Caner AKÜNER, İsmail TEMİZ

Marmara University Technical Education Faculty

Symmetrically broken rotor bars effect on the stator current of squirrel-cage induction motor

Abstract. *End rings and broken rotor bars are common faults in squirrel cage induction motors. For this purpose various broken rotor bars would have been obtained on a special designed rotor of a squirrel cage induction motor. Desired real current data of the broken bars through rings and brushes special designed a squirrel cage of induction motor have been measured. In this study, a three-phase with special designed rotor of a faulty squirrel cage induction motor have been run under nominal load. Stator current wave form analysis has been obtained. This obtained data are compared with stator current of the healthy condition of the rotor bars. The effects of the faults over the stator currents are investigated.*

Streszczenie. *Połamane pręty wirnika są najczęstszą przyczyną defektów silników indukcyjnych. Dlatego przeprowadzono badania wykorzystując różne egzemplarze takich prątów. W artykule przedstawiono wyniki badań silnika trójfazowego z uszkodzonymi prętami poddanego nominalnemu obciążeniu. Wyniki porównano z rezultatami badań silnika nieuszkodzonego. (**Wpływ uszkodzeń prętów wirnika silnika klatkowego indukcyjnego na prąd stojana**)*

Keywords: Induction motor, rotor bar break, rotor harmonics, symmetric broken effect.
Słowa kluczowe: silnik indukcyjny, pręty wirnika.

Introduction

To It is necessary time for starting-up and stopping of an induction motor. In case of the broken rotor starting-up time of the motor lasts longer or motor doesn't turn. Therefore, broken rotor bars of the rotor should be investigated. Moreover, motor with one or two broken bar of the rotor could be run. But starting-up time of the motor gets longer and current value of the stator increases[1-3].

The temperature increase around the cracked or broken bars of the rotor electric arc produces around broken bars region. This can be made damage to the lamination of the rotor body close to the broken bars region. This the reason for passing the broken bar current from the adjacent bars, and these adjacent bars transfer larger current and generate a larger stress to make enough torque. Hence, a new period of cracking begins; if a rotor bar is broken, the adjacent bars are opposed on a fault due to large applied stress. This means following the first broken bar and after a short period, other bars may be broken. The reasons cracking or broken of rotor bars could be given as follow as:

- Over load, non-uniform heat distribution, thermal stress due to over load, hot spot and arc
- Magnetic stress due to electromagnetic forces, Magnetic asymmetry forces, noises and electromagnetic vibrations.
- Residual stress from the fabrication process
- Dynamic stress due to rotor axial torque and centrifugal forces.
- Circumferential stress due to wearing and pollution of rotor material by chemical materials and humidity
- Mechanical stress due to mechanical fatigue of different parts, ball bearing damage, loosens laminations etc.
-

Stator winding model

It can be assumed that the stator winding is fully symmetrical. Generally, the number of stator phases is three for industrial type induction motors. Three phase sinusoidal voltage is applied to the induction motors. In this case the stator voltage equation can be written as

$$V_{S[i]} = R_S I_{S[i]} + L_{S\sigma}\frac{dI_{S[i]}}{dt} + \sum_{j=1}^{3} L_{Sm[i.j]}\frac{dI_{S[j]}}{dt} + \sum_{j=1}^{Nr} L_{Sm[i.j]}\frac{dL_{Sr[i.j]}I_{r[j]}}{dt} \quad (1)$$

In this equation VS and IS and Ir are the stator voltage and current and the rotor current, respectively. Due to the symmetry of the stator winding stator resistance RS and stator stray inductance LS are symmetrical.

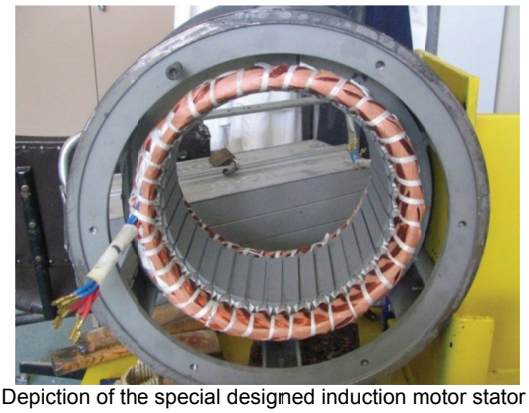

Fig.1 Depiction of the special designed induction motor stator part

Mutual coupling inductances between the stator and rotor influence on the stator voltage and stator current also. The effective number of turns, WS may be determined from a winding topology, which is indicated by the begin and end location and the number of turns of the stator winding coils. Alternatively, a symmetric stator winding can be parameterized by entering the effective number of turns[3-5].

