Fault detection of electric vehicle motor based on flux performance using FEM

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ABSTRACT

This paper presents the early faults detection in electric vehicle motor based on flux performance examination in defective electrical machine using finite element methods (FEM). Depend on time step, the proposed technique has been designed and examine to produce efficient method under high accuracy and short time to detect the faults in Electric Vehicle motors. To decrease the probability and time of electric motor faults, the early detection of these faults will give enough time to prevent many problems during the motion. The different waveforms timing of motor torque in every situation associated with the waveforms of stator current provide spreading in the proposed method. The results show fast fault detections and a Novel technology was established to extort the fault of induction motor.

Keywords: Electric Vehicle, fault detection, FEM

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1. Introduction

The worldwide used of induction motors as workhorse in many applications of industry push the researchers to subject his work in this field in existing time. This type of motor is robust machines used in general reason and in dangerous places with numerous environments basically in the vehicle that work under electrical principles [1]. Based on three phase AC induction motors, high performance system in electric vehicle could be used due to production of efficient torque in the emergency applications include full size, golf cart, industry, and motorcycle [2]. In addition, high area gardening, effectiveness vehicle, and recreational facility as golf route and enjoyment park magnetism [3]. The major reason to adopting the IM is severity, effectiveness cost, and reliable in all desired quality for electronic vehicle and high-performance electrical vehicles [4]. Hence, its recognized to variety of fault will occur in these types of motors through usual operation such as broken bar and end ring faults, stator inter turn, bearing faults, and eccentricity faults [5]. The motor fault that is not identifying in a first phase might become shattering and the induction motors will undergo many damages [6]. As a result, the undetected motor fault will cascade into motor failure and then shutdown the vehicles. These shutdowns are costly in term of lost time, waste raw material, and maintenance cost [7]. The most common fault in electric motor is inter turn short-circuits in the stator coil and this will increase the motor heating due to this short circuits which lead to turn to ground fault and inter turn fault [8]. These types of faults are typically basis by mechanical stresses, partial and moisture discharges and this will accelerate for electrical machine supply by the inverter [9]. The allocation of magnetic field parameter in the inter turn stator winding fault will distorted and the stored energy is reduced when the sternness of winding is increased [10]. The analysis of magneto static based of finite element analyzing is used to conclude the difference of flux and stored energy in the electrical machine [11]. Hence, based on this analyzing, the variety of magnetic flux, stored energy, and magnetic flux density could be computed correctly [12]. For security of 4-whell and direct drive electronic vehicle have to present minimum torque ripple to offer high driving soothe and vibration reducing [13]. Some rotor shape usher still in dangerous trouble and less torque. Hence, inappropriate rotor slot design guide to terrible torque behavioral with unwanted noise of IM [14-20]. Many studies were introduced to improve the motor starting behavioral, outcome of torque, and efficiency by change the shape and rotor slot type as in [20-30]. the disadvantage and advantage of all these parameters are indicated and torque is compared with harmonic specific to rotor current density for many rotor slot based on finite element analysis which provide achievable values. Numerical tools were established for the parameter analysis of electromagnetic phenomena in electric machine and valuable tool for motor designing. The non-load test and locked rotor are carried out in this analysis. As a result, the current density harmonic controlling in rotor slots is important in the unhealthy and healthy induction motor. The result of simulation phase show that the best outline of rotor slot is around shape since the gain in torque ripple peak to peak might attain to 50% compare with rectangular shape. In addition, the total harmonic distortion is considerably attenuated.

2. Research problem

Currently, the electric vehicles in the market suffer from many malfunctions while moving in remote areas, and the possibility of stopping them in areas far from the control center is very high due to many faults in the motors.

3. Purpose of search

The objective of the current study is to introduce an impact rotor geometry parameter such as shape, rotor slot type, rotor slot number, efficiency, electromagnetic noise, and torque performance to detect these faults as earlier as possible.

4. Limitations Technologies.

The limitations, deficiencies of existing technologies is not have faults prediction techniques in the services place before its happen in the road.

