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Behaviour Analysis of Induction Motor Under Various Fault Conditions of Rotor bar at Different Loading

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***Abstract*—** Induction motors have a vital influence in the protected and productive running of any modern plant. Faulty condition of these motors because of electrical and mechanical faults may antagonistically affect on line production and can cause unforeseen downtime. Along these lines, discovery of variations from the norm in the motor would maintain a strategic distance from exorbitant breakdowns and especially early location of early rotor bar faults are critical for productive activity of substantial induction motors. In this paper, execution of induction motor under 2D different failure's modes like broken rotor bars are examined under different loading condition using FEM approach. Maxwell 2D Transient solver is utilized for breaking down the conductor of motor under solid and diverse faulty conditions.

***Keywords*—** Maxwell Equations, Eddy Effect, Fault Detection, Broken rotor bar fault

I. INTRODUCTION

Induction motors, especially the asynchronous motors, play an important part in the field of electromechanical energy conversion. Generally three phase induction motors are preferred for large operations in industry that's why also known as workhorse of industry and usually single phase induction motors are used for small operations in household appliances.Infact,90% industrial drives are of induction motor as they are rugged in construction, small in size ,less in weight, highly efficient and low maintenance. Three phase squirrel cage induction motor is widely used as they are rugged, reliable and economical. It is well-known that interruptions of a manufacturing process due to a mechanical problem induces a serious financial loss for the firm. We know a variety of faults that can occur in induction machines [1], [2].

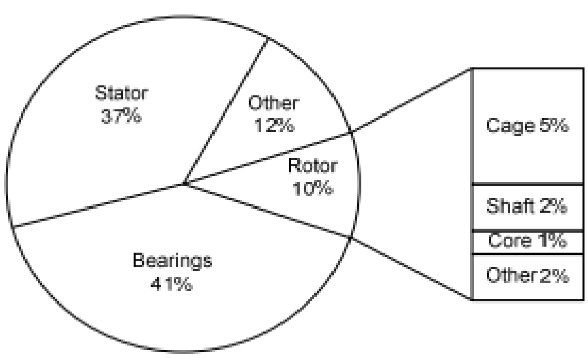


Fig. 1 EPRI survey results indicate that 5 percent of motor faults are because of rotor cage faults [3].

The major faults of electrical machines can broadly be classified as follows [3]:
1. Stator faults (37%)
2. Rotor faults (10%)
3. Bearing balls faults (41%)
4. Other faults (12%)

Rotor bar fault is an incipient fault. Its effects on the system in the beginning are almost unnoticeable. This motivates the online condition monitoring of induction motor. There are several condition monitoring methods proposed in the literature for monitoring rotor bar fault, which involves measurement of vibrations of the machine, flux in the machine, instantaneous power, instantaneous frequency and stator currents of the machine [4-9].In Section II we have discussed the various techniques used for fault detection and identification. Section III contains methodology of FEM for fault detection and also explains the simulation configuration setups and simulation results. Section IV describes result analysis on the basis of comparison of healthy with faulty conditions at different loading levels and finally consider the conclusion in section V.

II. FAULT DETECTION AND IDENTIFICATION TECHNIQUES

In order to avoid incipient failures, prior detection of fault is must. There are various different methods which are used for fault diagnosis and identification in online monitoring process.

A. Model based method: In this approach, Finite Element based methods are used to detect broken rotor bar faults using stator current by identifying effect on amplitudes of characteristics fault frequencies [10], [11].

i) In Transient: Model Technique for detecting stator and rotor faults, a single stator current is used [12], [13].

ii) Thermal monitoring: is another useful technique used for rotor fault detection by identifying rotor resistance [14]

iii) Time stepping coupled Finite Element State Space model: It is used for adjustable/variable drive [15] , [16].

iv) Parameter Estimation: In this model an algorithm is used for calculating model parameters and changes in these parameters measurement indicate the severity of fault [17].

B. Knowledge Based Methods: In this method, detection of faults depends upon various techniques like fuzzy logic, neural network, and artificial intelligence system.

i) Neural Network Technique : This technique makes use of model made up of neural connections in human brain [18] and is used for detecting faults in motor under overload and under voltage conditions[19],[20].

ii) Fuzzy Logic: In this type of method, the detection are based on classification of signals into a series of bands[21],[22].

C. Signal processing techniques: These techniques make use of sampled data for analyzing specific fault in induction motor.

i) Fourier Transform: this is most widely used technique for faults detection based on frequency spectrum analysis[23],[24],[25].

ii) Wavelet technique: This is used for transient analysis fault detection.

iii)Park's Vector Approach: Another useful technique used for identification of shorted turns and air gap eccentricity faults [26],[27].

