TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

Detection and Classification of Bearing and Single Phasing Faults of a Squirrel-Cage Induction Motor using Wavelet Transform

Ch. Sridhar[1], Dr.N. Rama Devi[2]
[1]*Research Scholar, Acharya Nagarjuna University, Guntur, India, sridharbec@gmail.com,*
[2]*Electrical & Electronics Engg. Bapatla Engineering College, Bapatla, India, ramadevi_eee@yahoo.co.in,*

Article Info
Volume 82
Page Number: 11349 - 11357
Publication Issue:
January-February 2020

Article History
Article Received*: 18 May 2019*
Revised*: 14 July 2019*
Accepted*: 22 December 2019*
Publication*: 21 February 2020*

Abstract

This paper describes a protection scheme for a 3phase induction motor to detect and classifingthe bearing faults and single phasing faults. The loyalty of an Asynchronous induction motor is of predominant importance in various applications like industrial, commercial, aerospace and military.. Rotating mechanical part bearings played an important role in the reliability and performance of all motor systems. In this paper the 3phase stator current signals are captured in P.C using DIP8000 that is having a sample frequency of 5.3KHZ. These signals are analyzed with Bior5.5 wavelet and decomposed up to 5th level. The values of d2 coefficient is above the predefined value of Threshold1 (th1) then the motor is under fault. In case of bearing faults all these values are above the predefined threshold otherwise it is healthy. The phase which is above Th1 represents the single phasing fault on that phase.

Keywords: *bearing fault, sampling frequency, Threshold and Wavelet Transform.*

I. INTRODUCTION

AC rotating Electrical motors especially induction motors are used for various industrial utilities because it plays a non-interchangeable role in many of the industrial processes [1]. Those asynchronous induction motors possess a variety of features those are not compatible with other motors like low cost, reliability and ruggedness but still those motors are devoted to some failures due to malfunctioning and manufacturing defects. Hence condition monitoring is necessary in order to reduce the cost of production [2].In rotating machinery bearing is one of the significant mechanical rolling part and it has expansive industrial and domestic applications proper function depends on the smooth operation performed by the bearings [3-4].Hence early fault detection is not done those faults are gradually degrade the performance of machine and also leads to motor interruption.

II. FAULTS CLASSIFICATION

Induction motor during running condition subjectected to various faults like electrical as well as mechanical faults. The fig.1 shows the percentage of various faults distribution shows in the pie diagram.

TEST Engineering & Management
January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

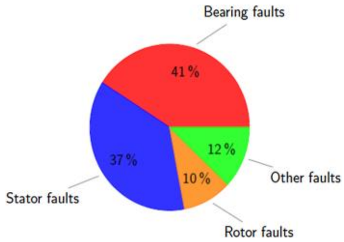


Figure 1. Pie diagram for various faults distribution

Similarly in the recent past several research studies shows that major category of faiulers in induction motor are bearing faults.The following below table I confer various research surveys performed by Electric Power Research Institute (EPRI), surveyed 6312 motors and the reliability Working Group of motor of the IEEE-IAS, surveyed 1141 working machines

Table 1 – Percentage of failure by component

Failed Component	Percentage Failures (%)	
	IEE-IAS	EPRI
Bearings Related	44	41
Windings Related	26	36
Rotor Related	8	9
Others	22	14

It is clear from the above table shows that the prevailing causes of the machines failures are mechanical rotating part bearing faults are major contribution. For significant fault detection various research studies gives out the least expensive bearing faults to fix the problem and at the same time it is most challenging to detect the fault under different operating conditions.

SINGLE PHASING FAULTS

Single-phasing means nothing but opening of one of the any three-phases. It leads to unbalance in the voltage. If a single phasing occurs in 3-phase motor full horse power will be delivered that is enough for driving the load. The motor continues to drive the load till it may burns out or until properly sized dual element and over load elements. The motor will be off from the line with the help of time delaying fuses. In the case of lightly loaded motors the phase currents increased by square root of three (√3) that secondary single-phasing conditions. This leads to draw an over current of 20% more than the full-load value. The motor may be damaged by the circulating currents if the overloads are sized at 125% of the rotating condition. Hence it is more appropriate to protect the motor against over loads rather than against the rated current.