5. Materials and methods

To investigate the induction motor damages and modelling the fault diagnosis, the winding function and FEM techniques is used in this work. The electromagnetic symmetric presentation in the induction motor can be used in the proposed model that point out any symmetric degree signs as shown in Figure 1.

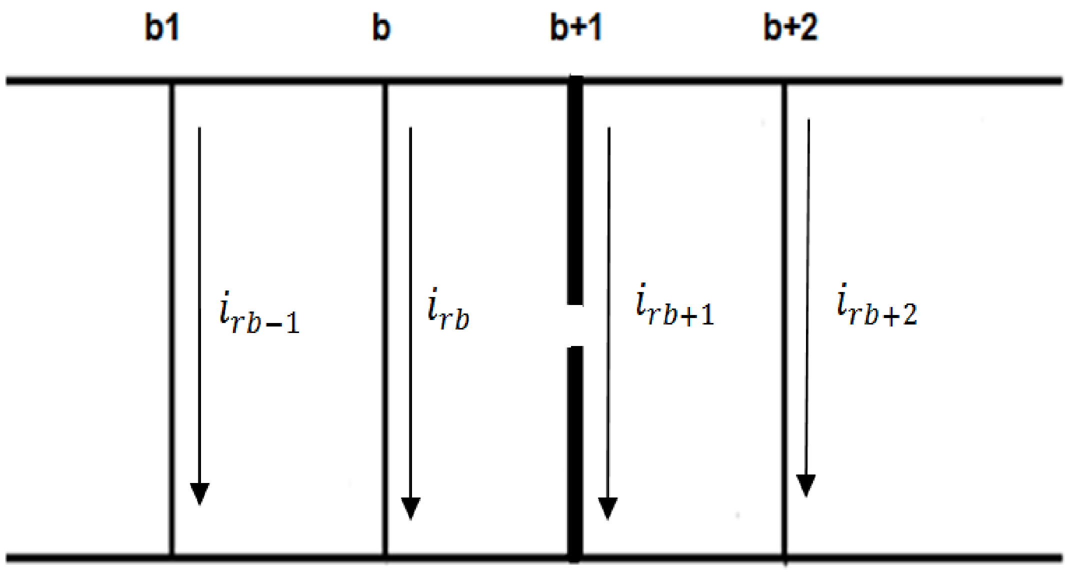

Figure 1. Spreading structure

In the motor, the asymmetric of electromagnetic field generate unequal in the phase resistance and electromagnetic field in the air gap which produce a harmonic frequency in the rotor and stator current. The mathematical model of these phenomena can be expressed to add additional resistance to rotor or phase.

$$\Delta r_{ra,b,c} = \frac{3n_{bb}}{N_b - 3n_{bb}} r_r \quad \text{.......... (1)}$$

were,
$\Delta r_{ra,b,c}$ is the phases modifies of rotors resistance.

The rotor effect produced a change which is derive depend on statement of broken bar by touch either magnetizing current or ring end resistance. The healthy machine resistance then could be expressed as:

$$r_r = \frac{(2N_S)^2}{N_b/3}\left[r_b + \frac{2}{N_b(2\sin\frac{\alpha}{2})^2} r_e\right] \quad (2)$$

where,
r_b , r_e is the resistances of rotor bar and end-ring
N_s is the winding turn

To simplify equation 2, assume r_e deserted, then equation 2 become:

$$r_r \approx \frac{(2N_s)^2}{N_b/3} r_b \quad (3)$$

And

$$r^*_r \approx \frac{(2N_s)^2}{\frac{N_b}{3} - n_{bb}} r_b \quad (4)$$

Hence

$$\Delta_r = r^*_r - r_r = \frac{3n_{bb}}{N_b - 3n_{bb}} r_r \quad (5)$$

$$\Delta I = f(\Delta_r) \quad (6)$$

Then the second quantifiable fault appraisal is:

$$\frac{I_{bb}}{I} = \frac{\sin\alpha}{P(2\pi - \alpha)} \quad (7)$$

Where
I_{bb} and I is a sideband frequency amplitude and α: is the angle of electrical

Consequently, the electrical angle could be articulated as:

$$\alpha = \frac{\pi P n_{bb}}{N_b} \quad (8)$$

to diagnosis the broken bar consequence in three phase motors, the FEM approaches is used to achieve accurate computing of faulty and healthy status with data collection of different flux source waveforms. These data could be used to extracts diverse signal of faults types without destroy the motor. In this work, opera 2D programs have been used to detect and observe the fault with proof providing of suggest approaches. The rated motor plots in symmetric and asymmetric rotor status are presents also. Figure 2 and Figure 3 illustrate the healthy and faulty motor flux density with low unbalance because the rotating field generated by faulty motors.