III. FAULT DETECTION METHODOLOGY

FEM approach is used to analyse the induction motor under various conditions. Finite element method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution.

In this paper,the proposed method is model based and the FEM method is used for analysis purpose.The proposed model of three phase squirrel cage induction motor having specifications 5kW, 415V,4 poles and 50Hz is designed using Rmxpert of Maxwell 2D software.

Table.1 Specifications of modelled three phase induction motor used

Parameters	Value
Rated Power	5kW
Rated Voltage	415V
Rated Speed	1462.7
Frequency	50Hz
Number of stator slots	36
Number of rotor slots	28
Number of poles	4
Stator Outer Diameter	219.8mm
Stator Inner Diameter	136mm
Rotor Outer Diameter	135.42mm
Rotor Inner Diameter	44.85mm

In this paper, performance of induction motor under different failure of broken rotor bars is compared using FEM approach. Maxwell Transient Solver is used for analysing the behaviour of healthy motor and the different varient of faulty conditions in motor. We have compared Flux Density Distribution, Current Density Plot, Torque Response, Flux Linkage Response, Current Response and Output Power Response of the motors under each fauly condition. We have used same specifications of motor which is given in Table 1 to simulate all the results so that we can easily detect fault characteristics in the faulty motor after comparing response with healthy motor.

The proposed FEM model of induction motor is given in Fig.2 which is in terms of its geometry and magnetic circuit is almost identical to real machine.

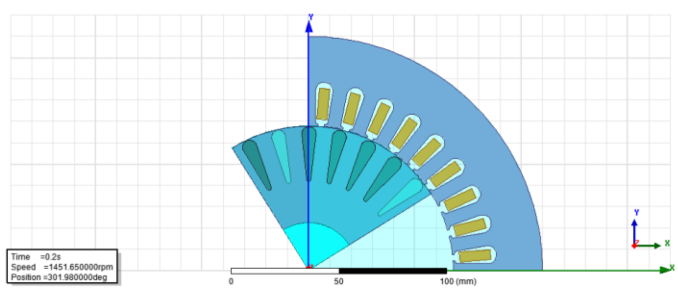


Fig. 2. Proposed FEM model of an Induction Motor

a. Induction Motor under Normal Healthy Conditions

Firstly here we would be simulating the healthy motor and the performance characteristics are plotted.

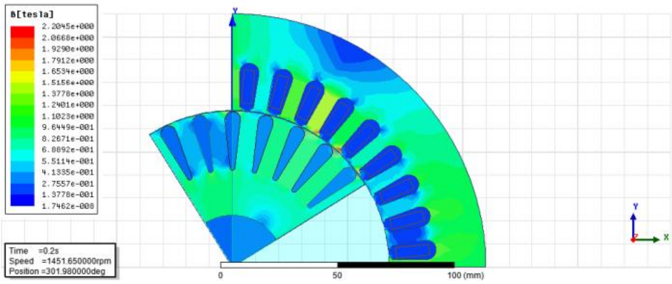


Fig.3 Flux density distribution of induction motor during normal condition

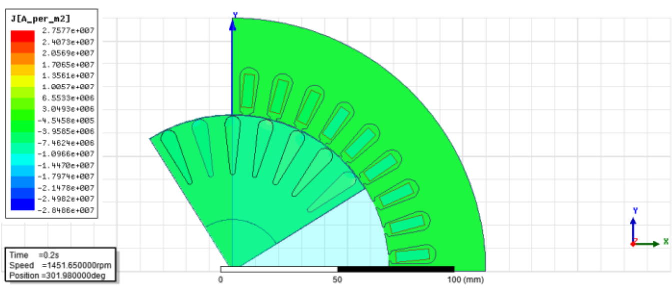


Fig.4 Current density plot of Induction motor during normal condition

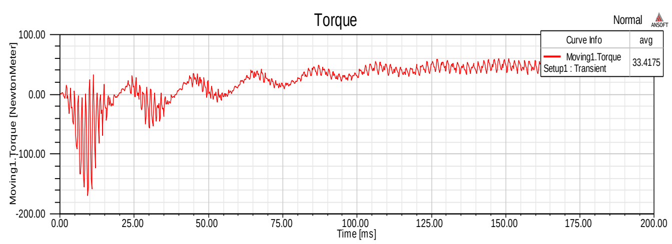


Fig.5 Torque response of Induction motor over period of Time during normal condition

