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Modeling, Simulation and FFT Based Dynamic Performance Analysis of Three Phase Asynchronous Machine

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Abstract— ***Induction machines are very popular in renewable energy sectors and load sectors, hence; it demands continuous performance assessments of the machines. This work highlighted the Park transformation based mathematical modeling of induction machine and total harmonic distortion (THD) based performance assessments of induction machine. Reference frame theory and axis transformation-based theory is used to design and simulate the machine in MATLAB environment. Fast Fourier transformation (FFT) based THD has also been calculated on the captured stator current signals of induction motor (IM) for its performance analysis. Results have come out very much optimistic which indicates proper designing and performance assessment of this type of machines. This analysis is also equally important for the analysis of protection and control of asynchronous machines.***

Index Terms— ***Three phase induction motor, Reference frames, Dynamic models, dq0 axis transformations, FFT, THD.***

I. INTRODUCTION

Motors are used everywhere in industries and they become complex and technical, sometimes making it a challenge to keep them running at peak performance. However, the efficiency and lifetime of IMs can be considerably affected by some operating conditions, in particular those related to unbalanced supply voltages (USV), Power quality issues, Transient voltage, Harmonic distortion, Variable frequency drives, Operational overloads, Shaft voltage. This study illustrates by building a simple protection system in MATLAB Simulink. The reference theory of machine has been effectively used as an efficient approach to derive mathematical model of a 3 phase Induction motor. The author presented a step-by-step MATLAB/Simulink implementation of an induction machine using dq0 axis transformations to better understand the behavior of IM in both state (steady and transient) [1]. The author designed a system and implemented to make protection for faults due to single phasing, voltage unbalance and under voltage in a 3-ph Induction motor using Microsoft PIC 16F877 microcontroller [3]. The efficiency and lifetime of IMs can be considerably affected by unbalanced supply voltages (USV), which is quite a common condition in industrial plants. Therefore, early detection and a precise severity estimation of the USV for all working conditions can prevent major breakdowns and increase reliability and safety of industrial facilities. Author proposed a reliable method allowing for a precise and USV condition detection, by monitoring a pertinent indicator calculated using the voltage symmetrical components. The usefulness of the proposed method is validated experimentally for several different working conditions [4]. The different unbalanced conditions have been analyzed for induction machines [5]. The results prove that, the operation performance of an asynchronous machine can be analyzed using simulated result from MATLAB without going through the rigorous analytical method. Adaptive strategies for protection in power system are briefly described by author based on the following techniques: Multi-agent Systems, Artificial Neural Networks, Genetic Algorithms, Expert Systems (ES) and (FL)Fuzzy Logic [6]. And the author's reviewed that some old unsolved issues of protection can be solved and well-known protection philosophies can become more reliable and effective.

As we know that motors are used everywhere in industrial environments & motor life span depends on insulation deterioration and system of protection against different faults. Though some mechanical protections are there for insulation deterioration. But a more effective method is needed for the protection of a three-phase IM. The integration of distributed energy resources (DERs) into distribution networks is becoming increasingly important, as it supports the continued adoption of renewable power generation, combined heat and power plants, and storage systems. Hence, in this work, axis transformation theory based on Park transformation, induction motor modeling has been proposed and then THD analysis based performance assessments of induction motor has also been discussed which can reduce the down time of the industry.

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II. A MATHEMATICAL MODEL OF AN ASYNCHRONOUS MACHINE

The stator windings are identical,i.e , both windings have an identical number of effective turns N_s, identical resistance r_s , identical leakage inductance L_{1s}, and identical self-inductance L_s. Similarly, equivalent rotor windings are identical and have the same turns N_r, resistance r_r,leakage inductance L_{1r} and self inductance L_r. The equations for the rotor and stator phase voltages are written below:

Stator:

$V_{qs} = r_s i_{qs} + w\lambda_{ds} + d/dt(\lambda_{qs})$ (1)

$V_{ds} = r_s i_{ds} + w\lambda_{qs} + d/dt(\lambda_{ds})$ (2)

$V_{0s} = r_s i_{0s} + w\lambda_{qs} + d/dt(\lambda_{0s})$ (3)

Rotor: $V_{qr} = r_s i_{qr} + (w - w_r)\lambda_{dr} + d/dt(\lambda_{qr})$ (4)

$V_{ds} = r_s i_{dr} + (w - w_r)\lambda_{qr} + d/dt(\lambda_{dr})$ …… (5)

$V_{0s} = r_s i_{0r} + d/dt(\lambda_{0r})$ …… (6)

And the equations for flux linkage are:

$\lambda_{qs} = (i_{qs}L_s + L_m i_{qr})$ …… (7)

$\lambda_{ds} = (i_{ds}L_s + L_m i_{dr})$ ……… (8)

$\lambda_q = (i_{qr}L_r + L_m i_{qs})$ ……… (9)

$\lambda_q = (i_{dr}L_r + L_m i_{ds})$ ………… (10)

Putting equ^n (vii) and equ^n (viii) in (i) for finding the value of i_{qs} :

$i_{qs} = \int(1/Ls)(V_{qs} - i_{qs}r_s - L_m d/dt(i_{qr}) - wL_s i_{ds} - wL_m i_{dr})$ (11)

Putting equ^n (vii) and equ^n (viii) in (ii) for finding the value of i_{ds} :

$i_{ds} = \int(1/Ls)(V_{ds} - i_{ds}r_s - L_m d/dt(i_{dr}) + wL_s i_{qs} - wL_m i_{qr})$ (12)

Putting equ^n (ix) and equ^n (ix) in (iv) for finding the value of i_{qr} :

$i_{qr} = \int(1/Lr)(V_{qr} - i_{qr}r_r - L_m d/dt(i_{qs}) - wL_r i_{dr} - wL_m i_{ds})$. (13)

Putting equ^n (vii) and equ^n (viii) in (v) for finding the value of i_{dr} :

$i_{dr} = \int(1/Lr)(V_{dr} - i_{dr}r_r - L_m d/dt(i_{ds}) + wL_r i_{qr} + wL_m i_{qs})$ (14)

Torque equation:

$T_e = (3/2)(P/2) L_m (i_{qs} i_{dr} - i_{ds} i_{qr})$ ………… (15)

Speed Equation:

$Wr = \int(Te - Tl) * P/(2 * J)$ ……… (16)

A mathematical model of a three-phase asynchronous machine using reference theory is developed on MATLAB. The simulation is done for the analysis of speed, torque, stator & rotor current of a three-phase asynchronous machine under healthy conditions shown in fig.1.and all equations for voltage, flux, current, torque and speed are written in (i) to (xvi)

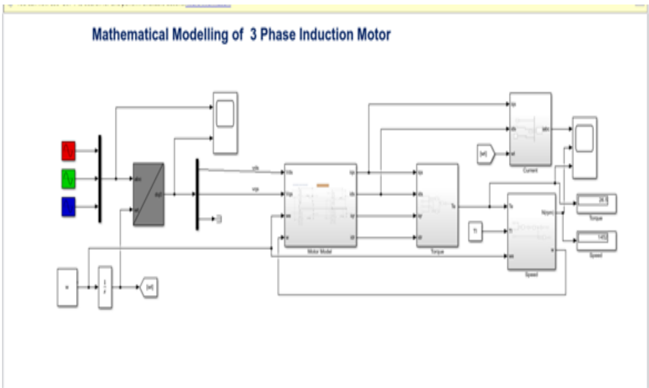

Fig 1. Mathematical Modelling of an 3 Phase Induction Machine Using MATLAB/Simulink

III. THREE PHASE INDUCTION MOTOR PARAMETERS

Table I: Electrical Parameters of a phase Induction motor

HP rating (Power)	3
Poles(P)	4
Frequency(f)	50
Line voltage (V_{line})	375 V
Magnetizing resistance(L_m)	0.1780
Rotor inertia(J)	0.0131
Base speed (w)	100*π
Load torque (Tl)	26.50
Rotor inductance (Lr)	0.1780
Stator inductance (Ls)	0.1780
Stator resistance (r_s)	1.4050
Rotor resistance (r_r)	1.3950

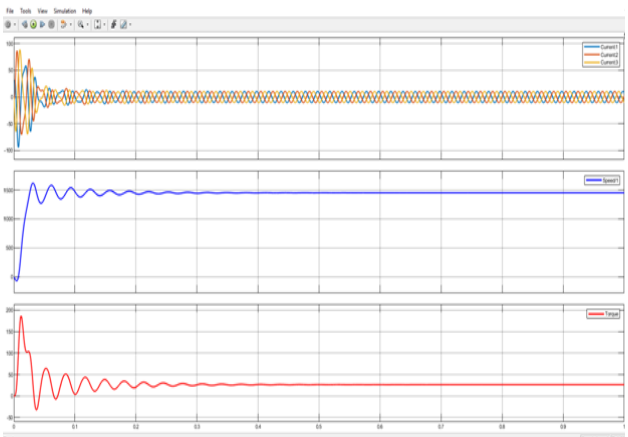

Fig2: Current, Torque & Speed curves for the healthy condition of a three phase Induction machine.

