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Analysis of Fault Detection and IoT Based Monitoring of Induction Motors

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ABSTRACT
Induction motors play a very important and crucial role in the development and overall productivity of industrial drives. Despite of the modern development the induction motor suffers from numerous faults and these faults consequence into lowering of overall industrial productivity and increased shutdown period. Thus, there is the need of pre-emptive detection of numerous faults while in operation. The prior detection of faults in induction motor and its optimum diagnosis can facilitate the industry to operate with least unexpected maintenance and industrial shutdown. An extensive literature survey conducted has indicated that the most common faults that could take place in induction motor are (i) inter-turn short circuit in stator winding, (ii) broken rotor bars, (iii) bearing failures and (iii) eccentricity faults. The presence of these faults in incipient phase may not necessarily deteriorate motor's performance; however, it points out that the component should be replaced before the likelihood of a catastrophic failure. Hence, it is necessary to detect these faults as soon as possible. The paper the diagnosis of these faultswith the state-of-the-art signal processing techniques. The condition monitoring and faults diagnosis mechanism are required to formulate a well-defined and skilled map in between motor signals as well as indications of the fault state of the induction motor. Hence, a number of advanced and optimum approaches have been identified and employed for detecting various faults on-line in a squirrel-cage induction motor. The paper presents the experimental investigations that are implemented in different setups and the respective results have been presented. Faults in the motor pose their signature frequencies as harmonics in the motor current spectrum. In Motor Current Signature Analysis, various approaches like Park's vector scheme, Fast Fourier Transformation (FFT), Discrete Wavelet Transform (DWT) based digital signal processing techniques have been taken into consideration.

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INTRODUCTION
The electric motor is an electromechanical device that converts electrical energy into mechanical energy. Being a very prominent part of modern industry, the induction motors play a vital role in major applications like pumping systems, fans, elevating systems, electric-powered vehicles, crushers, cement plants and many more industrial segments. An asynchronous motor, which is in fact an AC motor, where the current required for generating torque, is induced by electromagnetic induction from the magnetic field of the stator winding. Therefore, in general, induction motors do not need any external mechanical commutation, individual excitation or even any self-excitation for a part of the energy transmitted towards rotor from the stator. The rotor of an induction motor could be of any kind like squirrel-cage type or wound type.

These induction motors are mainly employed as a critical form of devices for major industrial activities and are in general, integrated with diverse commercially available apparatus and applications. All the equipments based on this motor drive, generally facilitate core competences, significant for making certain business success as well as operator safety. Numerous electrical components of the operational induction machines are highly prone to the system failure. For instance, the insulation breakdown in induction motor causes the stator winding fault, which is immensely influenced by factors like mechanical vibration, heat, functional duration or age of motor, damage occurred during installation. Similarly, in some cases, the contamination with oil material also causes faults in induction motors, that results in system failure. In case of a squirrel-cage rotor, its bars might be damaged by mechanical stresses that could arise in the machine. Meanwhile, the bearings in induction motor can be affected due to extreme wear and smash up, caused due to improper lubrication, unbalanced loading on motor, misalignment of bearing components with rotor, etc.

Conventionally, the majority of manufacturers and users trust on very traditional approaches of induction motor protection like estimation of over-current or over-voltage to ensure the reliable system function. The high paced and immensely complicated applications of induction motor in modern industrial applications are alarming for an optimized system monitoring and supervision for induction machines. Even the reduction of the human-machine interface also demands for an on-line detection requirements, which can effectively diagnose the faults in induction motor without any hazards and process disruption.