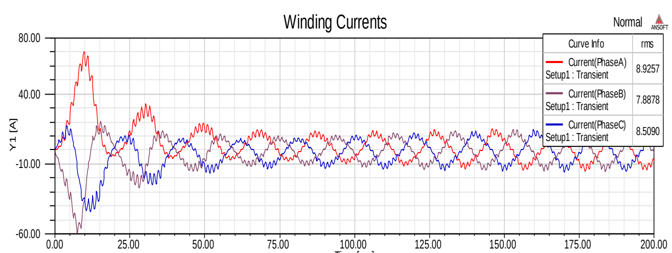


Fig. 6 Current response of Induction motor during normal condition

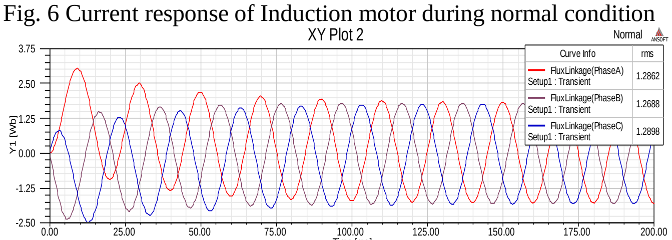


Fig. 7 Flux linkage response of Induction motor during normal condition

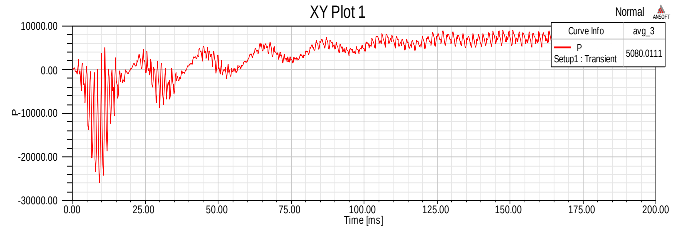
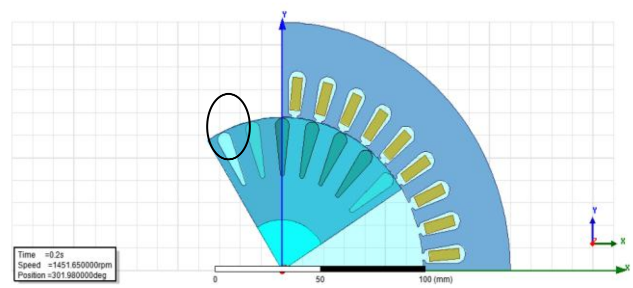


Fig. 8 Output Power response of Induction motor during normal condition

b. Induction Motor under Faulty Conditions

Early detection of a broken rotor bar minimizes motor damage and reduces repair costs. In some cases, the broken bar condition starts with a fracture at the junction between the rotor bar and the end ring as a result of thermal and mechanical stresses [28]. These stresses are more significant when starting motors with high-inertia loads. The bending of a fractured bar due to changes in temperature causes the bar to break. When one bar breaks, the adjacent bars carry currents greater than their design values, causing more damage if the broken bar condition is not promptly detected. Interbar currents that appear because of the broken bar affect the evolution of the fault in the rotor, causing damage in the laminations of the rotor core [28].

i. One Broken Rotor Bar


FigFig. 9 Model with one broken rotor bar

This paper aims to consider different models of motor with one, two, and three broken bars to analyze the harmonic content of the stator currents for these operating conditions.

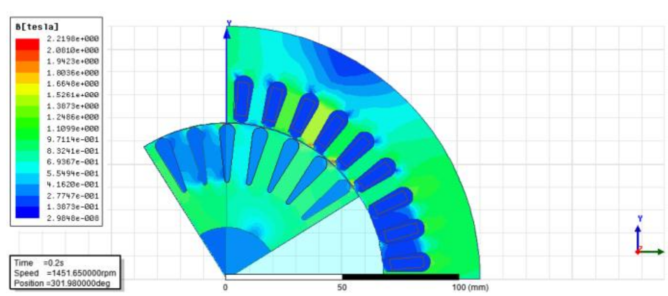


Fig.10 Flux density distribution of induction motor during fault condition with one broken rotor bar

