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Fault diagnosis of rotor broken bars in induction motor system

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Abstract. The comparison of the induction motor rotor common fault simulation, the fault characteristics are obtained this kind of failure of the motor through theoretical derivation and simulation model is established in the fault condition of the motor based on the multi loop theory, the running state of a motor fault fault in the rotor is simulated by MATLAB Simulink and Simpowersystem, imitation The results confirm the correctness of the theoretical derivation.

Introduction

Induction motor due to its high price and good environmental adaptability, in power system and production as the main power equipment has been widely used. The operation condition of induction motor directly affects the normal industrial production. If there is a serious fault, not only will damage the motor itself, but also will cause the interruption of the whole industrial production. The common faults of induction motor can be divided into the stator fault, rotor fault and bearing fault. Rotor fault of induction motor, there are two kinds of fault simulation method is applied to the rotor: the first one is to be improved based on the dq model The approximate realization of motor fault simulation, this method is more simple, faster computation speed, but more is used for analysis of the motor[1]. The other is based on magnetic coupling model[2-7] (multi loop theory).

Normal motor model

Induction motor model can be used to be based on magnetic coupling method, and through the winding function method to consider the space harmonic motor. This paper consider a 3 phase stator, rotor induction motor root number was n. In order to simplify the motor model assumption: a) ignore the saturation effect effect; b) ignore the eddy current loss; C ignore) motor friction loss and windage loss; d) mutual isolation between the rotor of the motor.

On this basis, the voltage equation of the motor can be written as:

$$Vs = RsIs + \frac{d\Lambda s}{dt} \tag{1}$$

$$Vr = RrIr + \frac{d\Lambda r}{dt} \tag{2}$$

Among them, Vs is the stator voltage vector motor, Vr motor rotor voltage vector, Is is the current vector of the stator, the rotor current vector loop is Ir, Rs is the motor stator resistance matrix, Rr is the resistance matrix of rotor circuit, a motor stator flux vector is s, R is a motor rotor flux vector loop.

Stator and rotor flux linkage:

$$\Lambda_s = L_{ss} I_s + L_{sr} I_r \tag{3}$$

$$\Lambda_r = L_{rs} I_s + L_{rr} I_r \tag{4}$$

Λ_s is motor stator flux vector, Λ_r is rotor flux vector, L_{ss} is motor stator inductance matrix, L_{sr} is stator and rotor mutual inductance, L_{rr} is motor rotor circuit inductance.

These vectors can be written:

$$L_{ss} = \begin{bmatrix} L_m^s & L_{ab}^s & L_{ac}^s \\ L_{ba}^s & L_m^s & L_{bc}^s \\ L_{ca}^s & L_{cb}^s & L_m^s \end{bmatrix} \tag{5}$$

$$L_{sr} = \begin{bmatrix} L_{a1}^{sr} & L_{a2}^{sr} & \cdots & L_{an}^{sr} & L_{ae}^{sr} \\ L_{b1}^{sr} & L_{b2}^{sr} & \cdots & L_{bn}^{sr} & L_{be}^{sr} \\ L_{c1}^{sr} & L_{c2}^{sr} & \cdots & L_{cn}^{sr} & L_{ce}^{sr} \end{bmatrix} \tag{6}$$

$$L_{rr} = \begin{bmatrix} L_{mm} & L_{r_1r_2}^b & L_{r_1r_3} & \cdots & L_{r_1r_{n-1}} & L_{r_1r_n}^b & L_e \\ L_{r_2r_1}^b & L_{mm} & L_{r_2r_3}^b & \cdots & L_{r_2r_{n-1}} & L_{r_2r_n} & L_e \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ L_{r_{n-1}r_1} & L_{r_{n-1}r_2} & L_{r_{n-1}r_3} & \cdots & L_{mm} & L_{r_{n-1}r_n}^b & L_e \\ L_{r_nr_1}^b & L_{r_nr_2} & L_{r_nr_3} & \cdots & L_{r_nr_{n-1}}^b & L_{mm} & L_e \\ L_e & L_e & L_e & \cdots & L_e & L_e & nL_e \end{bmatrix} \tag{7}$$

L_m^s is stator excitation inductance, L_{ij}^s is mutual inductance of stator I phase and j phase, L_{ij}^{sr} is i and the j rotor stator inductance loop, L_{ie}^{sr} is stator and rotor end ring of transformer I. L_e is the leakage inductance between the ends of two adjacent strips.

