Power Quality Monitoring of Induction Motor using Lab VIEW

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Abstract - Induction motors are widely used in transportation, mining, petrochemical, manufacturing and in almost every other field dealing with electrical power. These motors are simple, efficient, highly robust and rugged that's offering a very high degree of reliability. But like any other machine, they are vulnerable to faults, which is left unmonitored might lead to catastrophic failure of the machine in the long run. On line condition monitoring of the induction motors has been widely used in the detection of faults. This paper deals into the various faults and study of conventional and innovative techniques for induction motor faults with an identification of future research areas.

Keywords *- Condition Monitoring, Lab VIEW, Fault detection, induction motor, motor current signature analysis.*

1. Introduction

This section will discuss the overview of the work pursued in this paper. The motivation behind pursuing this paper will also be discussed. Poor power qualities affect functioning of utilities, different industrial units, productions, customer services and other system performance and operating costs. There is an ever increasing need for power quality monitoring systems due to the growing number of sources of disturbances in AC power systems. Monitoring of power quality is essential to maintain proper functioning of utilities, customer services and equipment's. Different existing methods of power quality monitoring already in use and available in literature and arrived at the conclusion that an improved and affordable power quality monitoring system is the need of the hour. This project gives the initial part of the research works of a simple power quality monitoring system by designing virtual instruments using Lab VIEW software.

Power quality monitoring programs are often driven by the demand for improving the system wide power quality performance. Many industrial and commercial customers have equipment thatis sensitive to power disturbances and therefore it is more important to understand the quality of power being provided. One of the most frequently used fault detection methods for induction motor is the current signature analysis. The motor current signature analysis method can detect these problems at an early stage and thus avoid secondary damage and complete failure of the motor. As a result, many power utilities perform power quality monitoring as an essential service for their main customers. Essential capabilities of a power quality monitoring system are reduced cost and remote data transmission capability.

2. Motivation

Lab VIEW provides an easy to use graphical programming environment. With this graphical programming language called "G", we program using a graphical block diagram that compiles into machine code. It is widely accepted by industry, academia, and research laboratories around the world as a standard for data acquisition and instrument control software. Since Lab VIEW is based on graphical programming, users can build instrumentation called virtual instruments(VIS) using software objects. Lab VIEW can be used to address the needs of various courses in a technology and science curriculum. It provides real-time simulation, testing as well as emulation[1].

Lab VIEW is chosen because this type of program allows students to spend less time writing the code to solve a problem and spend more time understanding the concepts. All other programs are text driven where the students have to write lines of code to analyze and design systems. Sometimes, these are not user-friendly and take a longer time. Power quality is becoming an increasingly important topic in the present day scenario. The electric utility system is designed to provide reliable, efficient, bulk power that is suitable for running the equipment. Any deviation to the magnitude and frequency of idealsinusoidal waveform can be regarded as a power quality disturbance. The increased requirements on supervision, control and performance in modern power systems make power quality monitoring a common practice for utilities. Current electronic devices like microprocessors, microcontrollers, sensitive computerized equipment etc. are all susceptible to power quality disturbances.

3. Methodology

The monitoring system observes the waveform signal and gives the information about distortion levels in it. It can be designed in such a way that if the distortion is beyond the limits, the computer notifies the user about the danger levels, using this information we can know the power quality at the consumption level. Hence we can make the necessary improvements to prevent the waveform distortions. This work proposes the development of a computer-based power analyzer that provides real time monitoring of various power quality parameters, with remote monitoring feature. The system runs on a desktop computer with National Instruments (NI) 9239 Data Acquisition (DAQ) card and cDAQ 9184 Chassis. The system is implemented as a virtual instrument (VI), whereby, a programming and user interface is developed using Lab VIEW. Monitoring of induction motor have been a challenging task for the engineers mainly in industries. There are many condition monitoring methods, including vibration monitoring, thermal monitoring, chemical monitoring, acoustic emission monitoring.

