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Detection and Diagnosis faults in Machine asynchronous based on single processing

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Abstract – *In this work, we proposed multi-winding model for the simulation of broken bars in squirrel cage asynchronous machine, this model allows to study the influence of the broken bar defects on the behavior general of machines in different operating conditions (healthy and faulty). The breaking of the most frequent bars of the rotor causes oscillations of the torque, speed, and the current, the increase of the resistance of the rotor creates the defects proportional with the number of breaks bar K .The diagnosis fault using technique of single processing based on Spectrum analysis for detection broken bar. The results of the simulation obtained allowed us to show the importance of this technique for detection broken bar.*

Keywords: *Machine asynchronous, Spectrum analysis, FFT, Detection, Diagnosis, Broken bat.*

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I. Introduction

The fault diagnosis induction motors are component of many industrial processes applications, because of their robustness, cost, and performance and used in wide variety of application of a mean of converting energy, pumps, electric vehicle and asynchronous generator [1] [2]. Major faults of electrical machines can broadly be classified as the following: stator faults, broken rotor bar, faults bearing are the most prevalent [3-4].

MCSA (motor current signature analysis) this work is the topic of several research works used to find out various faults such as: the impact of broken rotor bar to the stator current can be determined by analysing in the frequency [5-6].

The analysis of the stator current spectrum around the fundamental frequency current is used to diagnose the fault. And appear the amplitudes of the frequency components are increased because of the exists defect according relation $(1\pm2s)f_s$ [7].

In this work, we presented Multi-winding model for simulate the machine behavior in case healthy and fault when broken bar, the faults diagnosis is based on technique of single processing very important for detection rotor fault in the asynchronous machine.

II. Fault detection of induction motor

II.1. Detection of broken bars

Broken rotor bars can be detected by monitoring the stator current spectral components. These spectral components as in (1) [8]:

$$f_{brb} = (1 \pm 2ks) f_s \tag{1}$$

Where s is the per-unit motor slip and k =1,2,3,4…..etc.

The amplitude of the left sideband is proportional to the number of broken bars. The spectral component associated with broken rotor bars is found at the frequency, $(1 \pm 2s)f_s$. These two frequencies $(1 - 2s)f_s$ and $(1 + 2s)f_s$ are the classical twice slip frequency sidebands due to the broken bar [9].Figure. 1 picture show the bar broken used for the simulation study.

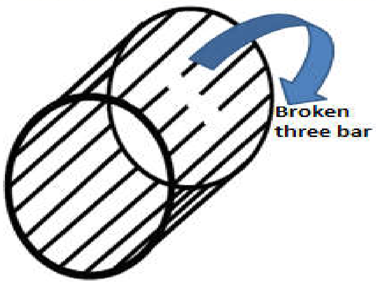

Figure 1.picture show the two bar broken adjacent

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II.2. *Techniques of single processing for faults detection*

Analysis by signal processing of quantities (current, voltage and power) can give a real picture of the imbalances that which happen in the machine, the advancement techniques of signal processing in field mechanical, the frequency in the signal become very important part of the detection of the rotor fault in the induction motor [10]. This analysis is based on classical techniques such as Fourier Analysis (FFT). The Fourier transform is as in (2):

$$X_{(f)} = \int_{-\infty}^{+\infty} x(t)\, e^{-2\pi f}\, dt \tag{2}$$

Fourier analysis is very useful for many applications where the signals are stationary.

III. Multi-winding model of the asynchronous machine

The model of the asynchronous takes into account the following hypotheses [11-12]:

- Negligible saturation and skin effect,
- Uniform air-gap,
- Sinusoidal MMF of stator windings in air-gap,
- Rotor bars are insulated from the rotor, thus no inter-bar current flows through the laminations,
- Relative permeability of machine armatures is assumed infinite.

Although the MMF of the stator windings supposed is to be sinusoidal, other distributions of rolling up could also be considered by simply employing the superposition theorem. It is justified by the fact that the different components of the space harmonics do not interact. In order to study the phenomena taking place in the rotor, the latter is often modeled by N_R meshes as shown on Figure 2.