Rotor winding model

Equivalent circuit diagrams both healthy and faulty condition of the special designed induction motor rotor is depicted in fig.2 are given in fig.3

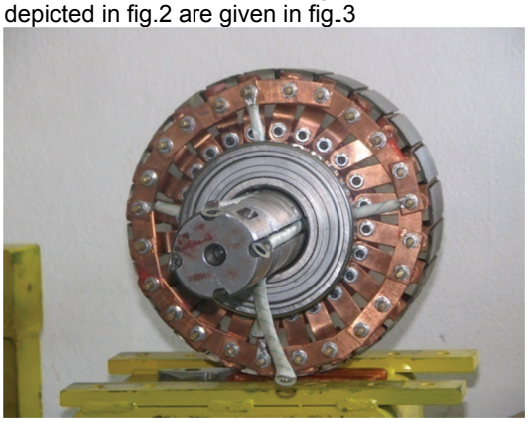

Fig.2 Depiction of the special designed rotor

Symmetrical rotor cage of the equivalent circuit diagram referred to the induction motor stator on a per phase basis of rotor parameters are given in Eq.2.and Eq.3

The rotor voltage equation can be derived from the topology of the squirrel cage. The relationship between the symmetric rotor bar and end ring resistance and rotor resistance with respect to the stator side is determined by

$$R_r^{'} = 2\frac{3w_S^{\ 2}\xi_S^{\ 2}}{N_r\xi_r^{\ 2}}\left\{R_{e.sym} + R_{b.sym}\left[1-\cos\left(\frac{2\pi p}{N_r}\right)\right]\right\} \quad (2)$$

A similar equation can be obtained for the rotor leakage inductance with respect to the stator side,

$$L_{r\sigma}^{'} = 2\frac{3w_S^{\ 2}\xi_S^{\ 2}}{N_r\xi_r^{\ 2}}\left\{L_{e\sigma.sym} + L_{b\sigma.sym}\left[1-\cos\left(\frac{2\pi p}{N_r}\right)\right]\right\} \quad (3)$$

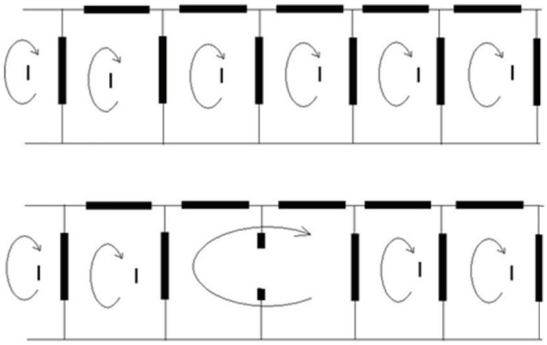

Fig.3 Rotor equivalent circuit

Fig.3 Distributed rotor cage in healthy induction motor with one broken rotor bar

Equivalent circuit diagrams are given in fig.3 both and Faulty condition of the special designed induction motor rotor is depicted in fig.2.

Experimental Study

Balanced three phase sinusoidal voltage is applied to stator of the special designed induction motor. Variations of the input currents for healthy condition and for symmetric broken two bars, and symmetric broken four bars and symmetric broken eight bars and adjacent broken six bars conditions have been measured with 434 Fluke type power analyzer. Measurement results for healthy condition in fig.4 for symmetric broken bars in Figs.5.6.7 and adjacent broken six bars in fig.8 are depicted.