As mentioned earlier, LabVIEW provides a user-friendly graphical programming environment. This work is an attempt to adopt the visual interface offered by LabVIEW for simplified design implementation and use of programmable measurement for system parameters. The aim is to generate a graphical user interface which includes displays, switches, buttons and other controls through which the user can monitor and adjust different parameters to customize monitoring tasks. Also, a National Instruments Data Acquisition card is chosen to interface the analog AC signal as a second step after taking the input. These inputs to the system are conditioned before interfacing and this helps curb the loss of data and ensures simultaneous sampling. Sensors are used for measurement of single phase currents and voltages.The power quality monitoring system includes both software and hardware development. The system software is developed in Lab VIEW. The graphical user interface includes waveform displays, switches, buttons and other controls through which the user can monitor and adjust different parameters to customize monitoring. The purpose of the sampler is to monitor a single phase of induction motor current. This is accomplished by removing the 50 Hz excitation component through low pass filtering, and sampling theresulting signal. The current flowing in single phase of theinduction motor is sensed by a current transformer and sent to a 50 Hz notch filter where the fundamental component is reduced. The analog signal is then amplified and low pass filtered. The filtering removes the undesirable high-frequency components that produces aliasing of the sampled signal while the amplification maximizes the use of the analog-to-digital A/D converter input range. The A/D converter samples the filtered current signal at a Predetermined sampling rate that is an integer multiple of 50 Hz. This is continued over a sampling period that is sufficient to achieve the required Fast Fourier Transform (FFT).

The preprocessor converts the sampled signal to the frequency domain using an FFT algorithm. The spectrum generated by this transformation includes only the magnitude information about averaging a predetermined number of generated spectra. This can be accomplished by using either spectra calculated from multiple sample sets or spectra computed from multiple predetermined sections (or windows) of a single large sample set. Because of the frequency range of interest and the desired frequency resolution, several thousand frequency components are generated by the processing section.

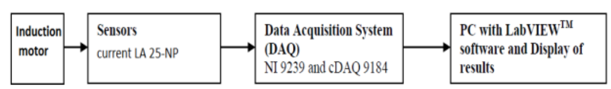

Figure 3.1: system level block diagram

The block diagram being a functional diagram of the system includes built-in functions, program control structures, and sub-Vis. Each component in the block diagram has an icon and a connector. The connectors enable data flow from one element to another. The simulations VIs generated thus can be used to produce voltage and current waveforms. The interfacing devices are used to connect the software and hardware. As can be seen from the above diagram, a National Instruments Data Acquisition card is chosen to interface the analog AC signal as a second step after taking the input. Sensors are used for measurement of single phase currents and voltages. Current probes and Hall Effect voltage and current sensors are employed to acquire voltage and current signals for proper and accurate measurements and the analog to digital conversion of the input signals are all taken care of by the DAQ card NI 9239 as these functions are inherent in the card.

The components used are as follows:

1. LEM Current Transducer (LA 25-NP)
2. Regulated Power Supplies for transducers: ±15V
3. Three phase Induction motor

4. Three phase Auto transformer
5. DAQ CARD NI 9239 and cDAQ 9184
6. Computer with Lab VIEW software

The specifications of these devices are listed further in the report.In order to prevent any loss of data and for ensuring accurate measurements, simultaneous sampling of the input signals is imperative. Hence NI 9239 has been employed which is a 4-Channel, 24-Bit Analog Voltage Input Module that provides simultaneous sampling.In order to diagnose motor faults, MCSA uses the current spectra, which contains potential information of motor faults. A motor failure due to stator winding faults may result in the shut down of a generating unit or production line. One major cause of the failures is breakdown of the winding insulation leading to puncture of ground wall. Early detection of stator short winding during motor operation may eliminate consequent damage to adjacent coils. It reduces repair cost and motor outage time.

The frequencies which appear in the spectrum showing the presence of a broken rotor fault are given by the following equation.

$$f_b = \left[\left(\frac{k}{p}\right)(1-s) \pm s\right] f \qquad (1)$$

Where p = pole pairs
s = rotor slip
k = 1, 3, 5 …
f = supply frequency
f_b = broken rotor frequency

The effects of air gap eccentricity produce unique spectral patterns and can be identified in the current spectrum. The presence of static and dynamic air gap eccentricity can be detected using MCSA. One of the equations describing the frequencies components is given by[3].

$$f_{ecc} = f_s \left[1 \pm m\left(\frac{1-s}{p}\right)\right] \qquad (2)$$

Where p = pole pairs
S = rotor slip
m = 1, 2, 3…
f_s = supply frequency

Installation problems are often caused by improperly forcing the bearing onto the shaft or in the housing. This produces physical damage in the form of brinelling or false brinelling of the raceways which leads to premature failure. Misalignment of the bearing, which occurs in the four ways depicted is also a common results of defective bearing installation. The relationship of the bearing vibration to the stator current spectra can be determined by remembering that any air-gap eccentricity produces anomalies in the air-gap flux density.