In order to get the most simple form, the equation of the motor is:

$$V = RI + \omega_{rm} \frac{dL}{d\theta_{rm}} I + L\frac{dI}{dt} \tag{8}$$

θ_{rm} is space position angle of motor rotor, ω_{rm} is mechanical angular velocity of motor rotor,will be used as the basic expression of the induction motor simulation.

Processing method for rotor bar fault

(1) the j+4 elements of the matrix R and L are added to the element corresponding to the line j+3;

(2) the elements of the R and L columns of the matrix are added to the corresponding elements of the j+3 column;

(3) delete the row j+4 and column j+4 elements of the matrix R and L;

(4) delete type 18 in the V, I in the corresponding j+4 elements.

Calculation of inductance of electric machine

Motor simulation, the motor inductance is calculated using winding function method. The function of motor of a phase winding of the motor is the magnetomotive force generated by the motor unit into [7]. is current when the MMF distribution depends on the motor winding structure (space harmonics) and corresponding current (time harmonic winding). Common winding motor function to describe the hypothesis. The motor A phase winding function as shown in Figure 2-3. The number of stator slots of the motor for the 36 pole pairs, P = 2, so each pole slot number of each phase of q = 3, the equivalent of the motor winding function three rise. This can be seen as per period N/3. N should be half of the Stator Turns [2] in the literature, Turns Stator for each phase of the series turns.

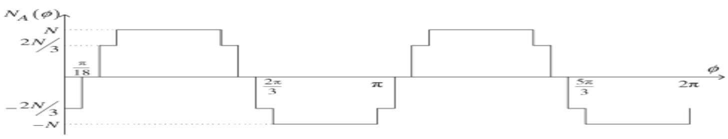


Fig.1 the winding function of A phase of 2-3 motor

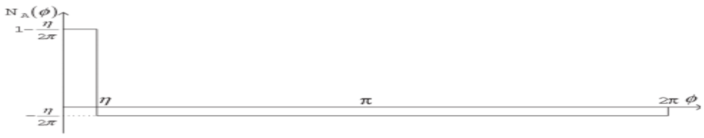


Fig. 2 winding function of rotor circuit

Fig. 2 mutual inductance between winding function I and winding J of rotor circuit:

$$L_{ij}(\theta_r) = \mu_0 l \int_0^{2\pi} \frac{r(\theta_r,\phi) n_i(\theta_r,\phi) N_j(\theta_r,\phi)}{g_{ag}(\theta_r,\phi)} d\phi \tag{9}$$

θ_r is the position of the motor rotor relative to the stator reference system, which is angular displacement along the inner surface of the motor stator. $g_{ag}(\theta_r,\phi)$ is effective air gap length function. $n_i(\theta_r,\phi)$ is the distribution of the winding i. $N_j(\theta_r,\phi)$ is the winding function of the winding J.

In the Simulink MATLAB environment, according to the formula (8) to set up the motor equation. The model is shown in figure 3.The motor model is shown in figure 4. the Cal I module is in accordance with the formula (8) S function module.

Cal Ib module is based on the rotor current loop current for motor rotor.

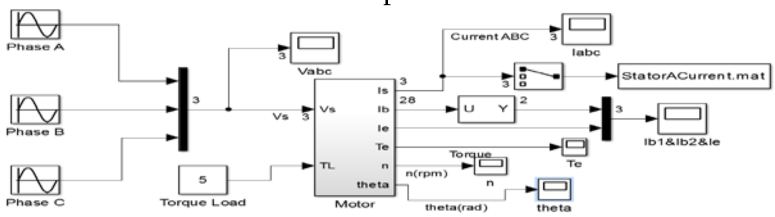


Fig.3 system simulation model

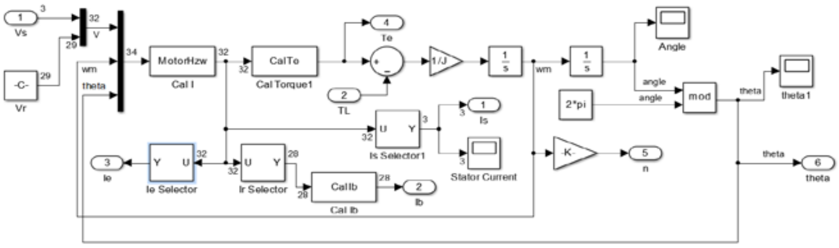


Fig. 4 motor model interior

Run the motor model, get the motor speed, stator current, electromagnetic torque and rotor guide bar and end loop current as shown in Figure 5.