In order to detect and classify the various faults several signal processing techniques involves the electrical machines data collection and the available data is processed by using several fault detection techniques. The rotating electrical machine condition monitoring is tested with the raw signal, those data collected by through various supportive equipment and sensors. The fault feature extraction done by comparing healthy case to faulty case by choosing a suitable signal processing technique. Earlier a several number of data acquisition approaches have been established for collection of certain parameters of electrical machines.

In most of the condition monitoring techniques the motors operating under different loaded conditions, for analyzing the fault feature the captured raw current with signal contaminated with noise, non-stationary condition. Hence it is very difficult to analyze the signal in the time-domain. For recent years advanced powerful signal processing techniques available analyze the signal in time-frequency domain for identification of faults and also other non-invasive vibration and motor current signature analysis are used for condition monitoring of bearings [5], especially the following four methods frequency, time domain, enhanced frequency [6] and time-scale [7] signal processing methods are used to extract the fault feature of the bearing.

WAVELET TRANSFORM

For the analyzation of a signal in both frequency and time domains, the wavelet is found to be a powerful mathematical tool. A given signal is split into a number of signals corresponds to different frequency bands. These splitted signals store information more efficiently than of Fourier transform.Varites of wavelets are used for condition monitoring of electrical machines out of them Discrete wavelet transform (DWT) with multi-resolution analysis is used frequently. It provides a signal information in time-scale domain. This transform is an ideal tool analyzing the signal in non-stationary and transient nature. The continuous wavelet transform (CWT) of a given function *f*(t) gives the approach in time-scale domain used for identified as overall sum of the signal is the product of shifted and scaled version of the mother wavelet function *Ψ(t)*.Those function was given by Smith and McFadden as follows below

$$WT\,(a,b) = \frac{1}{\sqrt{|a|}}\int_{-\infty}^{\infty} f(t)\Psi^{*}\left(\frac{t-b}{a}\right)dt \qquad (1)$$

Here the parameters *a* represented as scale index, it is a reciprocal of frequency and the parameter *b* shows the translation or time-shifting. The transform is derived from the discretization of CWT (*a*,*b*) and those function was proposed by Smith and McFadden as follows below

$$DWT\,(j,k) = \frac{1}{\sqrt{2^{j}}}\int_{-\infty}^{\infty} f(t)\Psi^{*}\left(t-\frac{2^{j}k}{2^{j}}\right) \qquad (2)$$

Here *a* and *b* replaced with by *2j* and *2jk*. In 1989 Mallat developed an efficient method using filters. The signal *f*(t) is passed through by two complementary filters and appears as low and high frequency signals. The signals are further broken into lower and higher resolution with successive approximations. The following fig.2 explains the Dyadic wavelet decomposition algorithm

