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Bearing fault detection in a 3 phase induction motor using stator current frequency spectral subtraction with various wavelet decomposition techniques

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ABSTRACT

Induction motors consumes 90% of total power consumed by industries due to large scale utilisation. Even though these motors are rugged in structure, they often face unexpected failure due to long usage without maintenance. Bearing failure is a major problem among various faults, which cause catastrophic damage to machine when unnoticed at incipient stage. So the bearing faults in induction machines should be continuously monitored. Motor current signature analysis (MCSA) has become popular for detection and localisation of these faults and has attracted concentration of many researchers. In this paper stator current is monitored by means of frequency spectral subtraction using various wavelet transforms to suppress dominant components. The spectral subtraction using discrete wavelet transform (DWT), stationary wavelet transform (SWT) and wavelet packet decomposition (WPD) is performed and a comparative analysis is carried out by means of different fault indexing parameters. The proposed topology is examined using 2.2 kW induction machine test bed.

1. Introduction

Induction machines have played indispensable role in industrial process and occupied major portion ranging from fraction of hp to thousands of hp. They do not need any external excitation and have high torque which enables to run much larger machines. Due to the reasons stated, induction machines are used in substantial amounts in industries. In contrast to this, induction machines are often face unexpected failure due to various faults. If these faults go unnoticed, they may cause severe damage to the machine. The faults that generally occur in an induction machine can be categorized as Rotor faults,Bearing Faults, Stator faults and Other faults. According to an IEEE survey contribution of these faults for a 200 hp motor is shown in Fig. 1. In addition to this, the bearing faults range from 40% to 90% depending on the size of machine; approximately 40% in higher rating machines and 90% in smaller rating machines [1–3]. Therefore continuous monitoring of bearing faults is highly desirable especially in small and medium voltage range machines. Condition monitoring means monitoring of specific condition of the machine such as temperature and vibration [4]. The use of vibration sensors and accelerometers for monitoring these faults is very difficult due to high cost, not suitable for noisy environment and requires high man power as the data is collected manually by field technicians and then analyzed [5]. On the other hand, stator current monitoring uses current signatures that can also be used for detection of other types of faults such as broken rotor bars [6], air gap eccentricity faults [7], along with bearing faults [8]. So the use of current monitoring technique is preferred over vibration monitoring and temperature monitoring.

Motor current signature analysis is very frequently done by using fast Fourier transform (FFT) [9]. But conventional FFT has few drawbacks like poor resolution, spectral leakage, inefficient to provide time-frequency relation, etc. So it would be difficult to find out the time at which the fault has occurred and moreover if the magnitude of fault is low compared to noise produced in the machine, it would be difficult to find out the fault component using conventional FFT. Therefore to overcome these drawbacks in FFT, many advanced signal processing techniques have been implemented. For example, to improve frequency resolution in FFT,

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Nomenclature

μ	mean value of the signal
ω_0	angular frequency
ϕ	contact angle
σ	standard deviation
D	pitch diameter
d	ball diameter
f_b	ball defect frequency
f_c	cage fault frequency
f_i	inner race fault frequency
f_o	outer race fault frequency
f_r	rotor speed in Hzs
F_s	sampling frequency
f_s	supply frequency
f_v	vibrating frequency
N	number of samples
n	time integer
N_b	number of balls
P	total power
R	fault index
SSI	simple square integral
$y(n)$	noise cancelled stator current

zoom FFT (ZFFT) is proposed in [10,11] and further developed using MUSIC algorithm as mentioned in [12–14]. MUSIC uses the concept of finding frequencies from the noise subspace obtained from Eigen vector matrix of the faulty signal. Though MUSIC is good in finding out the faulty frequencies, it is too complex to implement. To overcome the drawbacks associated with MUSIC algorithm combination of MUSIC and ESPRIT algorithm has been proposed in [15]. Eventhough the high frequency resolution achieved in recent works like ZFFT, MUSIC and ESPRIT, the spectral leakage is still a challenging task for researchers. To address this problem, window based transform techniques like short time Fourier transform (STFT) [16] and Wigner-Ville distribution (WVD) [17] are used in spectral analysis of stator current. Eventhough the STFT and WVD have given better results, they are not recommended because STFT uses fixed window intervals and WVD is complex due to cross terms. In order to overcome fixed window problem, a high frequency signal should be analyzed using small window and a low frequency signal should be analyzed using large window. So the variable window based spectral analysis called wavelet transform is proposed in [18–23]. Compared to STFT, wavelet transform is much better since the size of the windows in wavelet transform can be altered as compared to STFT where fixed length windows are used.

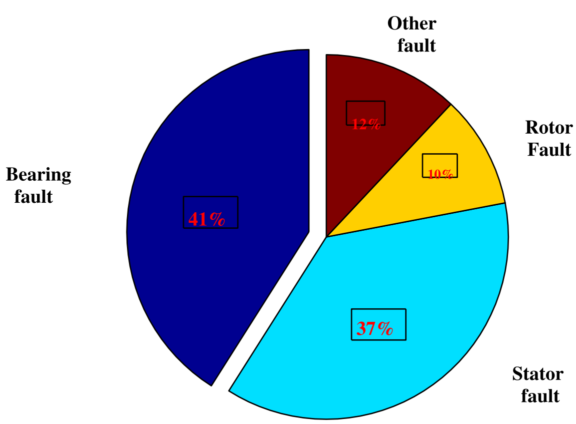

Fig. 1. Pie chart of faults experienced by induction motor.

Bearing faults will impose characteristic fault frequencies into stator current and develops detectable vibrations. The magnitude of fault frequencies is very low especially at incipient stage of fault and suppressed by dominant components in the stator current like fundamental, harmonics, etc. To remove the dominant components in stator current, frequency spectral subtraction is proposed in [3]. The methodology proposed in [3] to detect early bearing faults by spectral subtraction using conventional FFT and discrete wavelet transform (DWT) and the results are compared. Finally the authors concluded that, subtraction using DWT has shown good indication for fault. Therefore in this paper, frequency spectral subtraction using various wavelet decomposition techniques like DWT, stationary wavelet transform (SWT), and wavelet packet decomposition (WPD) and a comparative analysis is presented to detect various bearing faults. The fault severity is estimated using three different fault indexing parameters namely standard deviation (SD), Simple Square Integral (SSI) and total power (P) are proposed.

Fig. 2. Bearing with cage fault.

Fig. 3. Bearing with outer race fault.