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MOTOR CURRENT SIGNATURE ANALYSIS BASED FAULT DIAGNOSIS OF INDUCTION MOTOR

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ABSTRACT

Condition monitoring and fault diagnosis systems are employed in industries to monitor the health of the machines continuously. Induction motors are widely used in transportation, manufacturing, mining, manufacturing , petrochemical and in almost every other fields dealing with electrical power. For industry, a faulty induction motor signifies reduction in production and cost increase. Motor Current Signature Analysis (MCSA) is the most popular method used for fault detection in the induction motor. MCSA is a diagnosis method for induction motors fed by supplies with high harmonic content and also helps in the detection of faults due to remarkable noise on the line current, transient operating conditions. This harmonic content, which is normally known as a major side effect, gives rise to extra signatures which is utilized by the MCSA in distinguishing faulty current spectrum patterns from healthy ones. The proposed system is a diagnosis method for the detection of stator faults occurring in three phase squirrel cage induction motors and correction of extra signatures in the current spectrum using the combination of MULTISIM and LabVIEW.

Keywords: Condition monitoring, Current spectrum, diagnostic, MCSA, stator fault, fault detection.

1. INTRODUCTION

Induction motors are the mainstay for every industry. However these machines, will eventually fail because of heavy duty cycles, installation, poor working environment and manufacturing factors, etc. With increasing demands for efficiency and reliability, the field of fault diagnosis in induction motors is gaining importance [22]. There are many condition monitoring methods including chemical monitoring, vibration monitoring, thermal monitoring, acoustic emission monitoring but all does not require expensive sensors or specialized tools where as current monitoring out of all does not require additional sensors [17]. This is because the basic electrical quantities associated with electromechanical plants such as current and voltage are readily measured by tapping into existing voltage and current transformers at the protection system. With the hope of utilizing the advantages of current monitoring the Motor Current Signature Analysis (MCSA) based fault diagnosis system [24] is proposed here.

2. VARIOUS TYPES OF FAULTS IN INDUCTION MOTOR

A variety of faults occur within the three phase induction motor during the course of normal operation. These faults can lead to a potentially catastrophic failure if undetected [1]. Consequently, a variety of condition monitoring techniques has been developed for an analysis of abnormal conditions. The common internal faults can be mainly categorized into two groups:

1.**Electrical faults**

The following electrical faults are very common in three phase induction motor while operating in industries.

- ***Stator fault***

A stator turn fault in a symmetrical three phase ac machine cause a large circulating current to flow and subsequently generates excessive heat in the shorted turns [3][21].These can be Open circuit fault, line-to-line fault, Turn-to-turn fault, Coil-to-coil fault and Line-to-ground fault as in the Figure 1.

- ***Rotor fault***

The rotor faults occurs due to several reasons such as,

• During the breezing process in manufacture, non-uniform metallurgical stresses may be built into cage assembly and these can also lead to failure during operation.

• A rotor bar may be unable to move longitudinally in the slot it occupies, when the thermal stresses are imposed upon it during starting of machine.

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• Heavy end ring can result in large centrifugal forces, which can cause dangerous stresses on the bars.

2. Mechanical faults

Common mechanical faults found in three phase induction motor are Air gap eccentricity, this can be Static eccentricity, Dynamic eccentricity and Mixed eccentricity, Bearing faults and Load faults.

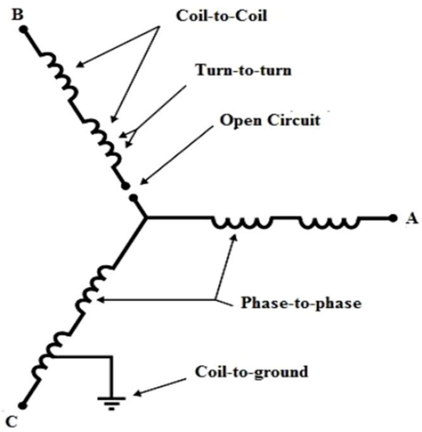

Fig 1 Types of stator winding faults of induction motor

3. NECESSITY OF FAULT DIAGNOSTIC

Fault diagnostic techniques are gaining importance in industry because of the need to increase reliability and to decrease the possibility of production loss due to machine breakdown. By comparing the signals of a machine running in normal and faulty conditions, detection of faults such as mass unbalance, shaft misalignment, gear failures and incipient failures of the components, through the online monitoring system, decreasing the possibility of catastrophic damage and the downtime [8][19]. Although often the visual inspection of the frequency domain features of the measured signals is adequate to detect the faults, there is a requirement for a reliable, fast, and automated procedure of diagnostics [2].

4. VARIOUS FAULT DIAGNOSTIC TECHNIQUES

Significant efforts have been devoted to induction machine fault diagnosis and many techniques have been proposed based on the following [6][7]

- Stator current spectral analysis, which uses the power spectrum of the stator current to detect broken rotor bar faults [4].
- Magnitude of certain frequency components of the stator currents.
- Analysis of the negative sequence components of the stator current (mainly used to detect inter-turn short circuits)

Other techniques include vibration analysis [20], acoustic noise measurement, temperature analysis, torque profile analysis and magnetic field analysis [8]. These techniques require sophisticated and expensive sensors, additional electrical and mechanical installations, and frequent maintenance and are not preferred [10] [13]. The most popular methods of induction machine condition monitoring utilize the steady-state spectral components of the stator quantities. These stator spectral components includes voltage, power and current and are used to detect turn faults, broken rotor bars, air gap eccentricities, bearing failures. Presently, many techniques that are based on steady-state analysis are Motor Current Signatures Analysis (MCSA) and the Extended Park’s Vector Approach (EPVA) [21], as well as a new transient technique that is a combination of the EPVA, the Discrete Wavelet Transform [10] [14]. The MCSA technique exploiting the current spectrum is discussed in brief.