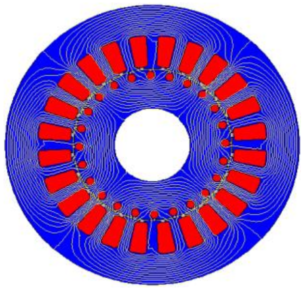

Figure 2: healthy machine

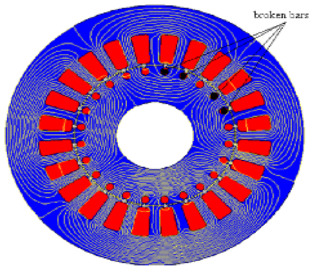

Figure 3. Faulty machine

6. Results and discussion

In the healthy and faulty state, the current through stator under load condition is illustrated in Figure 3. The current in the stator increased according to fine rotor due to the harmonic components which cause by fault and overlay into current of stator winding at frequency f_b. Intention to fault on one pole produce an increase in the harmonic mechanism values because of fault soused flux scattering carelessness and this will generate extra harmonic. The amount of creating flux is frequency with rotating waveform of flux. The waves of rotating flux could support current in equal frequencies associated with stator current. Figure 4 shows the faulty and healthy stator current condition.

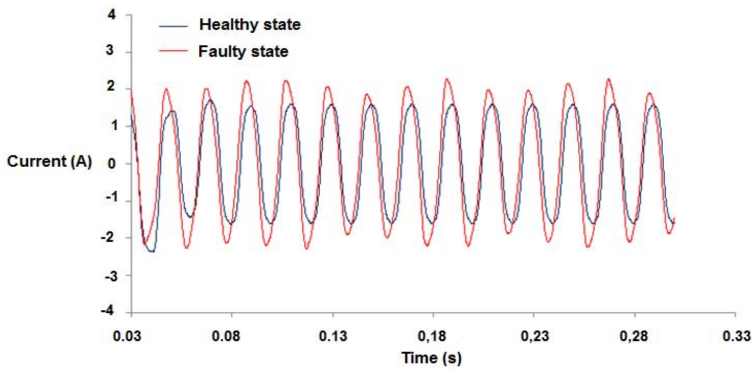

Figure 4. Faulty and healthy state condition in stator current

Due to the fault situation, the highlight different between two stator amplitude is because of asymmetric flux distribution which create more harmonic in the fault of motor performances. Therefore, any increase of broken bar number produces bad asymmetric flux. High rise in frequency harmonics could be showing in case of harmonic amplitude increasing of flux waveform. Besides, one can observe that the harmonics in the faulty motor applier more asymmetric compare with healthy motors. The air gap of magnetic flux in to state of motor is illustrated in Figure 5 with clear difference between them.