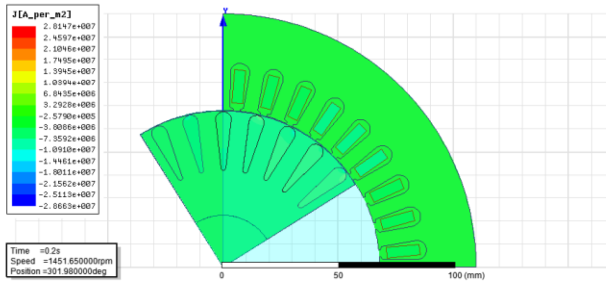


Fig.11 Current density plot of Induction motor during fault condition with one broken rotor bar

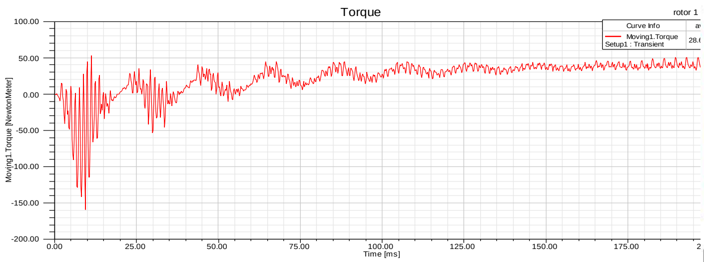


Fig. 12 Torque response of Induction motor over period of Time during fault condition with one broken rotor bar

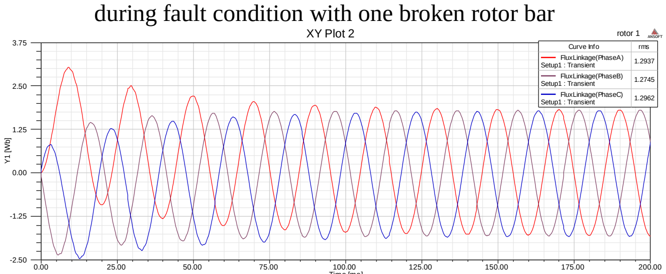


Fig.13 Flux linkage response of Induction motor during fault condition with one broken rotor bar

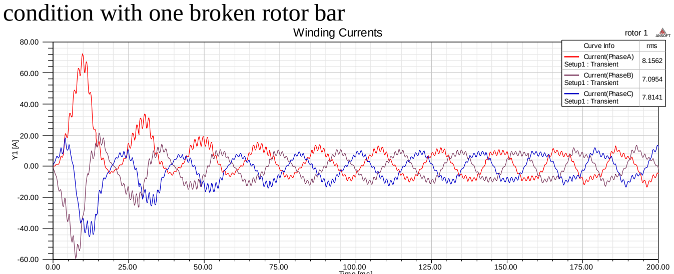


Fig.14 Current response of Induction motor during fault conditionwith one broken rotor bar

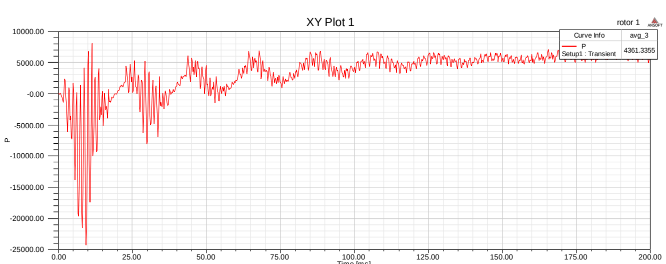


Fig.15 Output Power response of Induction motor during fault conditionwith one broken rotor bar

i. Two Broken Rotor Bar

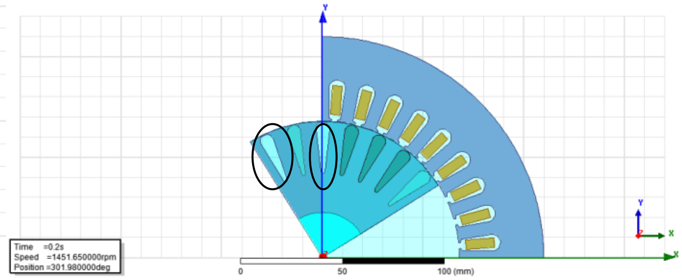


Fig. 16 Model with two broken rotor bar

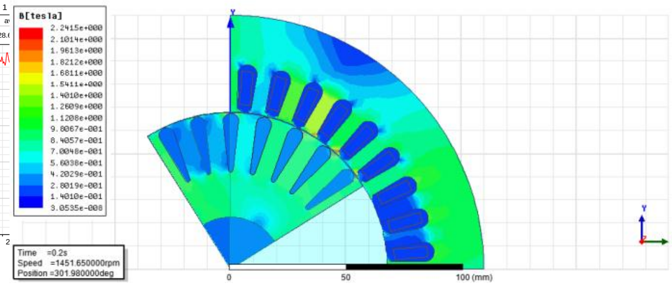


Fig. 17 Flux density distribution of Induction Motor during fault condition with two broken rotor bar