Since ball bearings support the rotor, any bearing defect will produce a radial motion between the rotor and stator of the machine. The mechanical displacement resulting from damaged bearing causes the machine air gap to vary in a manner that can be described. Since ball bearings support the rotors, any bearing defect will produce a radial motion between the rotor and stator of the machine. The mechanical displacement resulting from damaged bearing causes the machine air gap to vary in a manner that can be described by a rotating eccentricities moving in both directions. Due to rotating eccentricities, the vibrations generate stator currents at frequencies given by fallowing equations.one of the equation describing bearing fault frequency is given by

$$f_{bng} = |f_s \pm m f_{i,o}| \qquad (3)$$

Where f_s = supply frequency

m = 1, 2, 3

$f_{i,o}$= characteristicvibration frequency

fs = supply frequency

3.1 Implementation

As discussed earlier, the power quality monitoringsystem includes both hardware and software

Table No: 3.1. LA 25-NP/SP14 Current Sensor Specification

	Parameters	**Ratings**	**Units**
Ipn	Primary nominal current R.M.S	0.25	At
Ip	Primary current, measuring range	0…±36	At
R_m	Measuring resistance With ±15 V @ ±0.25A max @ ±0.36A max	$R_{min}R_{max}$ 100 320 100 190	Ω Ω
Isn	Secondary nominal current R.M.S	25	mA
Kn	Conversion ratio	100:1000	
Vc	Supply voltage (±5%)	±15	V
Ic	Current consumption	$10+I_s$	mA
V_d	R.M.S voltage for AC isolation test, 50 Hz, 1mm	2.5	kV
BW	Frequency Bandwidth(-1 dB)	DC..150	kHz

development. The hardware implementation includes the hardware design and the schematic diagram of the various components while the software implementation outlines the system software developed in LabVIEW™. The graphical user interface includes waveform displays, switches, buttons and other controls through which the user can monitor and adjust different parameters to customize monitoring.

3.1.1 Hardware Implementation

In terms of hardware, the system consists of one current sensor, regulated power supply for transducer, induction motor, a data acquisition card and a computer having Lab VIEW software.The selection of components and their specifications are as listed below.

3.1.1.1 Selection of components

The data acquisition card employed for this work is the NI 9239 which is a 4 channel USB carrier with 24 bit resolution providing channel to channel isolation and a sampling rate of 50KS/sec/channel. The biggest advantage that also led to the selection of this card is its provision for simultaneous sampling which is crucial to calculations.

3.1.1.2 Current Transducers

The current sensor is a closed loop Hall effect LEM transducer LA 25-NP/SP14. Closed loop transducers use the Hall generator voltage to create compensation current in a secondary coil for generation of a total flux, as measured by the Hall generator, equal to zero. In other words, the secondary current I_s, creates a flux equal in amplitude, but opposite in direction, to the flux created by the primary current.

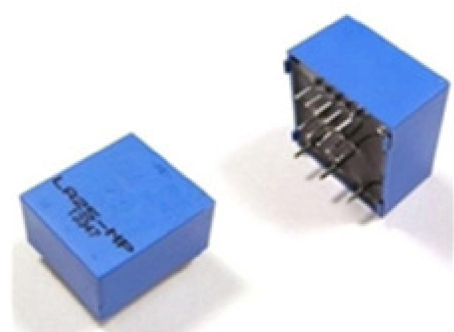

Fig: 3.2 LA 25-NP Current sensor

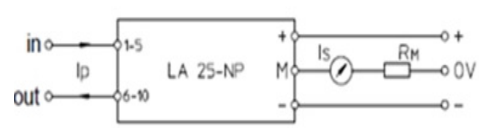

Fig: 3.3 LA 25-NP current sensor connection diagram

3.1.1.3 Regulated Power Supply for Transducer

A regulated power supply is an embedded circuit, it converts unregulated AC into a constant DC. With the help of a rectifier it converts AC supply into DC. Its function is to supply a stable voltage (or less often current), to a circuit or device that must be operated within certain power supply limits. The output from the regulated power supply may be alternating or unidirectional, but is nearly always DC. Many topologies have been used since the regulated supply was invented. Early technologies included iron hydrogen resistors, resonant transformers, nonlinear resistors, loading resistors, neon stabilizer tubes, vibrating contact regulators etc.Modern regulated supplies mostly use a transformer, silicon diode bridge rectifier, reservoir capacitor and voltage regulator IC. There are variations on this theme, such as supplies with multiple voltage lines, variable regulators, power control lines, discrete circuits and so on. Switched mode regulator supplies also include an inductor.

