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Research Paper

ROTOR SIDE FAULT DIAGNOSIS FOR INDUCTION MOTOR USING FUZZY BASED CONTROLLED IDENTIFIER

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ABSTRACT

Quality control is applied in production process. The good condition of electrical machines can be obtained by using diagnostics. There are a lot of methods that can be used for diagnostics of electrical machines. In the literature, standard methods are based on a study of electrical signals. This project work start with a novel automated practical implementation for non contiguous rotor side broken bars detection and diagnosis in induction motors. In this work a method for detection and diagnosis of rotor side broken bars is there based on the spectral analysis via fast Fourier transform (FFT) and classification of the spectral response based on fuzzy controlled identifier. For the fault diagnosis objective, two features are selected from the spectrum of the stator current, first is the amplitude of the harmonics representing the broken bars defect 2sf (where s is the slip and f is the fundamental harmonics) and the second is the dc value. By using these obtained parameters a fuzzy identifier will there to identify the number of broken bars. For the designing of this fuzzy identifier these two parameters will be used as inputs where the decision about the state of rotor will be made. After the implementation of that work it will provide that this technique will able to efficiently detect the number of broken bars at rotor side.

KEYWORDS: Rotor side fault detection, Three Phase Induction Motor, Fast Fourier Transform, Fuzzy Controller.

1. INTRODUCTION

Induction motor for many years has been regarded as the workhorse in industrial applications. In the last few decade, the induction motor has evolved from being a constant speed motor to a variable speed, variable torque machine. Its evolution was challenged by the easiness of controlling a DC motor at low power applications. When applications required large amounts of power and torque, the induction motor become more efficient to use. The good condition of electrical machines can be obtained by using diagnostics. There is lots of method that can be used for diagnostics of electrical machines. In the literature, popular method is based on a study of electrical signals. The paper proposes new implementation of diagnostics of imminent failure conditions of induction motor especially due to rotor side fault.

In this work a method for detection and diagnosis of rotor side broken bars will be there based on the spectral analysis via fast Fourier transform (FFT) and classification of the spectral response based on fuzzy controlled identifier. For the fault diagnosis objective, two features are selected from the spectrum of the stator current, first is the amplitude of the harmonics representing the broken bars defect 2sf (where s is the slip and f is the fundamental harmonics) and the second is the dc value. By using these obtained parameters a fuzzy identifier is there to identify the number of broken bars. For the designing of that fuzzy identifier these two parameters will be used as inputs where the decision about the state of rotor will be made.

2. Rotor Side Fault Detection and Analysis

The surveys on induction motors have shown that the rotor failure (10%). Precisely, the cast aluminium bars of the squirrel-cage rotor may be subject to faults as a result of internal mechanical stresses. A single broken rotor bar may cause its neighbours to fail dues to increased currents in adjacent bars and consequently increased thermal and mechanical stresses. These fault cause considerable economic losses. However, to obtain high level of reliability for an electric drive with induction motors, a diagnostic system is necessary [8]. Traditionally, the monitoring and diagnostic of rotor broken bars based on motor current signature analysis (MCSA) used as non-invasive method to detect sidebands harmonics around the fundamental supply frequency expressed by:

$$f_{rbb} = (1 \pm 2s) f \qquad ...(1)$$

where f_{rbb} is the related broken bar frequency. However, at low slip these components (1 ± 2s)f are relatively close to the fundamental component, which makes their detection much more difficult. To avoid this problem, the amplitude modulation (AM) of stator current induced by rotor asymmetry is exploited in aid of diagnostic. In fact, the rotor fault effect can be localized in the stator current envelope spectrum at frequency expressed by [9]:

$$f_0 = 2ksf \qquad ...(2)$$

As shown in figure (1, 2, and 3), the most important components amplitudes are localized in the low frequency bandwidth. In this range the important components amplitudes are related to the dc term and rotor broken bars (2sf). In this work, the Hilbert transform is used to extract the stator current envelope. Then this signal is processed via fast Fourier transform (FFT). To extract the fault frequency component (2*sf*) from the stator current envelope spectrum, the frequency bandwidth affected by broken bar can be easily limited at frequency [f_m f_M], where f_m et f_M are selected according to type of the machine. In our case, f_m , f_M are fixed respectively at 0.33 Hz and 6.2 Hz. However, the dependence of the component (2sf) amplitude, at the same time, to the load and to the defect severity, returns the detection of the broken bars number very difficult. For this reason, in order to make an efficient diagnosis at various loads, it is important to introduce a discernment criterion. This is presented by the dc component amplitude which reflects the slip image (Figure 4). These two previous amplitudes combined with fuzzy logic technique, as artificial intelligence diagnostic tool, can be defined as a new broken bar fault detection method [10-12].