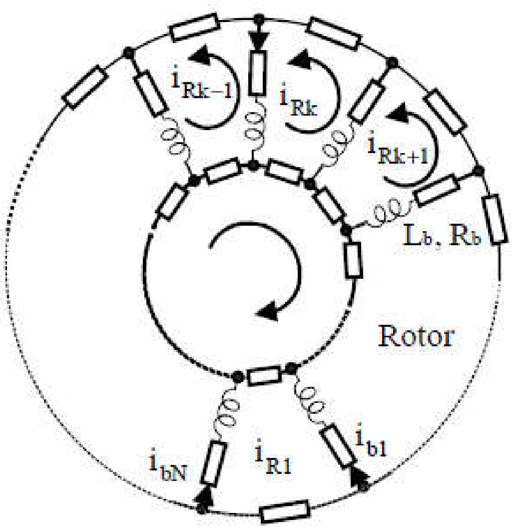

Figure .2 Rotor cage equivalent circuit.

A. Stator inductance

The principal inductance of the magnetizing stator phase is:

$$L_{sp}(\theta) = \frac{\Phi_{sp}}{i_a} = \frac{2\,\mu_0\, N_s^2\, RL}{e\pi\, p^2} \tag{3}$$

Therefore the total inductance of a phase is equal to the sum of the magnetizing and leakage inductances, thus:

$$L_s = L_{sp} + L_{sf} \tag{4}$$

The mutual inductance between the stator phases is computed as:

$$M_s = -\frac{L_s}{2} \tag{5}$$

B. Rotor inductance

The form of the magnetic induction produced by a rotor mesh in the air-gap is supposed to be radial and is represented in Figure 3. The principal inductance of a rotor mesh can be calculated from the magnetic induction distribution [11-12]:

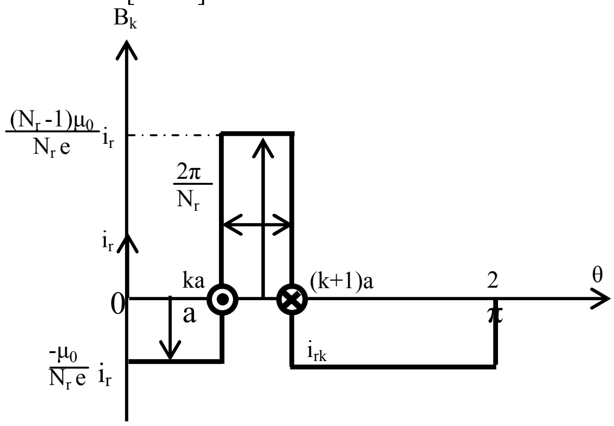

Figure .3 Form of magnetic induction of rotor mesh created by two bar

The total inductance of the k_{th} rotor mesh is equal to the sum of its principal inductance, inductance of leakage of the two bars and inductance of the leakage of the two portions of rings of the short circuit closing the mesh k as indicated in Figure 4.

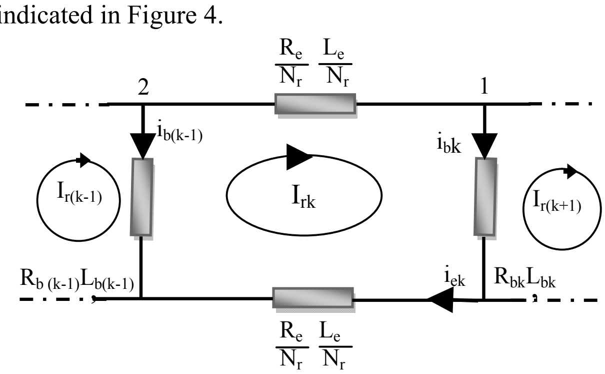

Figure .4 Electric diagram equivalent of a rotor mesh.