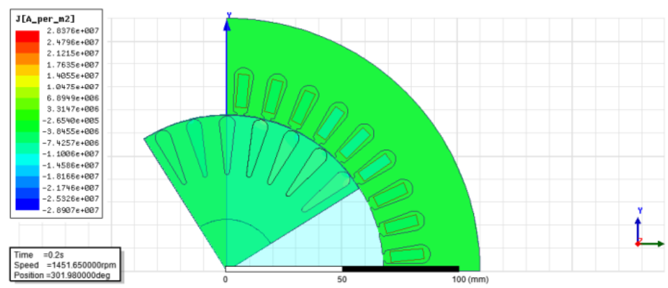


Fig.19 Current density plot of Induction Motor during fault condition with two broken rotor bar

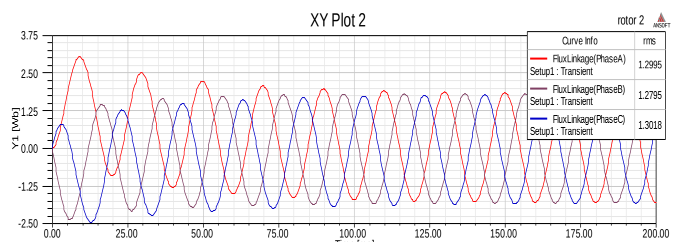


Fig.21 Flux linkage response of Induction Motor during fault condition with two broken rotor bar

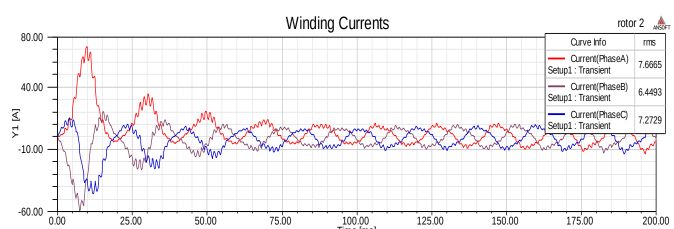


Fig.22 Current response of Induction Motor during fault condition with two broken rotor bar

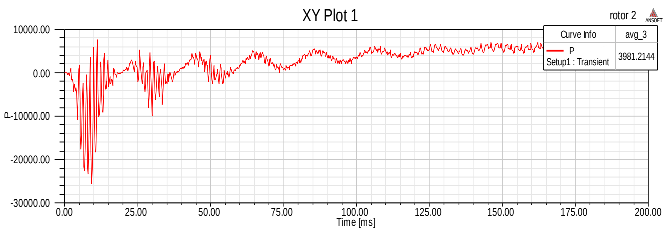


Fig.23 Output Power response of Induction Motor during fault condition with two broken rotor bar

i. Three Broken Rotor Bar

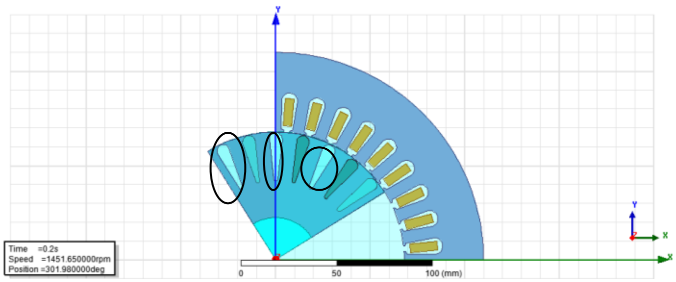


Fig. 24 Model with three broken rotor bar

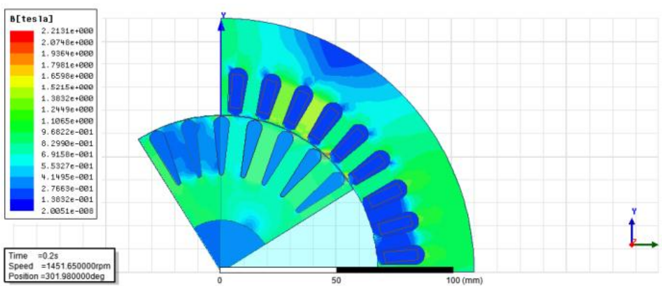


Fig.25 Flux density distribution of Induction Motor during fault condition with three broken rotor bar