2.1 Stator Phase Current Envelope:

Theoretically, in the case of rotor asymmetry created by broken bars, the stator current can be written as:

$$i_A(t) = I_F \cos(2\pi ft-\varphi) + \sum_k I^k_{RBB1} \cos(2\pi(f-2ksf)t-\varphi^k_{RRB1}) + \sum_k I^k_{RBB2} \cos(2\pi(f+2ksf)t-\varphi^k_{RRB2}) \ ... (3)$$

Where, I_f The fundamental value of the phase stator current, φ The main phase shift angle of the phase stator current, I^k_{RBB1} The left magnitude for the harmonic component f_{Rbb}, I^k_{RBB2} The right magnitude for the harmonic component f_{Rbb}, φ^{k}_{RRB1} The left phase shift angle of component f_{Rbb}, φ^{k}_{RRB2} The right phase shift angle of component $f_{Rbb.}$

Above expression can be rewritten as:

$I_A(t) = A(t)\cos(2\pi ft) + B(t)\sin(2\pi ft)$ ...(4)

And further can take the form:

$I_{A(t)} = A_m(t)\sin(2\pi ft + \theta(t))$

With:

$A_m(t) = \sqrt{A(t)^2 + B(t)^2}$, $\theta(t) = \arctan\left(\frac{B(t)}{A(t)}\right)$

$A(t) = I_f\cos(\varphi) +$

$\sum((I^{k}_{RBB1}\cos\varphi^{k}_{RRB1} + I^{k}_{RBB2}\cos\varphi^{k}_{RRB2})\cos(2\pi(2ksf)t)$

$+(I^{k}_{RBB2}\sin\varphi^{k}_{RRB2} - I^{k}_{RBB1}\sin\varphi^{k}_{RRB1})\sin 2\pi(2ksf)t))$

and

$B(t) = I_f\sin(\varphi) +$

$\sum((I^{k}_{RBB1}\sin\varphi^{k}_{RRB1} + I^{k}_{RBB2}\sin\varphi^{k}_{RRB2})\cos(2\pi(2ksf)t)$

$+(I^{k}_{RBB1}\cos\varphi^{k}_{RRB1} - I^{k}_{RBB2}\sin\varphi^{k}_{RRB2})\sin 2\pi(2ksf)t))$

As shown in previous relation, the rotor faults in induction motor as rotor asymmetry, induced by the broken bar, modulate the amplitude of stator current at frequency 2ksf, by exploiting this fact; the stator current envelope can be used as a diagnostic signal.

2.2 Extraction of the Stator Phase Current Envelope

Typically, the stator current envelope can be extracted via different methods as Hilbert transform, filter demodulation and others. Hilbert transform (HT) is a well-known signal analysis method, used in different scientific fields such as faults diagnosis, and others. The HT of a real signal $i_A(t)$ is defined as[13]:

$HT(i_A(t)) = y(t) = \frac{1}{\pi t} * i_A(t) = \frac{1}{\pi}\int_{-\infty}^{+\infty}\frac{i_A(\tau)}{(t-\tau)}d\tau$ ..(5)

The combination of the real signal with its HT, the so called analytic signal i(t) is formed:

$\tilde{\imath}(t) = i_A(t) + jy(t) = a(t)e^{j\theta(t)}$ ...(6)

Where

$a(t) = \sqrt{i_A(t)^2 + y(t)^2}$, and $\theta(t)\arctan\left(\frac{Y(t)}{i_{A(t)}}\right)$

a(t) is the instantaneous amplitude of i(t) known as envelope of $i_A(t)$ and θ(t) is the instantaneous phase of i(t).

3. Fuzzy Logic Approach For Rotor Faults Diagnosis:

A. *Fuzzy System Input-Output Variables*

The amplitude of the dc component accomplished this task. Thus, the amplitudes of dc and 2sf components called respectively $\mathbf{A}_{dc}$ and $\mathbf{A}_{fbb}$, will be used as input for the fuzzy system figure (6) [14]. By fuzzy inference, using a knowledge base, compressing a rule and data base, the condition of the rotor, is then obtained as output. The rotor condition, CM, is chosen as the output variable. The output provides three decision outputs ∈ {0,1}.

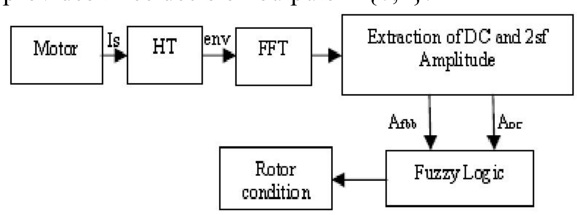

Figure 6: Proposed Motor fault diagnosis using fuzzy logic.

4. CONCLUSION

A diagnosis method using fuzzy logic to determine the state condition of the induction motor is there in this paper. In order to make an efficient diagnosis at low slip, the stator current envelope will be obtained via Hilbert transform and will be then used as diagnostic signal. The amplitude of the dc and 2sf components of the spectrum stator current envelope are intended as inputs to the fuzzy system which can be converted to variables linguistic by fuzzy subsets and their corresponding membership functions. The output of this system suppose to be the good representation of the rotor condition. It will sure that this system good and it will be capable to detect the correct number of broken bar.

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