$$L_{rp} = \frac{N_r - 1}{N_r^2} \mu_0 \frac{2\pi}{e} RL \qquad (6)$$

$$L_{rr} = L_{rp} + 2L_p + 2L_e \qquad (7)$$

$$M_{rr} = -\frac{1}{N_r^2} \frac{2\pi\mu_0}{e} RL \qquad (8)$$

The expression for the mutual inductance stator-rotor is can be calculated using the flux and is given by:

$$M_{snrk} = -M_{sr} \cos(p\theta_r - n2\pi + ka) \qquad (9)$$

Where:

$$a = p\frac{2\pi}{N_r} \text{ and } M_{sr}(\theta) = \frac{4\mu_0 N_s RL}{ep^2 \pi} \sin(\frac{a}{2})$$

$$Lrc = Lrp - Mrr + \frac{2L_e}{N_r} + 2Le\,(1 - \cos(a)) \qquad (10)$$

And:

$$R_r = \frac{2R_e}{N_r} + 2Rb(1 - \cos(a)) \qquad (11)$$

The application of transformation the Park's extended of rotor system so as to transform the system in Nr phases in a system (d,q). The mathematical model of squirrel cage induction motor can be written as:

$$[L]\frac{dI}{dt} = [V] - [R][I] \qquad (12)$$

C. Defect model of the rotor

In order to simulate the defect of rotor broken bars, a fault resistance R_{RF} is added to the corresponding element of the rotor resistance matrix R_R:

$$[R_{RF}] = [R_R] + \begin{bmatrix} 0 & \cdots & 0 & 0 & 0 & \cdots & & \cdots \\ \vdots & \cdots & \vdots & \vdots & \vdots & \vdots & & \cdots \\ 0 & \cdots & 0 & 0 & 0 & 0 & & \cdots \\ 0 & \cdots & 0 & R_{bk} & -R_{bk} & & 0 & \cdots \\ 0 & \cdots & 0 & -R_{bk} & R_{bk} & & 0 & \cdots \\ 0 & \cdots & 0 & 0 & 0 & & 0 & \cdots \\ \vdots & \cdots & \vdots & \vdots & \vdots & 0 & & \cdots \end{bmatrix}$$

The new matrix of rotor resistances, after transformations, becomes:

$$[R_{RF}] = \begin{bmatrix} R_{rdd} & R_{rdq} \\ R_{rqd} & R_{rqq} \end{bmatrix}$$

Where the four terms of this matrix are:

$$R_{rdd} = 2R_b(1 - \cos(a)) + 2\frac{R_e}{N_r} + \frac{2}{N_r}$$

$$(1 - \cos(a)) \textstyle\sum_k R_{bkf}(1 - \cos(2k - 1)a).$$

$$R_{rdq} = -\frac{2}{N_r}(1 - \cos(a)) \sum_k R_{bkf}\sin(2k - 1)a).$$

$$R_{rqd} = -\frac{2}{N_r}(1 - \cos(a)) \sum_k R_{bkf}\sin(2k - 1)a).$$

$$R_{rqq} = 2R_b(1 - \cos(a)) + 2\frac{R_e}{N_r} + \frac{2}{N_r}$$

$$(1 - \cos(a)) \sum_k R_{bkf}(1 - \cos(2k - 1)a).$$

The mechanical equations must also consider:

$$\frac{d}{dt}\omega = \frac{1}{j}(C_e - C_r) \qquad (13)$$

With : $\omega = \frac{d\theta}{dt}$

The electromagnetic torque with the expression:

$$C_e = \frac{3}{2} p.N_r.M_{sr}\left(I_{ds}.I_{qr} - I_{qs}.I_{dr}\right) \qquad (14)$$

IV. Results and discussion

IV.1 The case of healthy machine

For observe and simulate the multi-winding model of the asynchronous machine. At time 0.5 s apply in load torque of 3.5 (N.m). Figure.5 and Figure. 6 and Figure. 7, we indicate the evolution respectively the speed of rotation, the electromagnetic torque, stator currents, we notice speed of rotation decreases at nominal and the electromagnetic stabilizes towards the value of the resistance torque, the current stator increases and reach value nominal.