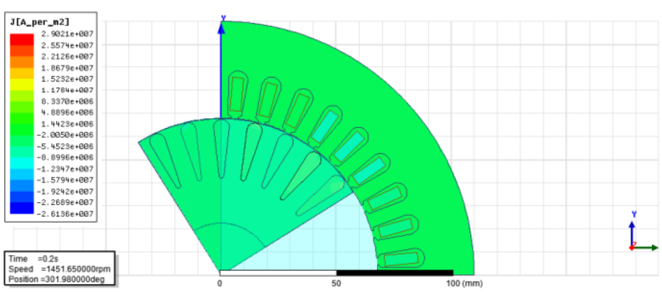


Fig.26 Current density plot of Induction Motor during fault condition with three broken rotor bar

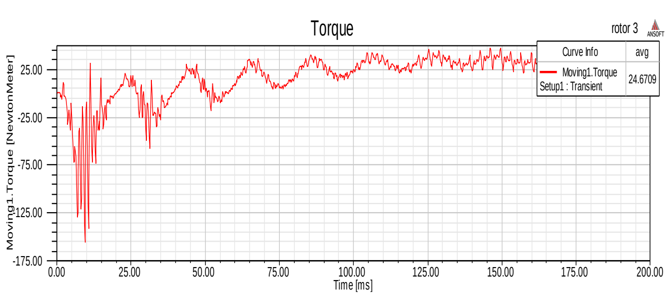


Fig.27 Torque response of Induction Motor over period of Time during fault condition with three broken rotor bar

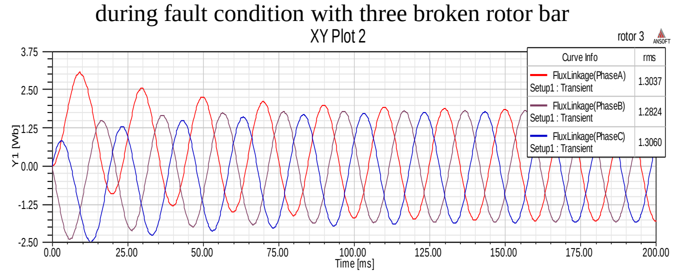


Fig.28 Flux linkage response of Induction Motor during fault condition with three broken rotor bar

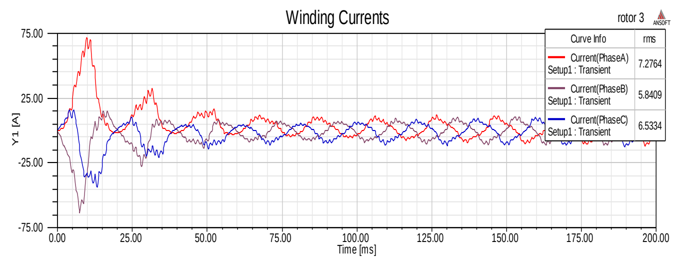


Fig.29 Current response of Induction Motor during fault condition with three broken rotor bar

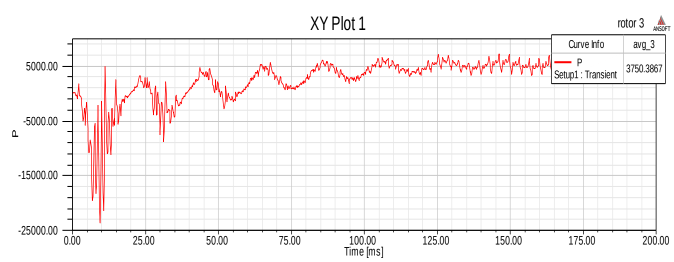


Fig.30 Output power response of Induction Motor during fault condition with three broken rotor bar

IV. Results and Discussion

The results of induction motor under various fault conditions are calculated and compared in the table below where Table 1 compares Average Magnetic Torque at two different speeds i.e.1451.65rpm and 1151.65rpm

Table :1 Average Magnetic Torque at two different Loading levels

Speed	1451.65 rpm	1151.65 rpm
Condition	Magnetic torque Nm (Average)	Magnetic torque Nm (Average)
Healthy	33.4175	29.4019
1 broken rotor bar	28.6899	29.8501
2 broken rotor bar	26.1894	29.9494
3 broken rotor bar	24.6709	30.2077

Here below in Table 2, it compares Stator Current at two different speeds i.e.1451.65rpm and 1151.65rpm.