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IV. ANALYSIS AND RESULTS

Simulation of a mathematical model of three-phase asynchronous machine are done using MATLAB/Simulink in a step-by-step manner shown in fig2.The response of the machine is satisfactory in terms of the torque and speed characteristics. Initially the torque is high, when speed comes under normal condition then torque decreases.

V. HARMONIC ANALYSIS OF CURRENT IN ROTOR AND STATOR SIDE

After modeling and simulation, THD analysis has been implemented of stator and rotor current signals. For this purpose, at first three phase currents in rotor and stator side has been captured at 20 kHz sampling frequency then FFT and THD has been done for frequency analysis. In stator current signals, THD value is observed 0.45% whereas in rotor current, it is 2.21%. Fig. 3 to Fig. 5 deleniates FFT results of R,Y and B phase current signals in stator respectively and Fig. 6 is used to depict the FFT result of rotor current.

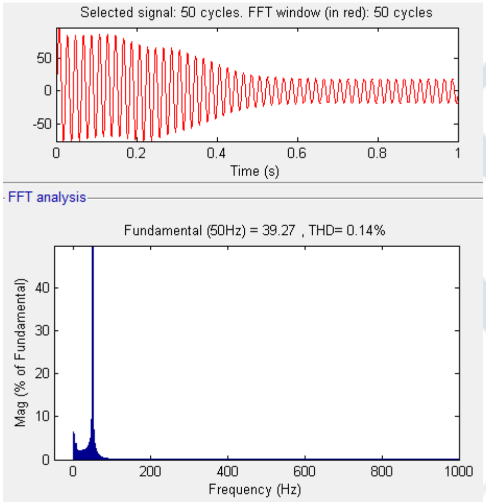

Fig. 3. FFT analysis of R phase stator currrent

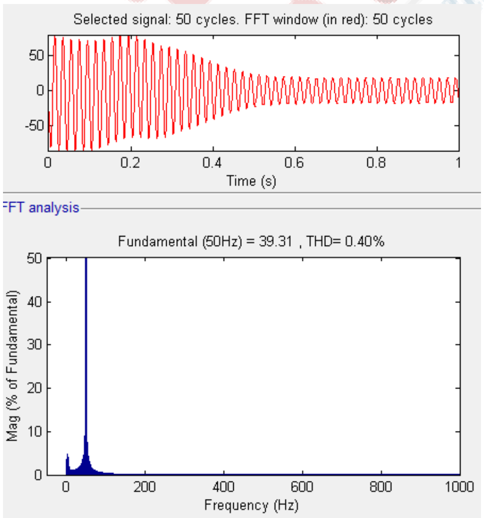

Fig. 4. FFT analysis of Y phase stator currrent

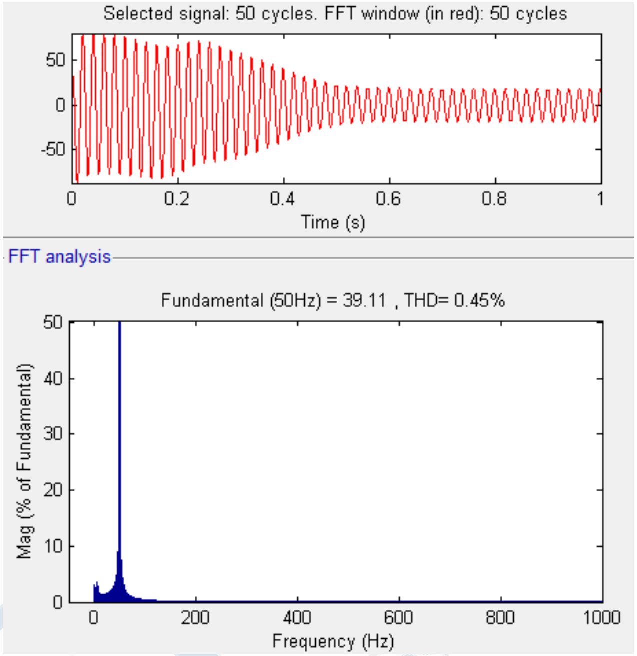

Fig. 5. FFT analysis of B phase stator currrent

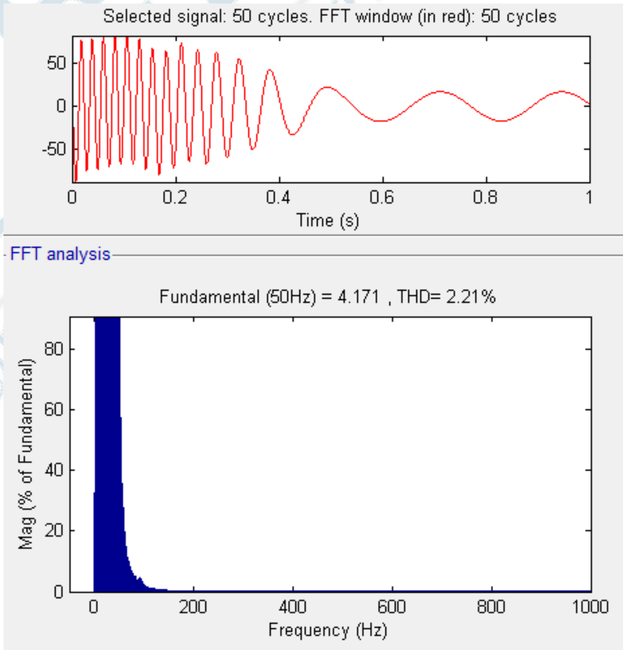

Fig. 6. FFT analysis of R phase rotor currrent

VI. SPECIFIC OUTCOME

In this analysis, a mathematical model of a three phase induction motor has been achieved and simulated in MATLAB Simulink environment. THD of stator current signals has also been measured for its performance analysis. Maximum THD has been recorded as 2% in normal condition which can be used to detect the unhealthy condition of induction motor. Here tested parameters for the model of three phase induction motor are given in Table I.

VII. CONCLUSION

Design of mathematical model of three-phase asynchronous machine in MATLAB can be used for getting the features of motors under healthy as well as faulty conditions of given ratings. It gives the advantage of independent control over the parameters. Here the THD analysis of stator current has been done in steady state condition. Maximum THD is observed very low in steady state condition. So, for furthur study, this model can be considered with changing the parameters to detect any abnormal condition of induction motor which can save the down time of the industry.