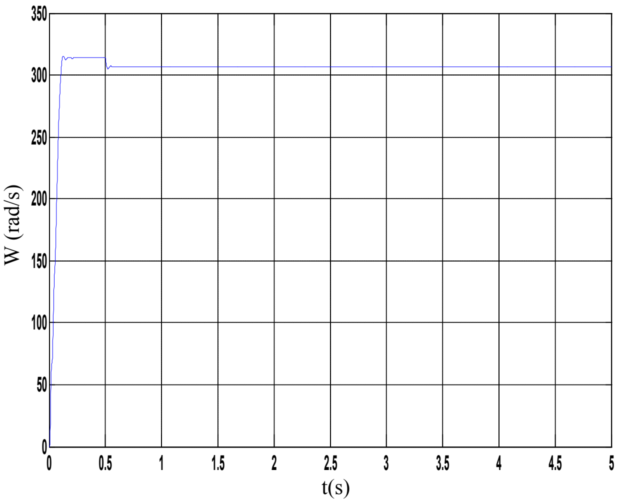

Figure. 5 speed for the healthy machine.

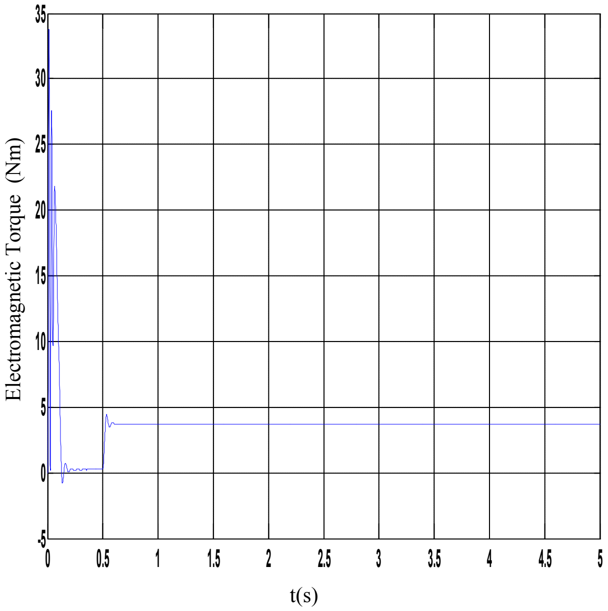

Figure. 6 Electromagnetic Torque for the healthy machine.

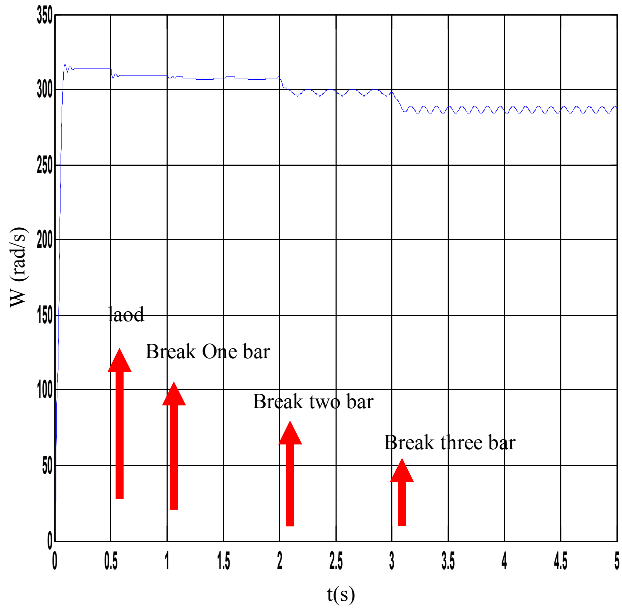

Figure. 8 speed for broken three bar adjacent.