To deliver voltage of ±15V to LA 25-NP current sensor with respect to ground a regulated power supply is essential. So for that a single phase 220V, 50Hz center tapped transformer and four IN4001 diodes, and different capacitors as shown in below figure as taken and IC 7815 is used for +15V and IC 7915 is used for -15V.

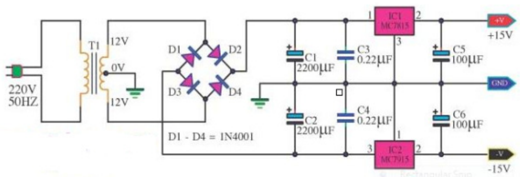

Fig: 3.4Circuit power supply regulator +15V -15V 1A by IC 7815 & 7915

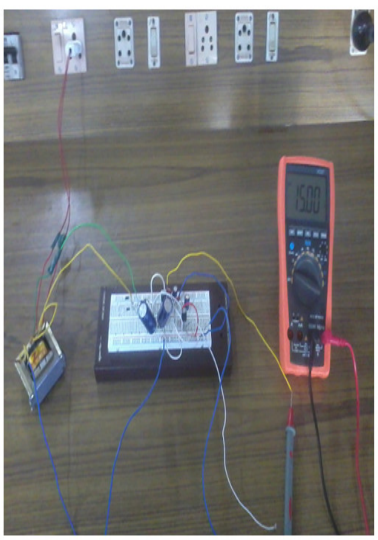

Fig: 3.5 Experimental setup of regulated power supply of +15V and -15V

3.1.2 Software Implementation

LabVIEW™ includes a set of VIs that allow configuration and acquisition of data from and sending data to DAQ devices. We can perform a variety of functions such as analog to digital conversion(A/D), digital to analog conversion(D/A), digital I/O, counter/timer operation etc. This application calculates various parameters used in the analysis of an electrical system: True RMS values, phase angles, voltage and current, power factor and power (active, reactive and apparent). In addition to the numerical values, the same information can also be plotted. An advantage of this application is the possibility of working in two different modes: "Simulation" and "Acquisition". In the mode "Acquisition", all the calculations are based on the signals measured by the sensors of the system designed while in the mode "Simulation", all the values of the system are calculated on the basis of signals generated by LabVIEW™. These generated signals can be configured by the user in the following parameters: amplitude, frequency and phase, introduction of harmonic components intended for each signal etc.

3.1.2.1 Data Acquisition card NI 9239 and cDAQ9184 Chassis:

The NI 9239 is a 4 channel USB carrier with 24 bit resolution providing channel-to-channel isolation. Its maximum range is ±10 VDC, has an isolation level of 250 VRMS and a sampling rate of 50 kS/s/ch.The NI cDAQ-9184 is a 4-slot NI Compact DAQ Gigabit Ethernet Chassis designed for remote or distributed sensor and electrical measurements and can measure upto 256 channels of sensor signals, analog I/O, digital I/O, and counter/timers with an Ethernet interface back to a host PC or laptop. The NI Compact DAQ platform delivers high-speed data and ease-of- use in a flexible, mixed-measurement system. Modules are available for a variety of sensor measurements including thermocouples, Resistance Temperature Detectors (RTDs), strain gages, load and pressure transducers, torque cells, accelerometers, flow meters, and microphones.[4]