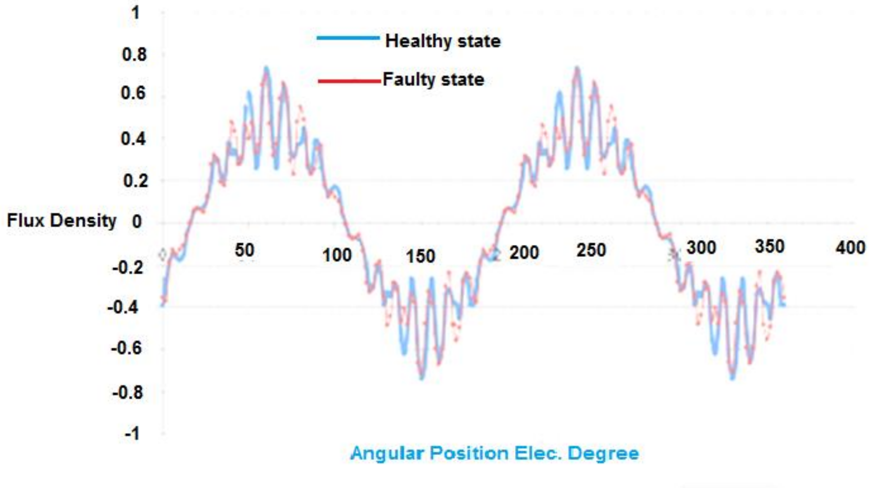

Figure 5. Faulty and healthy magnetic flux of Air gap

The magnetic torque waves in damage motor are more comparing in healthy machine as shown in Figure 6. The torque time variation in faulty and healthy machine is developed and increased in four situations in faulty machine more than conventional enveloped in healthy motor with high values. The torque shape time variation in faulty machine looks more than healthy motor with high ripple.

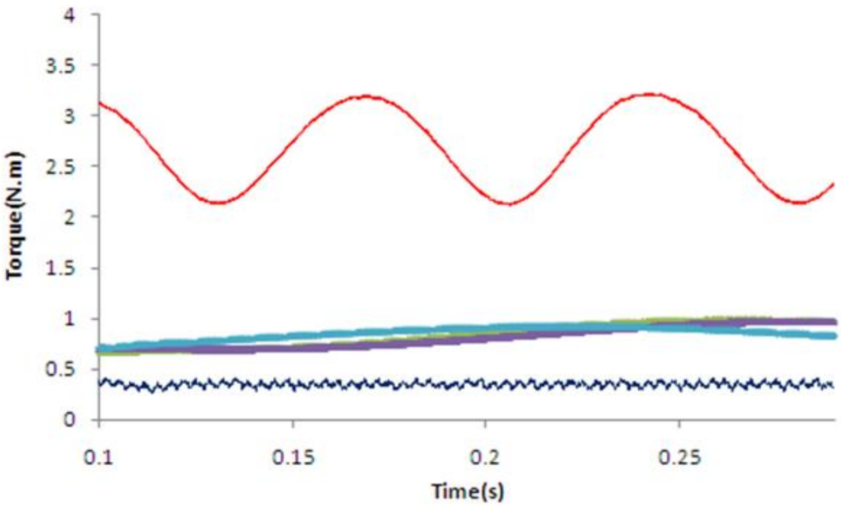

Figure 6. The torque distribution different

7. Conclusion

The fault detection in broken bar induction motor is presents in this paper. Under Opera -2d, this work is examined and evaluated as new approaches which will increase motor efficiency and the time life is high. The detection of fault in the motor in early time provides enough time to protect the motor with minimum cost by different phase in the running times. An enhanced of suggested methods offer developed technology to the fault detection in future and existing generation of induction motors.

References

[1] J. K. Noland, M. Leandro, J. A. Suul, and M. Molinas, “High- Power Machines and Starter-Generator Topologies for More Electric Aircraft: A Technology Outlook,” IEEE Access, vol. 8, pp. 130 104– 130 123, 2020.

[2] E. G. Strangas, S. Aviyente, J. D. Neely, and S. S. H. Zaidi, “The Effect of Failure Prognosis and Mitigation on the Reliability of Permanent-Magnet AC Motor Drives,” IEEE Transactions on Industrial Electronics, vol. 60, no. 8, pp. 3519–3528, 2013.

[3] A. Muetze and E. G. Strangas, “The Useful Life of Inverter-Based Drive Bearings: Methods and Research Directions from Localized Maintenace to Prognosis,” IEEE Industry Applications Magazine, vol. 22, no. 4, pp. 63–73, 2016.

[4] W. R. Jensen, E. G. Strangas, and S. N. Foster, “A Method for Online Stator Insulation Prognosis for Inverter-Driven Machines,” IEEE Transactions on Industry Applications, vol. 54, no. 6, pp. 5897–5906, 2018.