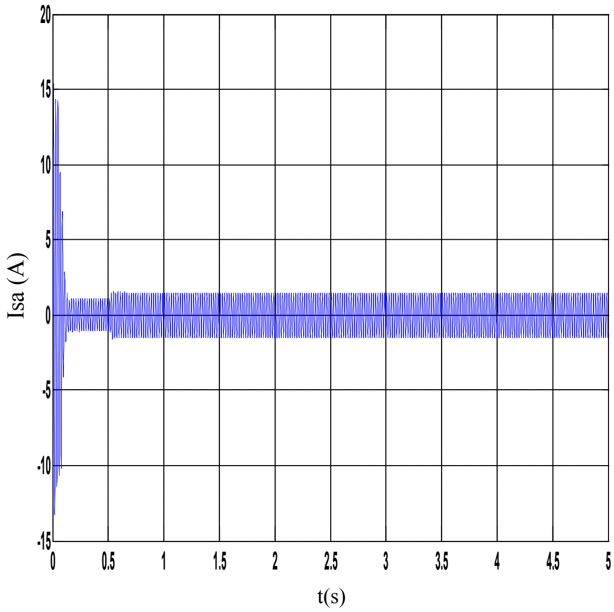

Figure. 7 Stator Current for the healthy machine.

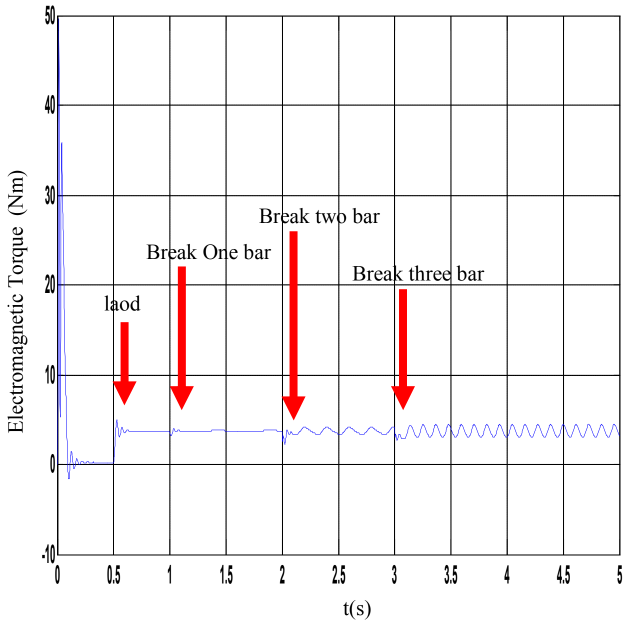

Figure. 9 Electromagnetic Torque for broken three bar adjacent.

IV.2 The case of fault machine

The time t=1 ,simulates the breaking of the first bar ,the time t = 2 s, breaking two bar adjacent, and the time t = 3 s, breaking three bar adjacent, we observation in the Figure.8 of rotational speed decreases during bar break and creates oscillations break the Figure.9 electromagnetic torque increase in the amplitude after the breaking of two bar, ,and the Figure.10 are illustrated modulation of the envelope of the stator current increase in the amplitude withe the number of broken bar.

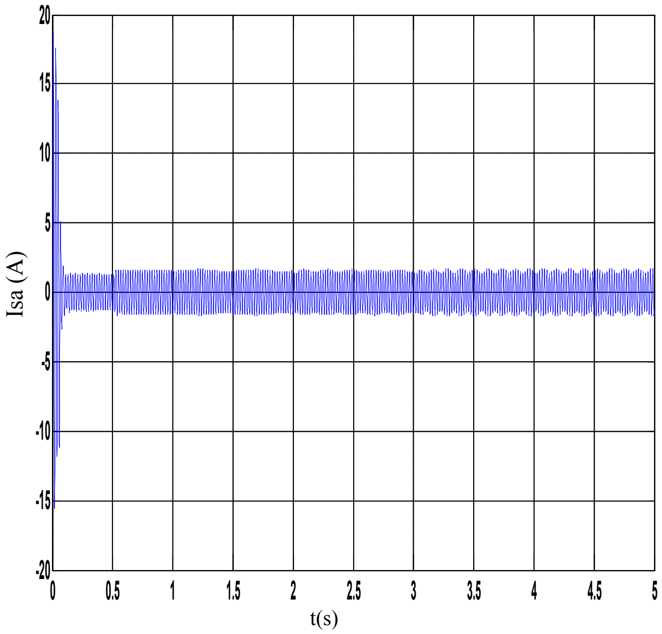

Figure. 10 Stator Current for broken three bar adjacent.