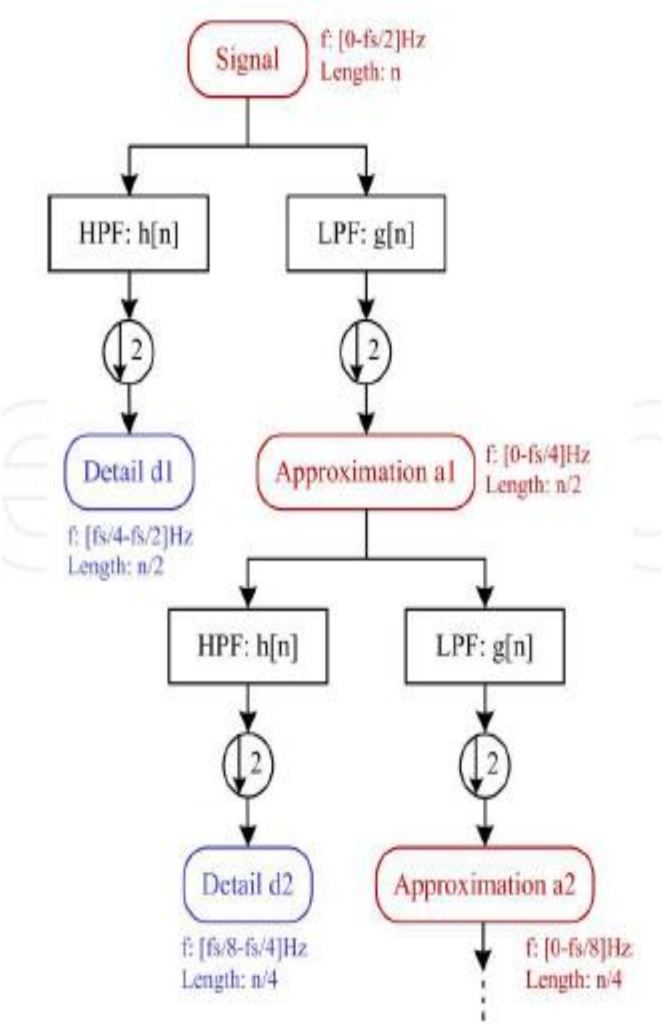


Figure 2. Dyadic wavelet decomposition algorithm

III. Experimental Setup and Data Acquisition

A 3-phase, 175 watts, 415 v, 50 Hz, 0.46 amp, 1395 rpm Induction motor is builted in LVDAM-EMS **(**Lab volt data acquisition and management for electro mechanical systems) for practical experimental purpose. The LVDAM-EMS system is built around the DAI (DATA ACQUISITION INTERFACE) module that interconnects the modules of the LAB-VOLT electromechanical and power electronics training systems with a personal computer. LVDAM allows data storage, graphical representation and simulation mode. In order to done the various bearing faults the squirrel rotor replaced with different faulty

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

bearings shown in following figure. The stator currents under various bearings faults condition are captured with UNIPOWER DIP8000 power network analyser with a measuring capacity of 5300 samples per second. After that export and import of those signals with a PC inter faced RS 232 port and complete the analysis with MATLAB software. The below Fig. 4. Shows the pictorial representation of Induction motor with UNIPOWER DIP8000.

Figure 3. Induction motor built with LVDAM-EMS interfaced system

The following fig.4,fig.5,fig.6 and fig.7 shows the squirrel cage rotor, pair of healthy bearings, pair of faulty bearings(outer race defect) and pair of faulty bearings(inner race defect) respectively used for done the bearing faults.

Figure 4. Induction motor squirrel cage rotor

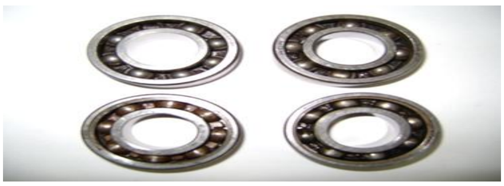


Figure 5. Pair of healthy bearings.

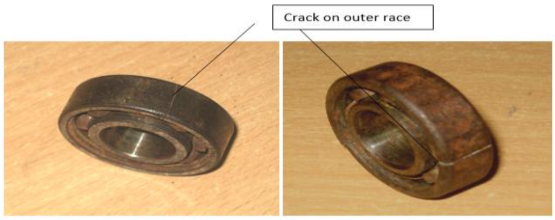


Figure6. Pair of faulty bearings (outer race defect)

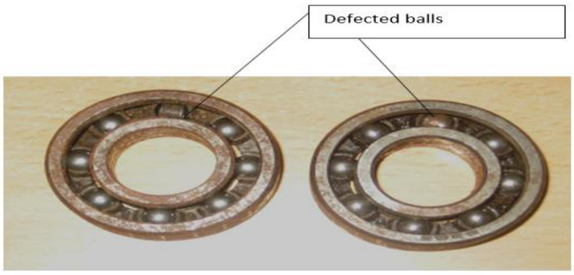


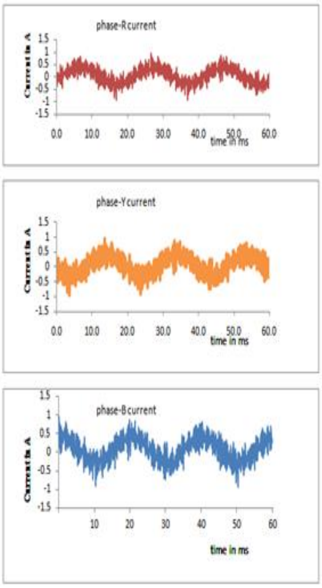
Figure 7. pair of faulty bearings (ball defect)