On-line Diagnosis of Faults in Induction Motor

This is the matter of fact that the process of induction motor condition monitoring and its potential fault diagnosis is as old as the induction motor itself. Initially the fault detection in induction motor was based on the conventional approaches of estimation of over-current and over-voltage for ensuring the optimum operation. Regardless of the availability of these tools, numerous organizations are still facing problems due to unexpected failure of machineries with minimized motor life span [1]. Since, the works delivered by induction motors progressed more and more complicated, the enhancements for system was realized for condition monitoring and its fault diagnosis [2]. A number of enhanced diagnostic approaches were advocated and control mechanisms were devised for ensuring the fault resilient control devices. Fig 1 shows typical fault diagnosis

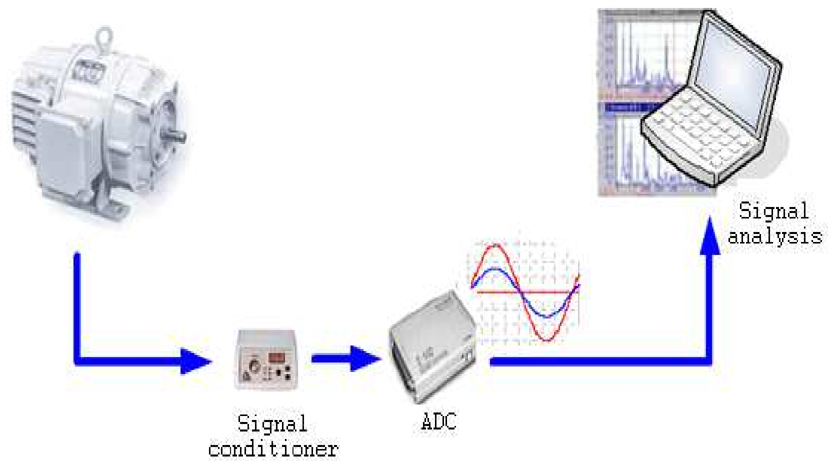


Figure 1 A typical fault diagnosis system for Induction Motor

Fig. 2 depicts desirable features of an effective fault detection system.

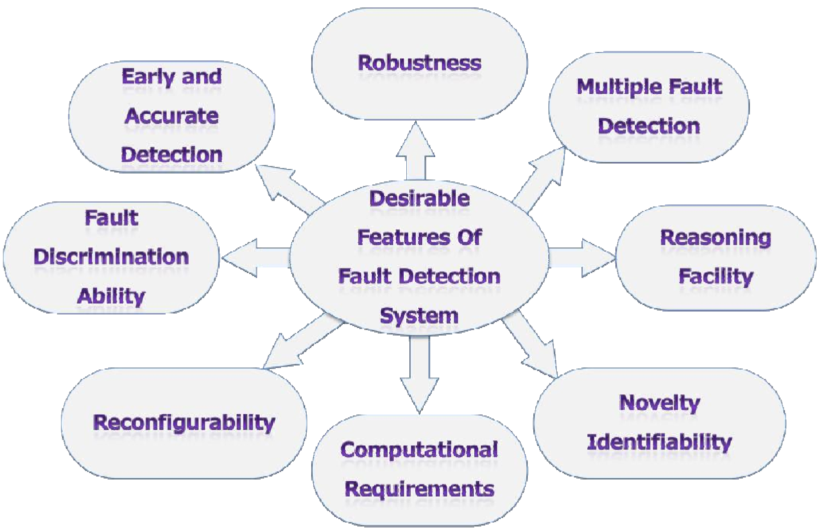


Figure 2 Desirable features of an effective Fault Detection System

Literature Survey

Kato, T et al. [7] suggests a technique for diagnosing the stator winding faults of an induction motor by the direct detection of asymmetry admittance component. In the diagnosis, initially, the asymmetry admittances for the considered fault situations under different load conditions are obtained using simulation procedures. The amplitude and phase of the positive and the negative sequence voltages, Vp and Vn and those of currents, Ip and In, are derived from the voltage and current Park vectors, respectively. The asymmetry admittance, Ya, is computed from them. These test steps are repeated for each sample and the motor condition is diagnosed as per the changes in the Ya value.