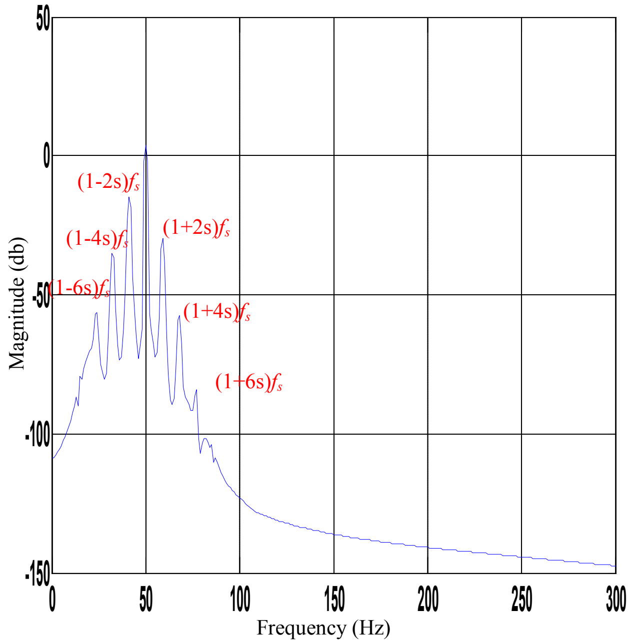

Figure.12 Stator current spectrum analysis for broken three bar adjacent.

Figure. 11 shows spectrum analysis of the stator current through the Hanning window in the healthy state, we observe no raise Frequency. Figure. 12, we notice the appearance of raise Frequency for broken three bar adjacent. These raise have amplitude which increases according of the break number bars, two frequencies appear around the fundamental f=50 Hz, one on the left and the other right according relation f_{cal}= (1 ± 2sk).

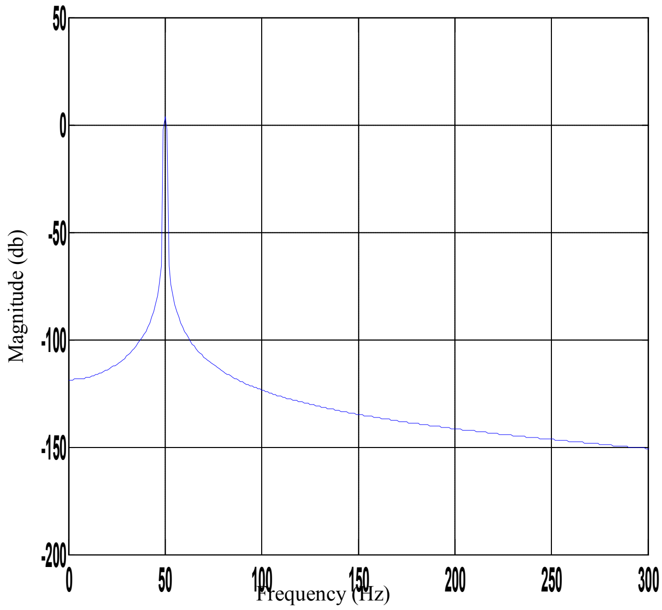

Figure.11 Stator current spectrum analysis for the healthy machine.

The amplitudes and frequencies for tests broken three bar adjacent are recorded in Table 1.

Frequency and magnitude of broken bar		(1-4s)f_s	(1-2s)f_s	(1+2s)f_s	(1+4sk)f_s
Healthy		/	/	/	/
broken three bar adjacent	Magnitude (db)	-35.70	-24.29	-29.86	-58.08
	f (Hz)	32.18	41.25	59.12	61.91

Table. 1 Frequencies and Magnitudes of the Stator Current : Healthy and broken three bar adjacent

The table 1 represents simulation frequencies and magnitude the current stator spectral for broken three bar adjacent.

IV. Conclusion

This study allows us highlighting on fault diagnosis technique are based on signal processing by spectral analysis of stator current analysis this method is very effective and widely used for detection the fault. Further using multi windings model for simulation broken bars. When applying the faults we obtain reduces the average value of electromagnetic torque and speed and increases the amplitude of oscillations. The current stator effect of bar break increases rapidly with the number of broken bars.