IV. Experimental Results

The Fig.8 performance the induction motor 3-ϕ currents of which are captured from the Dip 8000(power network analyzer). These currents are interpret with bior5.5 to acquire the d2 coefficients. Fig.9 represent the variation of d2 coefficients with respect to time for healthy bearings. The sum of absolute value of d2 coefficients are compared all the 3-ϕ currents with predefined Threshold1 as illustrated in fig10. All these values are below the threshold1 (3.9), hence the motor is in healthy condition.

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

A.HEALTHY BEARING:



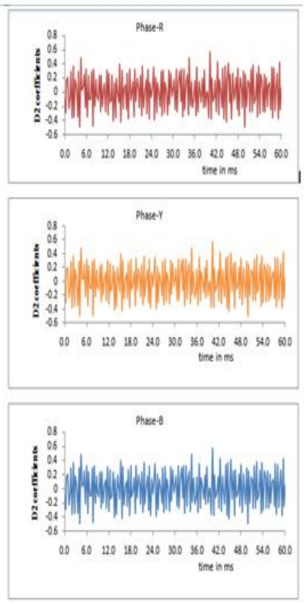


Figure 8 3-phase current wave forms for healthy

Figure 9.d2-coefficients variation for healthy

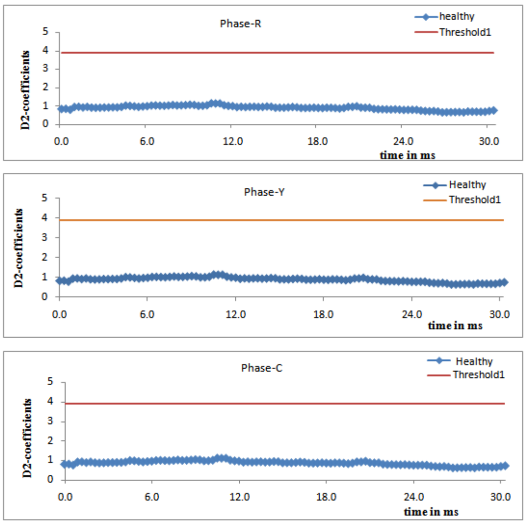
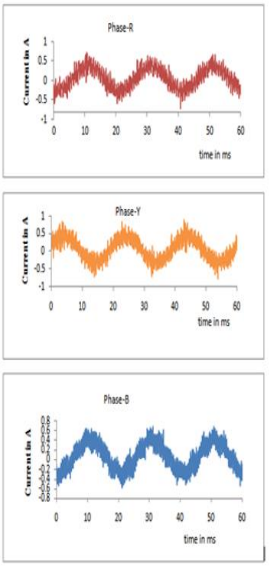


Figure 10: sum of absolute values of d2-coefficients for 3-phases

B.OUTER RACE DEFECT:

With one side fault bearing:

The following Fig 11. represents the currents in the 3-phase induction motor with one sided outer race defect & fig.13 explains the 3-ϕ stator currents with two side outer race defect, which are captured from the Dip 8000(power network analyzer). These currents are analyzed with bior5.5 to obtain the d2 coefficients. Fig 12, fig 14 represents the variation of d2 coefficients with respect to time for outer race defect. The sum of absolute value of d2 coefficients are compared with 3-ϕ currents of outer race defect with predefined Threshold1 as illustrated in fig.15 All these values are above the threshold1 (3.9), hence the motor bearings are faulty.