REFERENCES

[1] Ratnani, Punit L., and A. G. Thosar. “Mathematical modelling of an three phase IM using MATLAB/Simulink”, International Journal of Modern Engineering Research (IJMER) 4, no. 6 (2014): 62-67.

[2] Ms. Tripti Rai, Prof. Prashant Debre Electrical Engineering department Rajiv Gandhi college of Engineering and research Nagpur, India, “Generalized Mathematical Model Of three phase Induction Motor” 978-1-4673-9925-8/16/$31.00 ©2016 IEEE 927

[3] Aktai, Adel. "Daw ghanim,“Dynamic simulation of a3 phase induction motor using matlab simulink”, In 20th annual new foundation electrical and computer equation conference (NECEC 2011), IEEE.

[4] B. Liang “Simulation and Fault detection of three phase induction motor" TENCON'02. Proceedings. 2002 IEEE Region 10 Conference on Computers Communications Control Power Engineering vol. 3 pp. 1813-1817 28–31 Oct. 2002.

[5] [5] Mrs. M. Suidha', Dr. P. Anbalagan2, Member IEEE, Department of Electrical and Electronics Engineering, Coimbatore Institute of Technology, “A Novel Protecting Method for Induction Motor Against Faults Due to Voltage Unbalance and Single Phasing”, The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON) Nov. 5-8, 2007, Taipei, Taiwan

[6] Khaled Laadjal, Mohamed Sahraoui, Abdeldjalil Alloui and Antonio J. Marques Cardoso 1 Article “Three-Phase Induction Motors Online Protection against Unbalanced Supply Voltages”, doi.org/10.3390/machines9090203

[7] M. Kezunovic, “Intelligent systems in protection engineering”, In Power Con 2000. 2000 International Conference on Power System Technology. Proceedings (Cat. No. 00EX409), vol. 2, pp. 801-806. IEEE, 2000.

[8] B. Liang, “Simulation and Fault detection of three phase induction motor”, TENCON '02. Proceedings. 2002 IEEE Region 10 Conference o n Computers, Communications, Control Power Engineering (Volume:3), 28-31 Oct. 2002, 1813 - 1817 vol.3.

[9] W.H. Kersting, “Causes and Effects of Single-phasing Induction motors", IEEE Trans. on Industry applications, Vol.41, No.6, Nov/Dec2005, pp 1499-1505.

[10] W.H. Kersting, W.H. Phillips, “Phase Frame Analysis of the Effects of Voltage Unbalance on Induction Machines”, IEEE Trans. on Industry Applications, vol.33, No.2, March/April1997, pp415-420.