Appendix

List of Parameter and Symbols

Parameters	Value	Units
P_n	1.1	kW
V_s	220	V
f_s	50	Hz
p	1	
R_s	7.58	Ω
R_r	6.3	Ω
R_b	0.15	m Ω
R_e	0.15	m Ω
L_b	0.1	µH
L_e	0.1	µH
L_{sf}	0.0265	H
N_r	16	
N_s	160	
J	0.0054	kg m^2
e	2	mm

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References

[1] Subhasis Nandi, Hamid A. Toliyat,, Xiaodong Li, "Condition Monitoring and Fault Diagnosis of Electrical Motors—A Review", IEEE Transactions on Energy Conversion, vol. 20, n°4, December 2005, pp. 719-729.

[2] O. Moussa, D. Khodja, H. Benguesmia, "Comparative Study between Sliding Mode Control and the Vectorial Control of a Brushless doubly fed induction generator ",International Journal of Energetica (IJECA), vol. 3, 2018, Issue 2, pp. 22-28.

[3] A. Lebaroud, Guy Clerc, "Classification of Induction Machine Faults by Optimal Time- Frequency Representations", IEEE Transactions on Industrial Electronics, Institute of Electrical and Electronics Engineers, Vol. 55, N^{O}. 12, December 2008, pp.4290 - 4298.

[4] P.J. Tavner, "Review of condition monitoring of rotating electrical machines. Electric Power Applications", IET Electr. Power Appl., 2008, Vol. 2, No. 4, pp. 215–247. doi: 10.1049/iet-epa:20070280.

[5] Pratesh Jayaswal, A. K.Wadhwani, K. B.Mulchandani, "Machine Fault Signature Analysis", International Journal of Rotating Machinery Volume 2008, Article ID 583982, 10 pages doi:10.1155/2008/58398

[6] Chaitali S. Kalaskar, Vitthal J. Gond, "Motor Current Signature Analysis to Detect the Fault in Induction Motor",Journal of Engineering Research and Applications, ISSN : 2248-9622, vol. 4, Issue 6 (Version 1), June 2014, pp.58-61.

[7] SZABÓ Loránd – DOBAI Jenő Barna – BIRÓ Károly Ágoston, "Rotor Faults Detection in Squirrel-Cage Induction Motors by Current Signature Analysis", IEEE-TTTC, International Conference on Automation, Quality and Testing, Robotics May 13 – 15, 2004..

[8] K.M. Siddiqui, V.K. Giri, "Broken Rotor Bar Fault Detection in Induction Motors using Transient Current Analysis", International Journal of Electronics & Communication Technology, Vol. 2, Issue. 4, October – December 2011, pp. 114–119.

[9] Neelam Mehala, Ratna Dahiya, "Motor Current Signature Analysis and its Applications in Induction Motor Fault Diagnosis", International journal of systems applications, Engineering & Development, Vol. 2, Issue.1, 2007, pp. 29–35.

[10] Dragan MATIĆ, Željko KANOVIĆ, Vladimir BUGARSKI, Filip KULIĆ, Dejan RELJIĆ, Đura OROS, Veran VASIĆ, "Detection of the Broken Bar Fault. A Case Study For A 3.2 MW Induction Motor DETEKCIJA OTKAZA SLOMLJENE ŠIPKE. Analiza Asinhronog Motora 3,2MW ", Journal on Processing and Energy in Agriculture, 17:3, 2013, pp. 134–137.

[11] A. Menacer, S. Moreau, A. Benakcha, M.S. Nait Said "Effect of the position and the number of broken bras on Asynchronous Motor Stator Current Spectrum", EPE-Power Electronics and Motion Control, Portoroz, Slovenia, 2006, pp 973-978.

[12] A. Menacer, A. Benakcha, M.S. Nait Said, S. Drid, "Stator Current Analysis of incipient fault into asynchronous motor rotor bars using fourier fast transform", Journal of Electrical Engineering, Vol. 55, N°5-6, 2004, pp 122-130.