Soualhi, A et al. [8] demonstrated a new approach for detection and diagnosis of fault based on Hidden Markov Models. This approach applies pattern recognition combining motor current signature analysis (MCSA) and multiple features extraction. Feature extractions are obtained from transformations made on current and voltage signals to build the representation space. If the representation space is well picked each operating mode can be represented as a class. A hidden Markov model is then formed for each class and used as a classifier for the detection of faults. The proposed approach is tested for bearing failures and broken rotor bars detection of an induction motor of 5.5 KW. Additionally, the efficacy of this approach is compared to a neural network based approach. The experimental results prove that the hidden Markov model based approach is more efficient in condition monitoring of electrical machines.

Ahamed, S.K et al. [9] introduced an enhanced approach of identification of mass unbalance in the rotor of induction motor by performing analysis on the transient current being induced in the stator, while the motor is in starting mode. In this work, both CWT and DWT techniques have been used and the starting current at no-load has been obtained for diagnosing the faults. Since, the MCSA mostly relies on loading parameters of induction motor, when it is in steady-state condition, it was realized that the identification of faults by implementing MCSA approach with no-load condition becomes difficult for FFT techniques.

Premrudeepreechacharn et al. [10] presented two neural networks algorithms, supervised and unsupervised types with implementations to induction motor fault detection and diagnosis problems. The detection algorithm was simulated and its performance was verified for various fault types. Simulation results aptly illustrated the system can diagnose faults in induction machine.

Trabelsi, M. et al. [11] presents an investigation of insulated-gate bipolar transistors (IGBTs) open circuit faults detection and diagnosis in voltage source inverter fed three-phase induction motors. The proposed approach is based on the combination of the measurement of inverter pole voltage and the switching method. The signals derived by this combination allow not only the detection of single fault but also the multiple open circuit fault of the inverter switches. To avoid the false diagnosis indications, the time delays due to turn-on and turn-off process of the power switches are compensated while performing the switching pattern. The proposed technique was notable by an improved time delay between the fault event and its detection.

Khan, M. et al. [14] developed two DWT approaches that possess characteristics of identification as well as its classification in 3-phase induction motor. In the first scheme, DWT coefficient was considered as a criterion for comparison. While in another approach, they employed details of faults in various levels to differentiate faults.

Soualhi, A. et al. [15] presented a new approach for fault detection and diagnosis of Induction Motors using the signal-based method. It is based on signal processing and an unsupervised categorization technique called the artificial ant clustering. The proposed approach is experimented on a squirrel-cage Induction Motor of 5.5 kW to detect broken rotor bars and bearing failures at various load levels.

Methodology

Motor current signature analysis (MCSA) approach was employed to perform fault detection and then based on advanced techniques with various workload configurations the research was carried out in an optimum way. System architecture has been developed for different kinds of faults in induction motor, and accordingly, the developed schemes have been implemented for diagnosing the faults. Like in stator winding fault detection a computer-aided monitoring and stator current Park's vector approach have been developed which have been realized with the help of virtual instrumentation. In this implementation, the research employed the data acquisition followed by signal conditioning and analysis, which was eventually culminated in result visualization. The same approach was implemented with broken rotor bar fault detection and diagnosis process. Fig 3 depicts flowchart of Lab view.

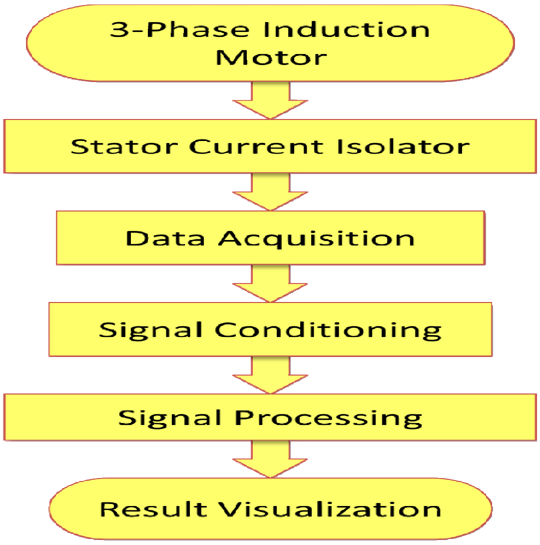


Figure 3 flowchart of Lab VIEW based DAQ

Fig 4 depicts the virtual instrument panel with particular voltage and current rating.