Table :2 Stator Current at two different Loading levels

Speed	1451.65 rpm	1151.65 rpm
Condition	Stator Current A (rms)	Stator Current A (rms)
Healthy	8.9257	18.1663
1 broken rotor bar	8.1562	17.0938
2 broken rotor bar	7.66651	16.3189
3 broken rotor bar	7.2764	15.4181

Here below in Table 3, it compares Average Mechanical Power at two different speeds i.e.1451.65rpm and 1151.65rpm.

Table:4 Average Mechanical Power at two different Loading levels

Speed	1451.65 rpm	1151.65 rpm
Condition	Output Power W (Average)	Output Power W (Average)
Healthy	5080.01	3545.88
1 broken rotor bar	4361.33	3599.94
2 broken rotor bar	3981.21	3611.91
3 broken rotor bar	3750.38	3643.06

V. CONCLUSION

In this paper RM-xpert & Maxwell is used to design and predict the behavior of Induction Motor under healthy and faulty conditions. The paper address the behavior of three phase Induction Motor under healthy condition and different fault condition like rotor bar broken for different combinations. From flux density and current density contour plot we have seen the condition of motor under different fault conditions. The broken rotor bars result in increased resistance which effects torque and other factors.

From the analysis of the results we can conclude that as the severity of fault increases with increases the number of broken rotor bar, fluctuations in the magnetic torque and stator current increases. The stator current is continuously decreasing with the increase in number of broken rotor bars at both the loading levels.

REFERENCES

[1] A. H. Bonnet, "Analysis of rotor failures in squirrel cage induction machines," *IEEE Trans. Ind. Appl.*, vol. 24, no. 6, pp. 1124–1130, Nov./Dec. 1988.

[2] A. H. Bonnet and G. C. Soukup, "Cause and analysis of stator and rotor failures in three-phase squirrel-cage induction motors," *IEEE Trans. Ind. Appl.*, vol. 28, no. 4, pp. 921–937, Jul./Aug. 1992.

[3] M. L. Sin, W.L.Soong and N.Ertugrul, "Induction Machine On-Line Condition Monitoring and Fault Diagnosis - A Survey", *AUPEC2003, Australasian Universities Power Engineering Conference,* Christchurch, New Zealand, pp. 1-6, 2003.

[4] W.R. Finley, M.M. Hodowanec and W.G. Holter, "An Analytical Approach to Solving Motor Vibration Problems," *IEEE Trans. on Ind. Appl.*, vol. 36, no. 5, Sep./Oct. 2000, pp.1467-1480.

[5] N. Arthur and J. Penman, "Induction Machine Condition Monitoring with Higher Order Spectra," *IEEE Trans. on Ind. Electronics*, vol. 47, no. 5, Oct. 2000, pp. 1031- 1041.

[6] B.S. Payne, A. Ball and F. Gu, "Detection and Diagnosis on Induction Motor Faults using Statistical Measures," *International Journal of Condition Monitoring and Diagnostics Engineering Management*, vol. 5, no. 2, Apr. 2002, pp. 5-19.

[7] M.F. Cabanas, M.G. Melero, G.A. Orcajo, F. Rodriguez Faya and J. Solares Sariego, "Experimental Application of Axial Leakage Flux to the Detection of RotorAsymmetries, Mechanical Anomalies and Interturn Short-Circuits in Working Induction Motors," *Int. Conf. on Elect. Machines*, 1998, pp.420-425.

[8] Sergio CRUZ, Flavio GASPAR, "A new method to diagnose rotor faults in 3- phase induction motors coupled to time varying loads," *PRZEGLAD ELEKTROTECHNICZNY (Electrical Review)*, ISSN 0033-2097, R.88 NR 1a/ 2012, pp. 202-206

[9] Manuel Pineda- Sanchez, Martin Riera-Guasp, Jose Alfonso Antonino-Daviu, Jose Roger-Folch, Juan Perez- Cruz and Ruben Puche-Panadero, "Instantaneous frequency of the left sideband harmonic during the start –up transient: A new method for diagnosis of broken bars," *IEEE Trans. on Industrial Electronics*, Vol.56, No. 11, Nov 2009, pp. 4557-4570.

[10]Ahmed, N. Ertugrul, and W. L. Soong, "A Study on the Detection of Fault Frequencies for Condition Monitoring of Induction Machines," Australian Universities Power Engineering Conference, Tasmania, Australia 2005.

[11] R. Fiser and S. Ferkolj, "Application of Finite Element Method to Predict Damaged Induction Motor Performance," IEEE Trans. on Magnetics, Vol. 37, no 5,Sep. 2001, pp. 3635-3639.

