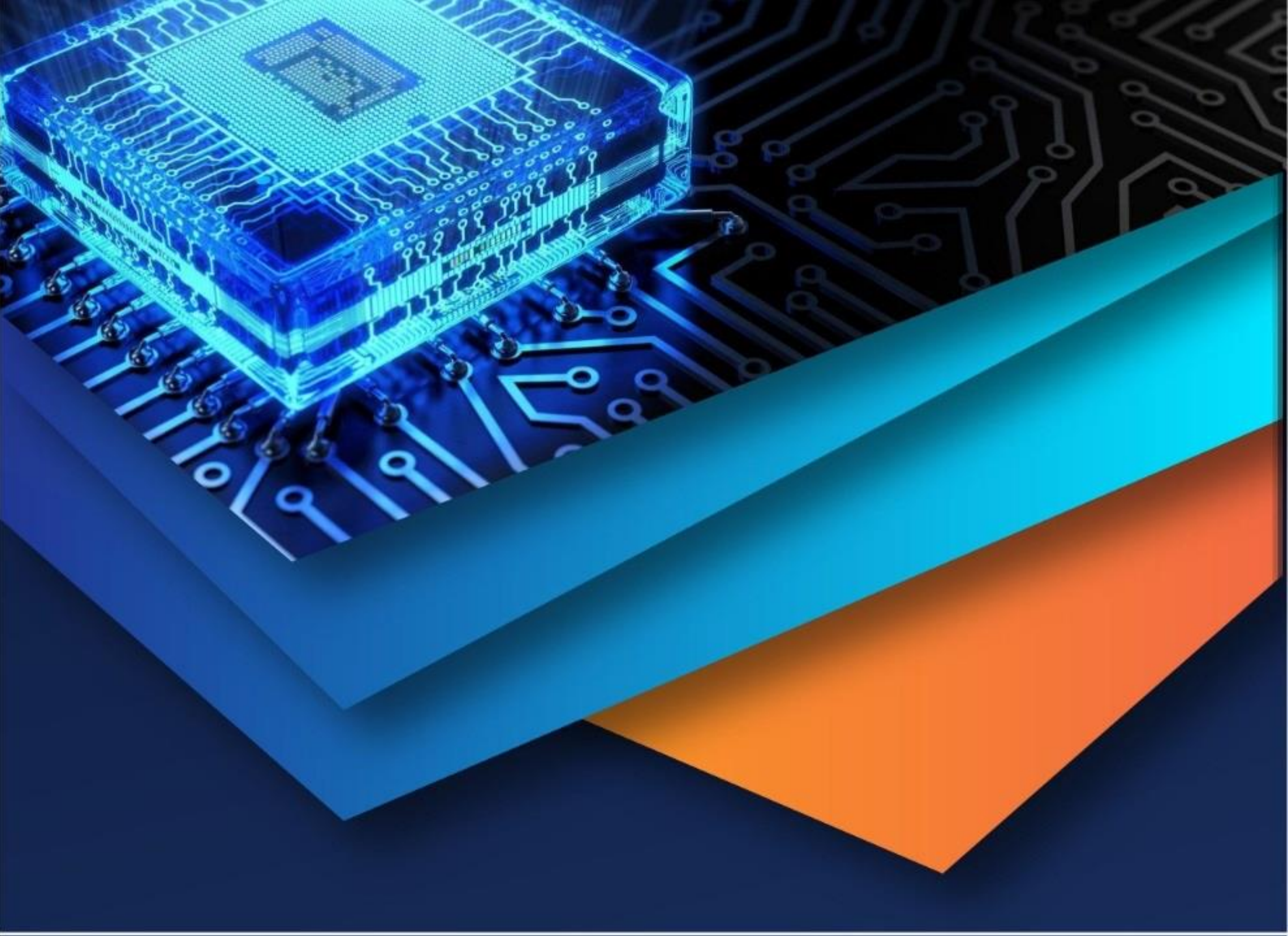

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