[11] Sukhjeet Singh, “Motor Current Signature Analysis for Bearing Fault Detection in Mechanical Systems”, Computer Modeling and Simulation, 2008. EMS '08. Second UKSIM European Symposium, 8- 10 Sept. 2008, pages 347 – 352.

[12] Cummings, P.B.; Dunki-Jacobs, J.R.; Kerr, R.H. Protection of induction motors against unbalanced voltage operation. IEEE Trans. Ind. Appl. 1985, IA-21, 778–792.

[13] Bento, F.J.F.; Adouni, A.; Muxiri, A.C.P.; Fonseca, D.S.B.; Cardoso, A.J.M. On the Risk of Failure to Prevent Induction Motors Permanent Damage, Due to the Short Available Time-to-Diagnosis of Inter-Turn Short-Circuit Faults. IET Electr. Power Appl. 2021, 15, 51–62.

[14] Adouni, Amel, and Antonio J Marques Cardoso. "Thermal analysis of low-power three-phase induction motors operating under voltage unbalance and inter-turn short circuit faults”,Machines 9, no. 1 (2021): 2.

[15] Bonnett, Austin H., and George C. Soukup. “Cause and analysis of stator and rotor failures in three-phase squirrel-cage induction motors", IEEE Transactions on Industry applications 28, no. 4 (1992): 921-937.

[16] Y. Takezawa et all, “Thermal Deterioration Diagnosis by Optical Fiber Sensors for Mica-epoxy Insulation of HV Induction Motors”, IEEE Transactions on Dielectrics and Electrical Insulation Vol. 8 No. 1, Februayy 2001

[17] Suri Sathya Prashant and S. Shyam Sundar et. al “Computer Aided Online Fault Diagnosis of Induction Motor”, 9 th International Conference, Electrical Power and Quality Utilization Barcelona pp. 9- 11 Oct. 2007

[18] N.A. Nordin, H. Singh, Detection and classification of induction motor faults using motor current signature analysis and multilayer perceptron, IEEE Int. Power Eng. Optim. Conf. (PEOCO) (2014) 35–40

[19] [19] M. Seera, C.P. Lim, Online motor fault detection and diagnosis using a hybrid FMM-CART model, IEEE Trans. Neural Netw. Learn. Syst. 25 (2014) 806–812.

[20] A. Siddique, G.S. Yadava, B. Singh, Identification of three phase induction motor incipient faults using neural network, IEEE Int. Symp. Electr. Insul. (2004) 30–33

[21] R. Palácios, I.N. Silva, A. Goedtel, W.F. Godoy, “A comprehensive evaluation of intelligent classifiers for fault identification in three-phase induction motors”, Elsevier Electr. Power Syst.Res. 127 (2015) 249–258,

[22] Celli, Gianni, Emilio Ghiani, Fabrizio Pilo, and Gian Giuseppe Soma. “Reliability assessment in smart distribution networks”, Electric Power Systems Research 104 (2013): 164-175.

[23] A. Bellini, F. Filippetti, C. Tassoni, and G.-A. Capolino, “Advances in diagnostic techniques for induction machines”, IEEE Trans. Ind. Electron., vol. 55, no. 12, pp. 4109–4126, Dec. 2008

[24] Zhao, Xiaoyue, and Xinyan Zhang. “Artificial intelligence applications in power system”,Advances in Intelligent Systems Research 133 (2016): 158-161.

[25] R.P. Broadwater, J.C. Thompson, S. Rahman, A. Sargent, “An expert system for integrated protection design with configurable distribution circuits. I", Power Delivery, IEEE Transactions on, vol.9, no.2, pp.1115-1121, Apr 1994.

[26] S.D.J. MacArthur, J.R. McDonald, S.C. Bell, G.M. Burt, “Expert systems and model-based reasoning for protection performance analysis”, Artificial Intelligence Applications in Power Systems, IEE Colloquium on, vol., no., pp.1/1-1/4, 20 Apr 1995.

[27] Abdelmoniem, Abdelaziz Mohamed, Abdel-Fattah Mahmoud Abdel-Fattah, Abdelmonem Asem Abdelmomem, Ahmed Refaat Mohamed Attia ElShamy, Ahmed Tarek Taha Ghoneim, El-Sayed Mohamed Gayel Mohamed, Hossam Ashraf Abdel Motaal et al. "Protective Device Coordination and Arc-Flash Hazard Analysis of Industrial Distribution Networks", (2018).

[28] Zhao, Xiaoyue, and Xinyan Zhang. "Artificial intelligence applications in power system", Advances in Intelligent Systems Research 133 (2016): 158-161.