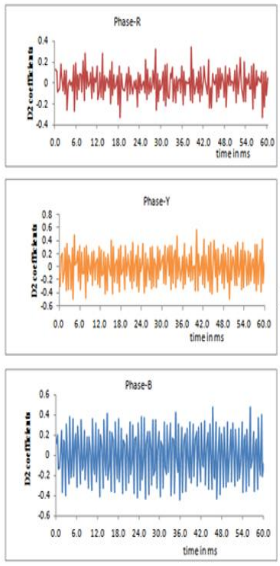


Figure 11.3-phase currents with Outer race defect

Figure12.variation of d2-coefficients of 3-phase currents

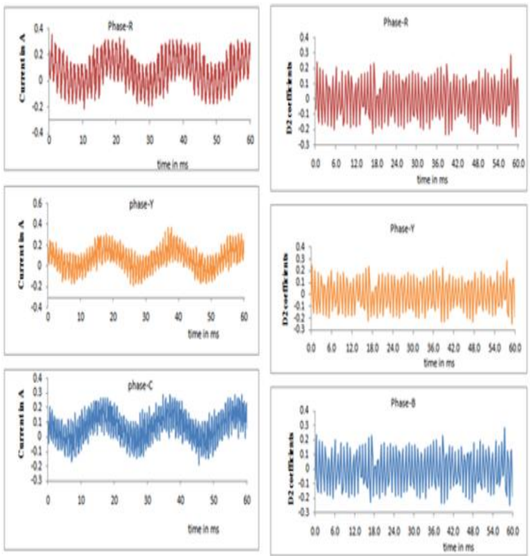


Figure 13.3-phase currents with Two-sided race defect

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

Figure 14.variation of d2-coefficients of 3-phase currents

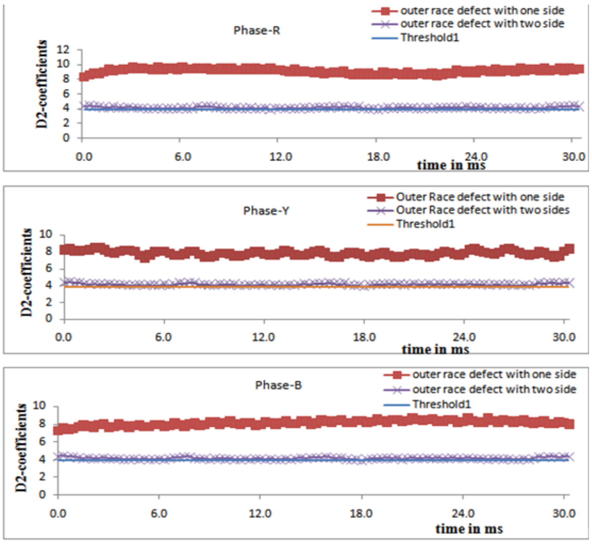


Figure 15: sum of absolutes values of d2-coefficients for 3-phases

C.BALL DEFECT:

With one side fault bearing:

The Fig.16 explains the 3-phase currents of the induction motor with one sided Ball defect & fig.18 shows the 3-phase currents with two side Ball defect, which are captured from the Dip 8000(power network analyzer). These currents are interpret by using with biorthogonal5.5 mother wavelet to acquire the d2 coefficients. Fig 17, fig 19 represents the variation of d2 coefficients with respect to time for Ball defect. The sum of absolute values of d2 coefficients are compared for all 3-ϕ currents of Ball defect with predefined Threshold1 as illustrated in fig20. All these values are above the threshold1 (3.9), hence the motor bearings are faulty.

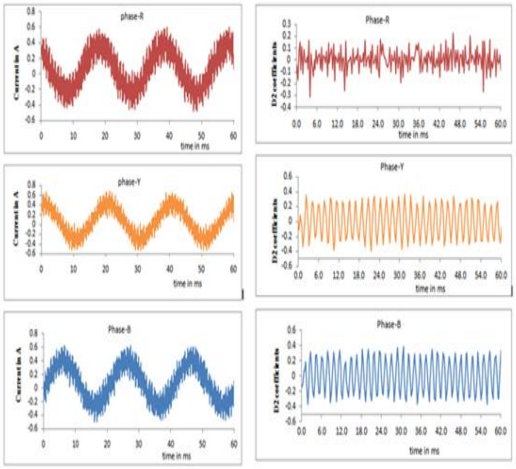


Figure 16.3-phase currents with Ball- defect
Figure 17.variation of d2-coefficients of 3-phase currents

With two side fault bearing:

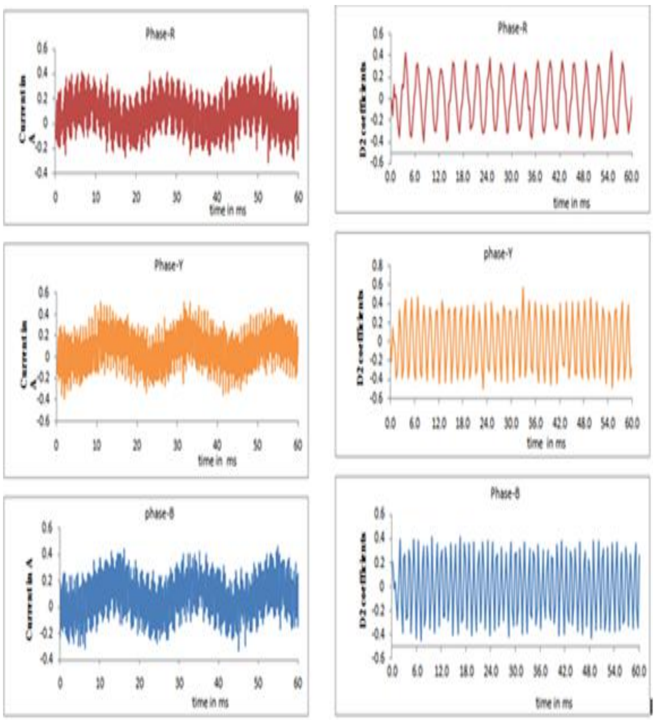


Figure 18.3-phase currents with2 side ball defect
Figure 19.variation of d2-coefficients of 3-phase currents

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

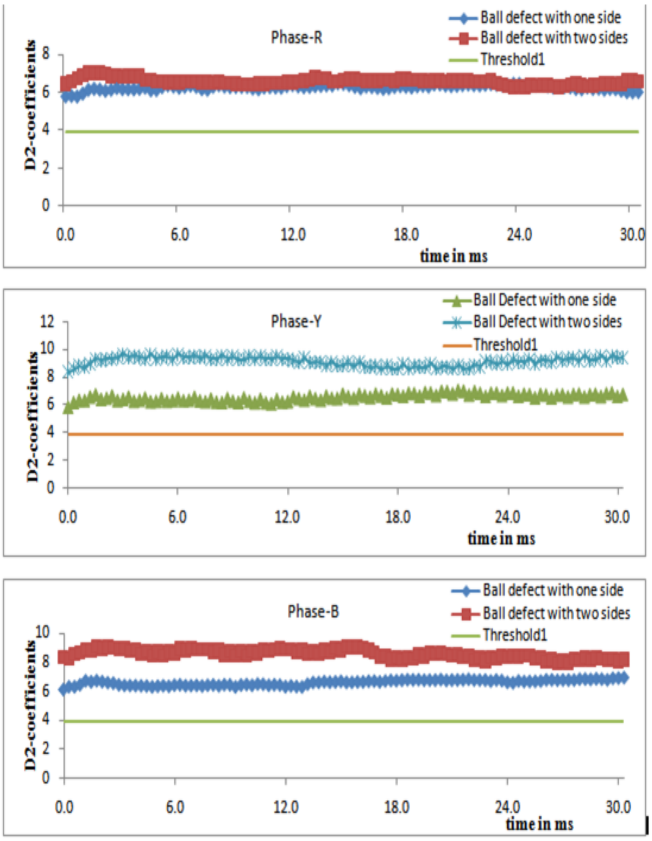


Figure 20. sum of absolutes values of d2-coefficients for 3-phases

CLASSIFICATION OF BEARING FAULTS:

The D5-coefficients of all the 3-phase currents of induction motor with faulty bearings are obtained. To classify the bearing faults by comparing the sum of absolute values of D5-coefficients for all the phase currents with the predefined Threshold2 (0.2).fig21. Shows the sum of absolute values of D5 coefficients with fault bearings, in that the D5 coefficients above the predefined Th2 (0.2) results the outer race defect in bearings. The Sum of absolute values of D5 coefficients below the predefined Th2 (0.2) results the Ball defect in bearings.