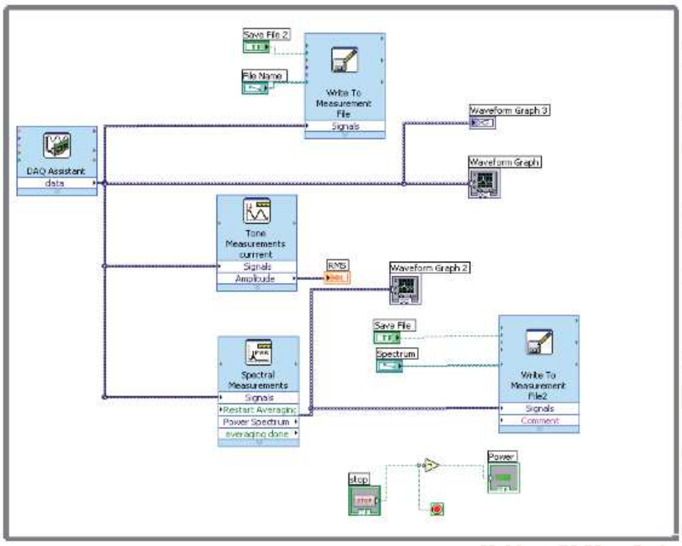


Fig 4: virtual instrument

Results:- The results can be distinctly observed from Figure 5 (where the power spectral density of the measured currents for the motor having 4 broken bars are plotted for three different cases. As it can be ascertained, the magnitude of the sideband frequency constituents is also increasing as the load is increased.

As already stated, the presence of the slip frequency sidebands establishes the existence of the broken rotor bars. The magnitude is the function of the number of the broken bars. This can be ascertained by referring to the Table 5 in which, amplitudes of fault frequency components for healthy and faulty motors are given. Figure 6 shows the variation of fault frequencies and their amplitudes with the number of broken rotor bars. It is evident from the plot that the number of broken bars can be found out through the measurement of fault frequencies and their amplitudes.

This phenomenon can be distinctly observed from Figure 5.1 (a) to (c), where the power spectral density of the measured currents for the motor having 4 broken bars are plotted for three different cases. As it can be ascertained, the magnitude of the sideband frequency constituents is also increasing as the load is increased.

As already stated, the presence of the slip frequency sidebands establishes the existence of the broken rotor bars. The magnitude is the function of the number of the broken bars. This can be ascertained by referring to the Table 5.1 in which, amplitudes of fault frequency components for healthy and faulty motors are given. Figure 5.2 shows the variation of fault frequencies and their amplitudes with the number of broken rotor bars. It is evident from the plot that the number of broken bars can be found out through the measurement of fault frequencies and their amplitudes.