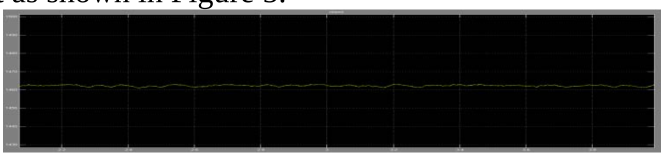


Figure 5 speed local zoom

A phase current for FFT analysis, the results are shown in Figure 6

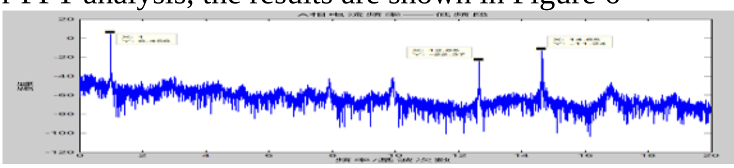


Figure.6 A phase current spectrum

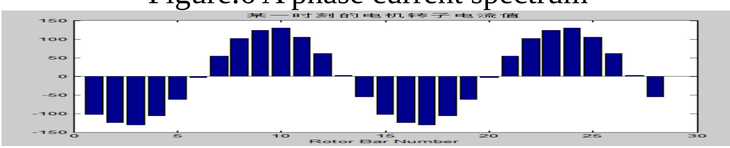


Fig. 7 current distribution in the rotor bar of a certain time

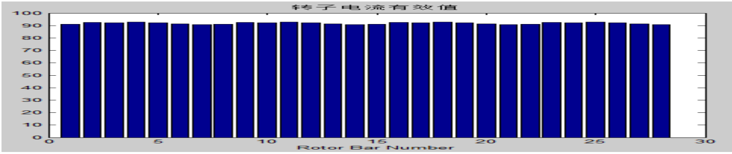


Fig.8 the effective value of the current in the rotor of the motor

Fault simulation and variable frequency component method

According to the method of the motor rotor fault processing. According to the MDL file, only need to modify the I Cal module in the MotorHzw function, the R, L, dL to modify it.

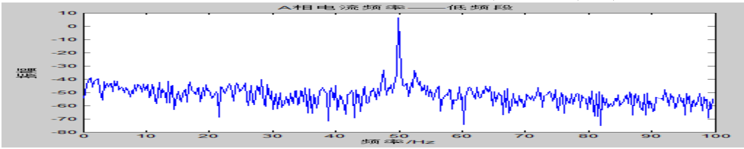


Fig. 9 A phase current spectrum of motor in the case of motor with a guide strip

Its simulation and analysis of the motor stator current spectrum (Figure 9). It can be seen that there is a variable frequency component of the motor current, which is consistent with the theory.The rotor current is analyzed, get a moment current of the motor rotor bar current and motor rotor RMS respectively as shown in Figure 10 and figure 11. We can see that in the case of a motor rotor fault current, fault bars on both sides will be greatly increased. Because of this, when the motor a guide bar is easy to fracture, fault spread to adjacent bars above. This is one reason why the motor fault detection. In addition, other current bar motor in the effective value are not the same.

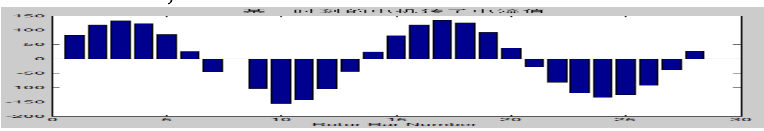


Fig.10 current distribution in rotor at a time when eighth rotor guide bars are broken

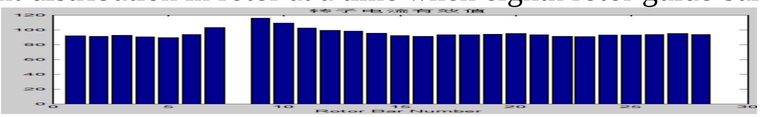


Fig. 11 effective value of current in rotor during fault of eighth following rotor bar