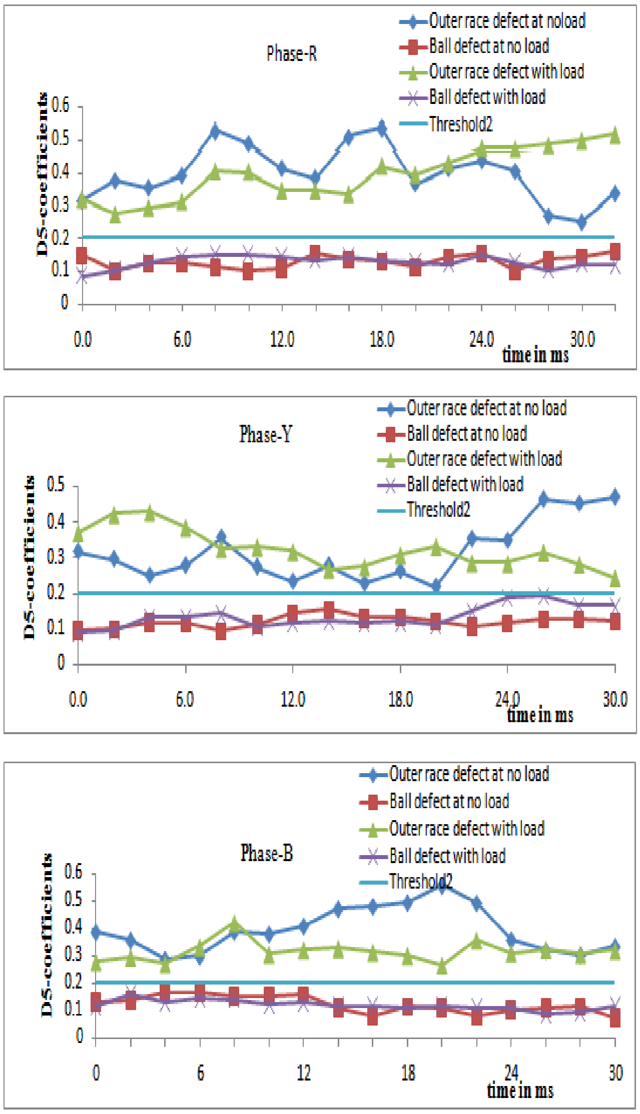


Figure 21. Sum of absolute values of D5-coefficients of 3-ph currents

With Ball & outer race defected bearings

SINGLE PHASING FAULT:

The Fig 22. Shows the induction motor 3-ϕ stator currents with single phasing of R-phase, which are captured from the Dip 8000(power network analyzer). These currents are interpret with bi-orthogonal5.5 to acquire the. Fig .23 represents d2 coefficients variation with respect to time for single phasing fault. The sum of absolute values of d2 coefficients are compared all 3-ϕ currents of single phasing ph.-R with predefined Threshold1 as illustrated in fig.24. One of the phases is above the threshold (Th1) and reaming phases are below the

Th1. The phase which is above Th1 represents the single phasing fault. Similarly in the remaing two phases Y and B-phases validated results are verified.

Single phasing Phase -R:

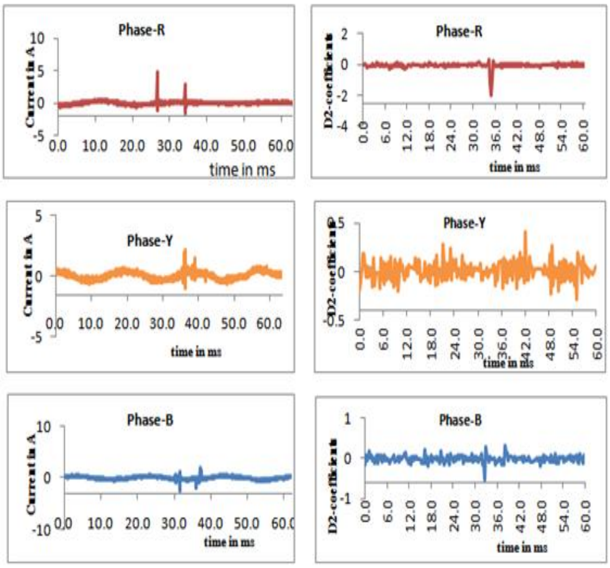


Figure 22 3-phase current for Single phasing-R
Figure 23.d2-coefficients variation Single phasing-R