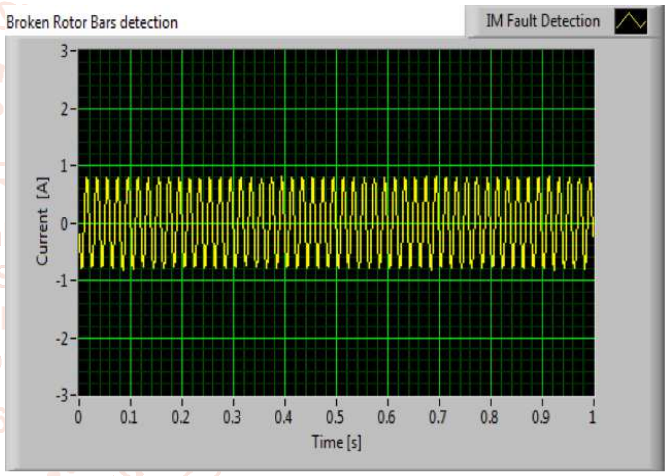


Fig 5:- stator current waveform

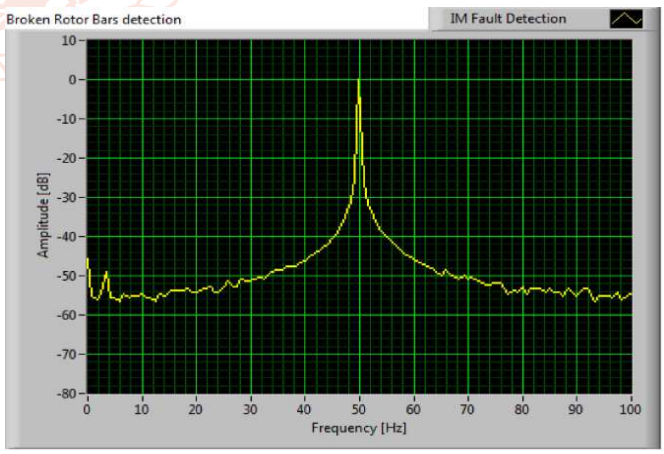
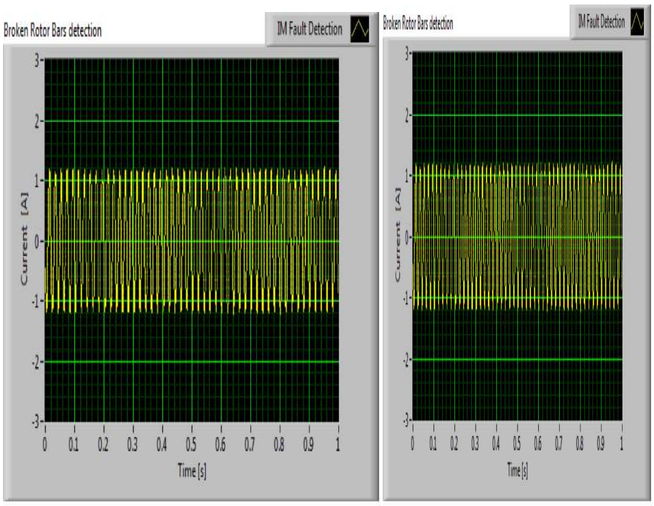


Fig 5 stator current spectrum



b) Stator current waveform and current spectrum in faulty state motor at half-load

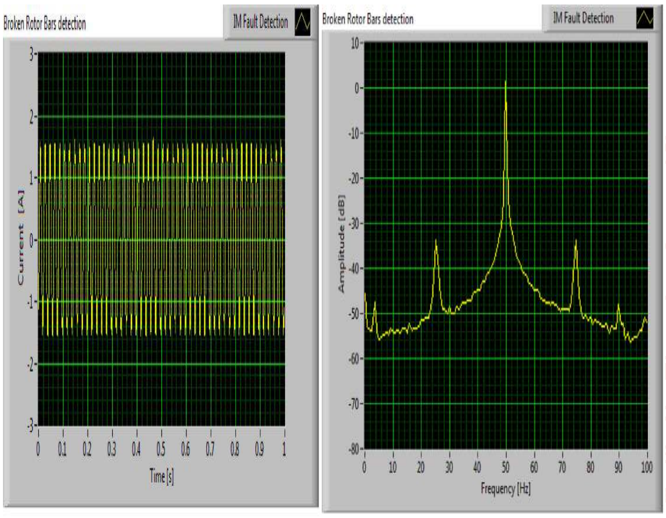


Fig 6 stator current waveform and current spectrum at full load

Conclusion:- Our experiment for Detection of broken rotor bar faults a system for fault identification in rotor bars of induction motors was developed. Here, investigations were conducted on 3-phase squirrel-cage induction motor for the detection of faulty rotor bars. The LabVIEW based spectrum analysis and Matlab based system models were developed, and performance with both healthy as well as faulty situations is presented.

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