[12] W. T. Thomson and A. Barbour, "On-Line Current Monitoring and Application of a Finite Element Modelling of Induction Motor Faults with Finite Element Method to predict the Level of Static Airgap Eccentricity in Three-Phase Induction Motors," IEEE Transactions on energy Conversion, Vol. 13, no 4, December 1998, pp. 347-352.

[13] R. J. Tallam, T. G. Habetler and R. G. Harley, "Transient Model for Induction Machines With Stator Winding Turns Faults," IEEE Transactions on I8ndustry Applications, Vol. 38, no 3, May/June 2002, pp. 632-637.

[14] E. Schaeffer, E. L. Carpentier and M. E. Zaim, "Failure Detection in Induction Machine by Means of Parametric Identification," CESA'98, IEEE Conference on Computational Engineering in Systems Applications, Nabeul-Hammament, Tunisia, 1-4 April 1998.

[15] R. Beguenane and M.E.H. Benbouzid, "Induction Motors Thermal Monitoring By Means of Rotor-Resistance Identification", IEEE Transaction on Energy Conversion, Vol. 14, No 3, September 1999, pp 566 – 570.

[16] J. F. Bangura and N. A. Demerdash, "Diagnosis and Charactization of effects of Broken Rotor Bars and Connectors in Squirrel-Cage Induction Motors by a Time-Stepping Coupled Finite Element-State Space Modeling Approach," IEEE Transactions on energy Conversion, Vol. 15, December 1999, pp. 1167-1176.

[17] R. J. Povinelli, J. F. Bangura, N. A. Demerdash and R. H. Brown, "Diagnostic of Bar and End-Ring Connector Breakage Faults in Poly-phase Induction Motors Through a Novel Dual Track of Time-Stepping Coupled FE-State Space Modelling," IEEE Transactions on energy Conversion, Vol. 17, no 1, March 2002, pp. 39-46.

[18] F. Filippetti, G. Franceschini, P. Vas and C. Tassoni "Broken Bar Detection in Induction Machines: Comparison between Current

spectrum Approach and Parameter Estimation Approach”, IEEE Industry Application Society, Vol. 1, pp. 95-102, 1994.
[19] F. Filippetti, G. Franceschini and C. Tassoni “Neural Networks Aided On-Line Diagnostics of Induction Motor Rotor Faults”, IEEE Industry Application Society, Vol. 1, pp. 316-323, 1993.
[20] M.L. Sin, W.L. Soong and N. Ertugrul, "Induction Machine On-Line Condition monitoring and Fault diagnosis- A Survey" AUPEC 2003, Christchurch, New Zealand.
[21] F. Filippetti, G. Franceschini, C. Tassoni, G. Gentile, S. Meo, A. Ometto and N.Rotondale, “Deterministic Approach and Neural Network Approach for Stator Short Circuits Diagnosis in Induction Motor,” 7 Industry Application Society, Vol. 1, pp. 316-323, 1993.
[22] M. Y. Chow, “Methodologies of Using Neural Network and Fuzzy Logic Technologies for Motor Incipient Fault Detection,” World Scientific, Singapore,1997.
[23] W. T. Thomson and M. Fenger, “Current Signature Analysis to Detect Induction Motor Faults”, IEEE Industry Applications Magazine, pp. 26-34, July/August 2001.
[24] Ahmed, R. Supangat, J. Grieger, J, N. Ertugrul, and W.L Soong, "A Baseline Study for On-Line Condition Monitoring of Induction Machines." Australian Universities Power Engineering Conference, Brisbane, Australia 2004,
[25] M.L. Sin, W.L. Soong and N. Ertugrul, "Induction Machine On-Line Condition monitoring and Fault diagnosis- A Survey" AUPEC 2003, Christchurch, New Zealand.
[26] A.A. Da Silva et al., “Rotating machinery monitoring and diagnosis using short-time Fourier transform and wavelet techniques,” in Proc. 1997 Int. Conf. Maintenance and Reliability, vol. 1, Knoxville, TN, pp. 14.01–14.15.
[27] B. S. Payne, A. Ball and F. Gu, “Detection and Diagnosis on Induction Motor Faults using Statistical Measures”, International Journal of Condition Monitoring and Diagnosis Engineering Management, vol. 5, no.2, April 2002, pp.5-19.
[28] A. H. Bonnett and G. C. Soukup, “Analysis of Rotor Failures in Squirrel-Cage Induction Motors,” IEEE Transactions on Industry Applications, vol. 24, no. 6, pp. 1124–1130, November/December 1988

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