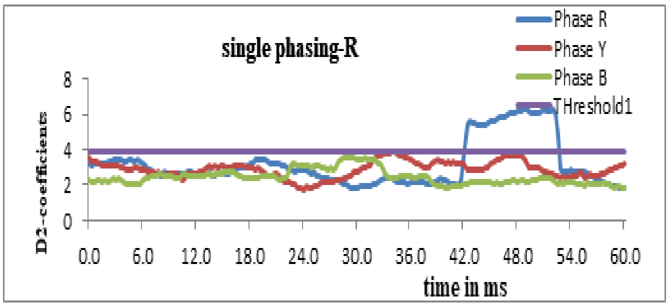


Figure 24. Variation of sum of absolute values of

D2-coefficients of 3-phases

CONCLUSION

A wavelet decomposition technique used for the analyzation of 3-phase transient captured current signals of induction motor is presented in this paper. This scheme effectively detects and discriminate the type of fault(i.e. bearing fault or single phasing fault) by comparing the sum of absolute values of D2 coefficients with a predefined threshold1 (3.9). This scheme also classifies the bearing faults effectively by comparing the sum of absolute values of D5-coefficients with predefined threshold2 (0.2). This scheme is reliable and fast for classifying and detecting the bearing faults including single phasing fault.

REFERENCES

[1] IAS Motor Reliability Working Group, "Report of large motor reliability survey of industrial and commercial installations, part I," IEEE Trans. on Industry Applications, 1985, 21(4): 853-864.

[2] Chow MY. Guest editorial special section on motor fault detection and diagnosis. IEEE Transactions on Industrial Electronics. 2000; 47.5: 982–983.

[3] Yan R. and Gao R X 2009 Base Wavelet Selection for Bearing Vibration Signal Analysis Int. J. Wavelets Multiresoluton & Inf. Process 7(4) 411-26

[4] Tandon N and A Choudhury 1999 A Review of Vibration and Acoustic Measurement Methods for The Detection of Defects in Rolling Element Bearings Tribolgy International 469-80.

[5] R. B. Randall, Vibration-Based Condition Monitoring: Industrial, Aerospace and Automotive Applications, John Wiley & Sons,Chichester, UK, 2011.

[6] L. Eren and M. J. Devaney, "Bearing damage detection via wavelet packet decomposition of the stator current," IEEE Transactions on Instrumentation and Measurement, vol. 53, no. 2, pp. 431-436, 2004.

[7] S. Prabhakar, A. R. Mohanty, and A. S. Sekhar, "Application of discrete wavelet transform for detection of ball bearing race faults," Tribology International, vol. 35, no. 12, pp. 793-800, 2002.

AUTHORS PROFILE

Ch. Sridhar received the B.Tech. degree in electrical and electronics engineering from J.N.T.U. Engineering College, Anantapur, India in 2002, and the M.Tech degree in Electrical power Engg from the J.N.T.U. Engineering College, Hyderabad, India in 2007.He is working as Asst.Professor in the Department of Electrical and Electronics Engineering at Bapatla Engineering College, Bapatla,India since

January - February 2020
ISSN: 0193 - 4120 Page No. 11349 - 11357

2006. Presently, He is pursuing Ph.D. degree at the Acharya Nagarjuna University, Guntur, India.

N. Rama Devi received the B.Tech. Degree in electrical and electronics engineering from J.N.T.U. Engineering College, Kakinada, India in 1997, and the M.Tech degree in power systems from the Regional Engineering College, Warangal, India, in 2000. She received his doctorate degree from the National Institute of Technology, Warangal, India in 2018. Presently, she is working as a Professor and Head of the Department of Electrical & Electronics Engineering at Bapatla Engineering College, Bapatla, India. Her areas of interest condition monitoring of AC motors and Artificial- Intelligence.