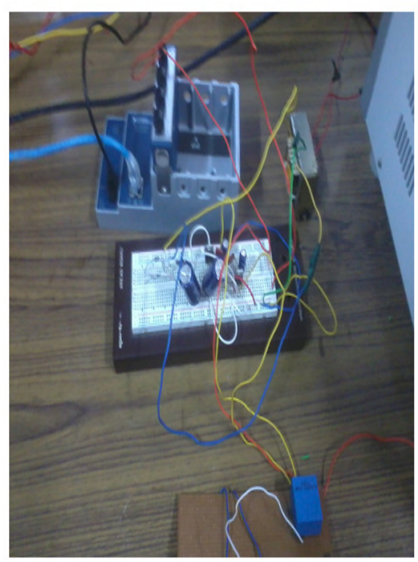

Fig: 3.6 Experimental setup of NI cDAQ-9184 chassis & NI 9239

IJCAT International Journal of Computing and Technology, Volume 1, Issue 2, March 2014
ISSN : 2348 - 6090
www.IJCAT.org

3.1.2.2 Measurement & Automation Explorer (MAX)

National Instruments provides Measurement & Automation Explorer (MAX), a graphical user interface, to configure IVI drivers. MAX is usually installed with one of the NI application development environments such as Lab VIEW or Measurement Studio, or with one of NI's hardware product drivers such as NI-488.2 or NI-DAQ.

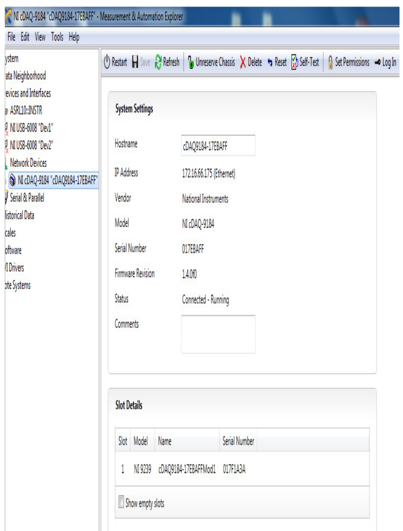

Fig.3.7 MAX System Settings

The NI cDAQ-9184 chassis icon changes from white, to blue as can be seen from fig 6.10 indicating that it is recognized and present on the network. Self-test is to be performed on the chassis before making any measurements. This can be done in MAX by expanding Devices and Interfaces, right-clicking NI cDAQ model number and selecting Self-Test.

Self test performs a brief test to determine successful chassis installation. When the self-test finishes, a message is displayed and this indicates successful verification or occurrence of an error.

To perform any DAQ functionality on the C series modules, including reset chassis and self-test, one must reserve the cDAQ chassis in MAX. Only one user at a time can reserve the cDAQ chassis. MAX cDAQ 9184 configuration settings are shown in below figure.3.8

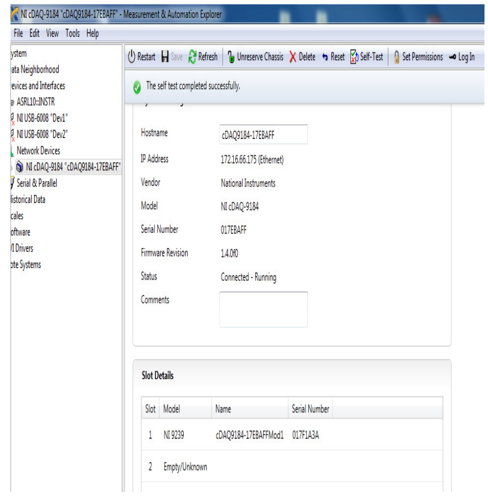

Fig.3.8 MAX cDAQ 9184 Configuration Settings

3.1.2.3 DAQ Assistant

National Instruments data acquisition devices have a driver engine that communicates between the device and the application software. NI-DAQmx is the latest NI-DAQ driver with new VIs, functions and development tools for controlling measurement devices. This includes the DAQ assistant for configuring channels and measurement tasks for a device. Here, NI USB 9239, a multi-channel data acquisition card is used for analog to digital conversion, and is configured by the data assistant to the application software. This includes the DAQ Assistant for configuring channels and measurement tasks for a device.