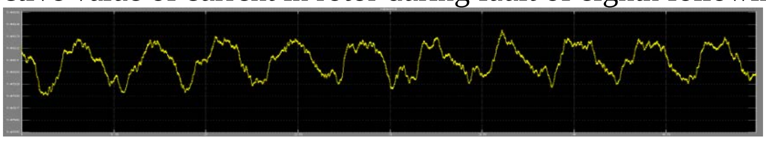


Fig. 12 speed of the motor in the case of a broken rotor bar

Quantitative analysis of faults

With MATLAB simulation, number of broken bars is 0,1, 2 when motor simulation.

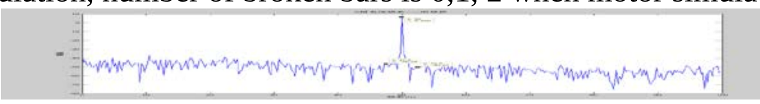


Figure 13 the number of broken bars is 0

Figure 14 number of broken bars for 1

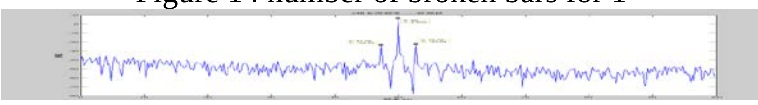
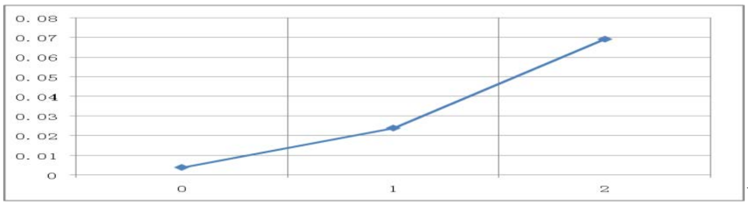


Figure 15 number of broken bars for 2

Broken bars number	Left frequency component amplitude	Right frequency component amplitude	Amplitude of fundamental wave component	$\frac{I_L + I_R}{I}$
0	0.004937	0.003044	2.105232	0.003791
1	0.023523	0.027008	2.117873	0.023859
2	0.068945	0.079068	2.139193	0.069191

Figure16Numerical relationship between the number of broken bars and the left and right side frequency components

$\frac{I_L + I_R}{I}$



broken bars' number

Figure 17 the number of broken bars and the left and right side frequency component values of the line chart

Conclusion

By the line figure 17 shows that with the increase of the number of broken rotor, then the fault severity of the quantization factor will also increase, that is, the fault of the motor is more and more serious.

References

[1] Cruz S M A, Stefani A, Filippetti F, et al. A New Model-Based Technique for the Diagnosis of Rotor Faults in RFOC Induction Motor Drives[J]. Industrial Electronics, IEEE Transactions on. 2008, 55(12): 4218-4228.

[2] Jee-Hoon J, Bong-Hwan K. Corrosion Model of a Rotor-Bar-Under-Fault Progress in Induction Motors[J]. Industrial Electronics, IEEE Transactions on. 2006, 53(6): 1829-1841.

[3] Toliyat H A, Arefeen M S, Parlos A G. A method for dynamic simulation of air-gap eccentricity in induction machines[J]. Industry Applications, IEEE Transactions on. 1996, 32(4): 910-918.

[4] Milimonfared J, Kelk H M, Nandi S, et al. A novel approach for broken-rotor-bar detection in cage induction motors[J]. Industry Applications, IEEE Transactions on. 1999, 35(5): 1000-1006.

[5] Ikeda M, Hiyama T. Simulation Studies of the Transients of Squirrel-Cage Induction Motors[J]. Energy Conversion, IEEE Transactions on. 2007, 22(2): 233-239.

[6] Toliyat H A, Lipo T A. Transient analysis of cage induction machines under stator, rotor bar and end ring faults[J]. Energy Conversion, IEEE Transactions on. 1995, 10(2): 241-247.

[7] Min Kang. Research on single winding multi phase non bearing motor[D]. Hangzhou: Zhejiang University, 2008.