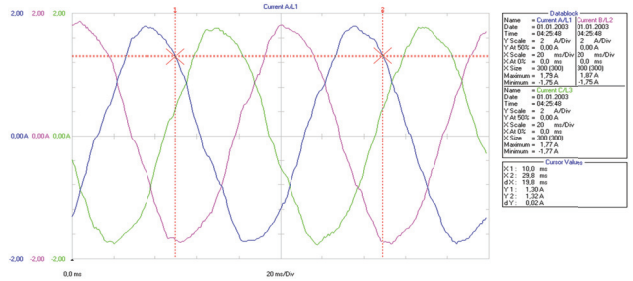

Fig.4 Healthy condition

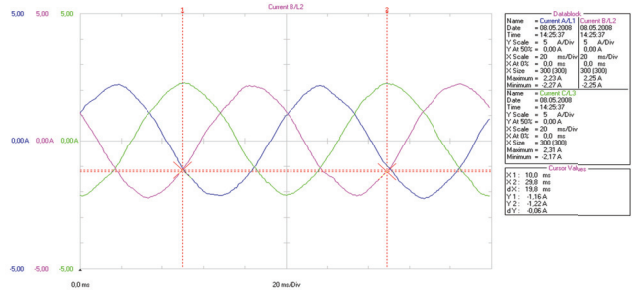

Fig.5 Symmetric broken two bars,

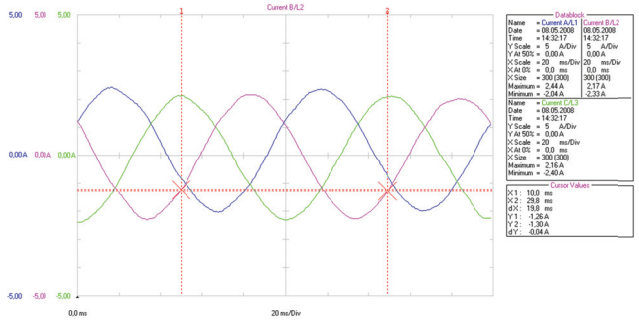

Fig.6 Symmetric broken four bars (Counter broken two bars),

Broken rotor effects have been evaluated from high level harmonics of the measured motor currents. Motor current harmonics is given in Table1.

Table 1. Current harmonics

Frequency (Hz)	Healthy motor stator current (A)	broken two bars stator current (A)	broken four bars stator current (A)
0	0,022418	0,027916	0,098488
50	1,240281	1,524140	1,535774
100	0,003094	0,005500	0,006806
150	0,009397	0,004334	0,010210
200	0,002349	0,002381	0,005534
250	0,035640	0,027536	0,021373
300	0,002658	0,004032	0,005000
350	0,004553	0,001242	0,001457
400	0,001035	0,002646	0,001470
450	0,002264	0,001291	0,001509

Conclusions

Broken rotor effects have been investigated on the squirrel cage induction motors from experimental studies. As the broken rotor bar's number is increased, the stator current is driven from the source will be increased to compensate to the load power. As 3'th ,7'th and 9'th harmonics are decreased, 5'th and 1'st harmonics 50Hz. are increased. In addition to, broken rotor bars causes unsymmetrical running and appears even harmonics of the motor. It has been seen almost each frequency increasing from even harmonic components of the rotor current. More ever, DC component of the source frequency is increased % 340 percent after two broken bars.

REFERENCES

[1] Al-Jufout S. Analysis of the induction motor reclosing process. In: Proceedings of the 2nd Middle East Symposium on Simulation and Modeling. SCS;2000. p. 115–9.

[2] Jianyi C, Smith RH. High efficiency induction motors design. In: 29th Universities Power Engineering Conference (UPEC'94), Ireland, 14±16 Sept. vol. 1. 1994. p. 13±6.

[3] Fitzgerald AE, Kingsley Jr C, Umans SD. Electric machinery. UK: McGraw Hill;1992.

[4] Al-Jufout S. Modeling of transients and steady-state operation of the induction motor. In: Proceedings of the 11th European Simulation Symposium. SCS;1999. p. 670–

[5] Nasar SA. Handbook of electric machines. New York, USA: McGraw-Hill, 1987.

[6] Andreas JC. Energy ascent electric motors. New York and Basel: Marcel Dekker, 1988.

Authors

Ph.D Caner Aküner Marmara University, Tehnical Education Faculty Electrical Education Dept. Goztepe Campus, Kadikoy, Istanbul, TÜRKİYE akuner@marmara.edu.tr

Ph.D Ismail TEMİZ, Marmara University, Tehnical Education Faculty Electrical Education Dept. Goztepe Campus, Kadikoy, Istanbul, TÜRKİYE, itemiz@marmara.edu.tr