[5] X. Jin, Z. Que, Y. Sun, Y. Guo, and W. Qiao, “A Data-Driven Approach for Bearing Fault Prognostics,” IEEE Transactions on Industry Applications, vol. 55, no. 4, pp. 3394–3401, 2019.

[6] L. Frosini, “Monitoring and diagnostics of electrical machines and drives: A state of the art,” in Proceedings of the 2019 IEEE WEMDCD, 2019, pp. 22–23.

[7] D. Verginadis, J. Antonino-Daviu, A. Karlis, and M. G. Danikas, “Diagnosis of stator faults in synchronous generators: Short review and practical case,” in Proceedings of the 2020 ICEM, vol. 13, 2020, pp. 5066–5087.

[8] M. Irhoumah, R. Pusca, E. Lefevre, D. Mercier, R. Romary, and C. Demian, “Information Fusion with Belief Functions for Detection of Interturn Short-Circuit Faults in Electrical Machines Using External Flux Sensors,” IEEE Transactions on Industrial Electronics, vol. 65, no. 3, pp. 2642–2652, 2018.

[9] M. Irhoumah, R. Pusca, E. Lefevre, D. Mercier, and R. Romary, “Detection of the Stator Winding Inter-Turn Faults in Asynchronous and Synchronous Machines Through the Correlation Between Harmonics of the Voltage of Two Magnetic Flux Sensors,” IEEE Transactions on Industry Applications, vol. 55, no. 3, pp. 2682–2689, 2019.

[10] G. Mirzaeva and K. I. Saad, “Advanced Diagnosis of Stator Turn- to-Turn Faults and Static Eccentricity in Induction Motors Based on Internal Flux Measurement,” IEEE Transactions on Industry Applications, vol. 54, no. 4, pp. 3961–3970, 2018.

[11] A. C. P. Muxiri, F. Bento, D. S. B. Fonseca, and A. J. M. Cardoso, “Thermal analysis of an induction motor subjected to inter-turn short- circuit failures in the stator windings,” in Proceedings of the 2019 ICIEAM, 2019, pp. 25–29.

[12] J. Yun, S. W. Park, C. Yang, S. B. Lee, J. A. Antonino-Daviu, M. Sasic, and G. C. Stone, “Airgap Search Coil-Based Detection of Damper Bar Failures in Salient Pole Synchronous Motors,” IEEE Transactions on Industry Applications, vol. 55, no. 4, pp. 3640–3648, 2019.

[13] J. Antonino-Daviu, V. Fuster-Roig, S. Park, Y. Park, H. Choi, J. Park, and S. B. Lee, “Electrical Monitoring of Damper Bar Condition in Salient-Pole Synchronous Motors Without Motor Disassembly,” IEEE Transactions on Industry Applications, vol. 56, no. 2, pp. 1423–1431, 2020.

[14] H. Castro-Coronado, J. Antonino-Daviu, A. Quijano-Lopez, P. Llovera- Segovia, and V. Fuster-Roig, “Stray-flux and current analyses under starting for the detection of damper failures in cylindrical rotor synchronous machines,” in Proceedings of the 2020 ICEM, 2020, pp. 23– 26.

[15] M. Jeong, J. Yun, Y. Park, S. B. Lee, and K. N. Gyftakis, “Quality Assurance Testing for Screening Defective Aluminum Die-Cast Rotors of Squirrel Cage Induction Machines,” IEEE Transactions on Industry Applications, vol. 54, no. 3, pp. 2246–2254, 2018.

[16] K. N. Gyftakis, D. V. Spyropoulos, I. Arvanitakis, P. A. Panagiotou, and E. D. Mitronikas, “Induction motors torque analysis via frequency extraction for reliable broken rotor bar detection,” in Proceedings of the 2020 ICEM, 2020, pp. 23–26.

[17] P. A. Panagiotou, I. Arvanitakis, N. Lophitis, J. A. Antonino-Daviu, and K. N. Gyftakis, “On the broken rotor bar diagnosis using time–frequency analysis: ‘Is one spectral representation enough for the characterisation of monitored signals?’,” IET Electric Power Applications, vol. 13, no. 7, pp. 932–942, 2019.