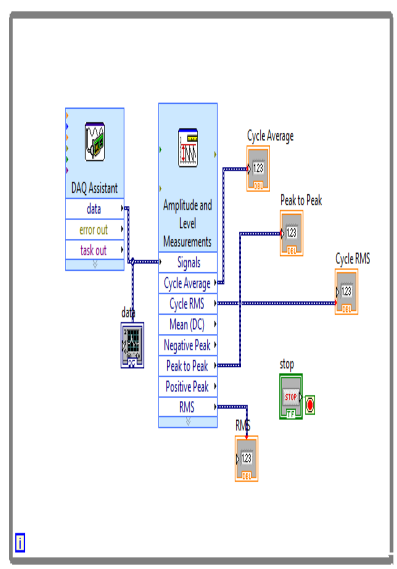

Fig.3.9 Block diagram for data acquisition using DAQ Assistant

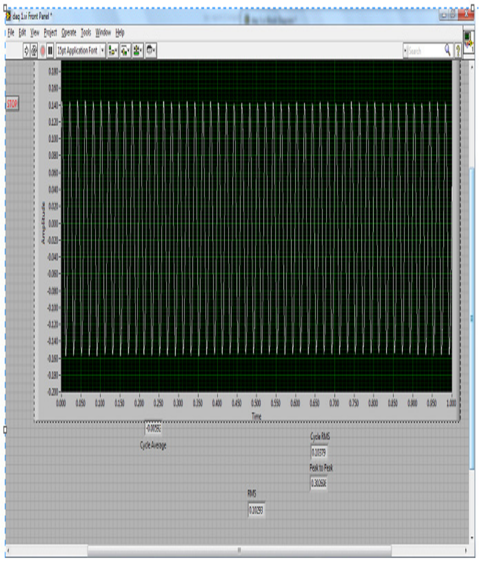

Fig.3.10 Front panel view of data acquisition of induction motor

4. Tools

Finding the cause of a power quality problem is in many cases the first step in solving and mitigating the problem. With these kinds of measurements, it is important to extract as much information as possible from recorded voltage and current waveforms. In this phase data sheets, Tools, software's are used.

- Catalog of current transducer LA 25 NP
- Data sheets of NI 9239 and NI cDAQ-9184
- Lab VIEW Software

5. Result Analysis

It is observed that the technique called 'Motor Cureent Signature Analysis' (MCSA) is baseed on current monitoring of induction motor, therefore it is not very expensive. The MCSA uses the current spectrum of the machine for locating characteristic fault frequencies. When a fault is present, the frequency spectrum of the line current becomes different from healthy motor. Such a fault modulates the air-gap and produces rotating frequency harmonics in the self and mutual inductances of the machine. It depends upon locating specific harmonic component in the line current. Therefore, it offers significant implementation and economic benefits. In the project, Motor Current Signature Analysis based methods are used to diagnose the common faults of induction motor such as broken bar fault, short winding fault, bearing fault, air gap eccentricity fault, and load faults.

The proposed methods in the project allows continuous real time tracking of various types of faults in induction motors operating under continuous and variable loaded conditions. The effects of various faults on current spectrum of an induction motor are investigated through experiments.In order to perform accurate and reliable analysis on induction motors, the installation of the motors and measurement of signal need to be accurate. Therefore, an experimental procedure and an experimental set up has been designed that can accurately repeat the meassurements of signals and can introduce a particular fault to the motor in isolation of other faults. Stator current contains unique fault frequency components that can be used for detection of various faults of motor. Therefore, this project work investigates how the presence of common faults, such as rotor bar fault, short winding fault, air gap eccentricity, bearing fault, load fault, affects on different fault frequencies under different load conditions.In the present work, signal processing techniques are to be use for condition monitoring and fault detection of induction motors. The signal processing techniques have advantages that these are simple to implement. Therefore, fault detection based on the signal processing techniques is suitable for anautomated on-line condition monitoring system. Signal processing techniques usually analyze and compare the magnitude of the fault frequency components, where the magnitude tends to increase as the severity of the fault increase.Therefore, signal processing techniques can be used to detection of common faults of induction motor.

Fig.5.1 Experimental setup of the model

6. Conclusion

Induction machines play a pivotal role in industry and there is a strong demand for their reliable and safe operation. They are generally reliable but eventually do wear out. Faults and failures of induction machines can lead to excessive downtimes and generate large losses in terms of maintenance and lost revenues, and this motivates the examination of on-line condition monitoring. On-line condition monitoring involves taking measurements on a machine while it is operating in order to detect faults with the aim of reducing both unexpected failures and maintenance costs. This paper surveys the current trends in on-line fault detection and diagnosis of induction machines and identifies future research areas.

Accurate means for condition monitoring can improve the reliability and reduce the maintenance costs of induction motors. Condition monitoring involves sampling sensor signals, processing these signals to extract features which are sensitive to the presence of faults, deciding if a fault exists and identifying its type.

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