[18] P.A. Panagiotou, I. Arvanitakis, N. Lophitis, et al., “A new approach for broken rotor bar detection in induction motors using frequency extraction in stray flux signals,” IEEE Trans. Ind. Appl, vol. 55, pp. 3501–3511, 2019.

[19] K. N. Gyftakis, P. A. Panagiotou, and S. B. Lee, “The role of the mechanical speed frequency on the induction motor fault detection via the stray flux,” in Proceedings of the 2019 SDEMPED, 2019, pp. 27–30.

[20] J. A. Ramirez-Nunez, J. A. Antonino-Daviu, V. Climente-Alarcon, A. Quijano-Lopez, H. Razik, R. A. Osornio-Rios, and R. de J. Romero- Troncoso, “Evaluation of the Detectability of Electromechanical Faults in Induction Motors Via Transient Analysis of the Stray Flux,” IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 4324–4332, 2018.

[21] V. Fernandez-Cavero, J. Pons-Llinares, O. Duque-Perez, and D. Morinigo-Sotelo, “Detection of broken rotor bars in non-linear startups of inverter-fed induction motors,” in Proceedings of the 2019 SDEMPED, 2019, pp. 27–30.
[22] W. F. Godoy, I. N. D. Silva, A. Goedtel, R. H. C. Palácios, P. Scalassara, D. Moriñnigo-Sotelo, and O. Duque-Perez, “Detection of broken rotor bars faults in inverter-fed induction motors,” in Proceeding of the 2018 ICEM, 2018, pp. 3–6.
[23] B. Asad, T. Vaimann, A. Belahcen, and A. Kallaste, “Broken rotor bar fault diagnostic of inverter fed induction motor using FFT, Hilbert and Park’s vector approach,” in Proceeding of the 2018 ICEM, 2018, pp. 3–6.
[24] D. V. Spyropoulos, E. D. Mitronikas, and E. S. Dermatas, “Broken rotor bar fault diagnosis in induction motors using a Goertzel algorithm,” in Proceeding of the 2018 ICEM, 2018, pp. 3–6.
[25] S. H. Kia, “Monitoring of wound rotor induction machines by means of discrete wavelet transform,” Electr. Power Compon. Syst, vol. 46, pp. 5066–5090, 2018. [26] S.-M. M. Moosavi, J. Faiz, M. B. Abadi, and S. M. Cruz, “Comparison of rotor electrical fault indices owing to inter-turn short circuit and unbalanced resistance in doubly-fed induction generator,” IET Electric Power Applications, vol. 13, no. 2, pp. 235–242, 2019.
[27]I. Zamudio-Ramirez, J. A. Antonino-Daviu, R. A. Osornio-Rios, R. de Jesus Romero-Troncoso, and H. Razik, “Detection of Winding Asymmetries in Wound-Rotor Induction Motors via Transient Analysis of the External Magnetic Field,” IEEE Transactions on Industrial Electronics, vol. 67, no. 6, pp. 5050–5059, 2020.
[28] J.-C. Urresty, J.-R. Riba, M. Delgado, and L. Romeral, “Detection of Demagnetization Faults in Surface-Mounted Permanent Magnet Synchronous Motors by Means of the Zero-Sequence Voltage Component,” IEEE Transactions on Energy Conversion, vol. 27, no. 1, pp. 42–51, 2012.
[29] D. Reigosa, D. Fernandez, M. Martinez, Y. Park, S. B. Lee, and F. Briz, “Permanent Magnet Synchronous Machine Non-Uniform Demagnetization Detection Using Zero-Sequence Magnetic Field Density,” IEEE Transactions on Industry Applications, vol. 55, no. 4, pp. 3823–3833, 2019.
[30] A. A. Salah, D. G. Dorrell, and Y. Guo, “A Review of the Monitoring and Damping Unbalanced Magnetic Pull in Induction Machines Due to Rotor Eccentricity,” IEEE Transactions on Industry Applications, vol. 55, no. 3, pp. 2569–2580, 2019.