5. MOTOR CURRENT SIGNATURE ANALYSIS (MCSA)

Motor-current-signature analysis (MCSA) is a condition monitoring technique that will be widely used to diagnose problems in electrical motors. MCSA focuses its efforts on the spectral analysis of the stator current and has been successfully applied to detect abnormal levels of air-gap eccentricity, broken rotor bars, and shorted turns in stator windings, among other mechanical problems. The main purpose of MCSA is to analyze the stator current in search of current harmonics directly related to new rotating flux components, which are caused by faults in the motor-flux distribution [15][16].

Motor Current Signature Analysis (MCSA) is a system used for analyzing or trending dynamic

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energized systems [5]. The results of MCSA assist in the identification of the following:

1. Incoming winding health
2. Stator winding health
3. Rotor Health
4. Air gap static and dynamic eccentricity
5. Coupling health, together with direct, belted and geared systems
6. Load issues
7. Bearing health

5. PROCESS INVOLVED IN MCSA BASED FAULT DIAGNOSIS

The block schematic for the analysis of the current spectrum of the three phase induction motor using MCSA is shown in Figure 2.The MCSA fault detection system includes the following

- ***Current Transformer***

Current transformer (CT) senses the signal from the induction motor. Depending on the installation, the CT can be of two types, namely a clip-on CT around one of the phases of the supply or around the secondary side of an existing instrumentation. Only one CT is required for MCSA based systems and can be in any one of the three phases. The fundamental reason is that the rotating flux waves produced by the different faults cut all three stator phase windings and corresponding currents are induced in each of the three phases [11].

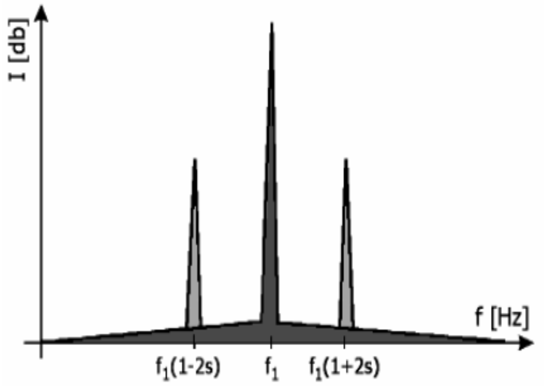

Fig 2. Idealized current spectrum

An idealized current spectrum is shown in Figure 3. It represents the twice slip frequency sidebands along decibel (dB) versus frequency spectrum (referred as linear root mean square (rms)) giving a wide dynamic range to detect the unique current signature patterns that are characteristic of different faults. In the occurrence of any fault, results in a backward rotating field in the air gap and the spectrum of stator current will change.

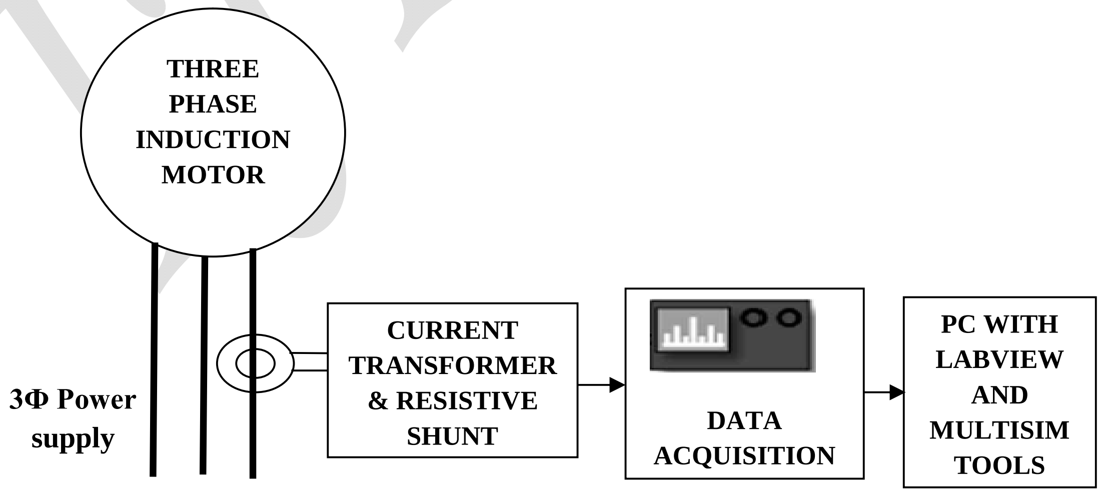

Fig 3. Block Schematic of the proposed system

- ***Motor Current Signature Analysis(MCSA) of Induction motor***

Current Signature analysis is the procedure of capturing a motor's current & voltage signals and analyzing them to detect various faults. 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

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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 [23].

The spectrum of supply current of an induction motor can be analyzed for the diagnosis of faults appearing in it. This is done by verifying and comparing certain parts of the analyzed signal's harmonic content with those of the signal measured for a healthy machine. For a healthy motor, there will be no existence of backward rotating field and only the forward rotating magnetic field rotates at synchronous speed [25].

In an induction machine, depending on the type of fault, the detected sideband harmonic components of the line current may differ. By comparing the faulty spectrum with the healthy spectrum the detection of various faults can be identified [18].

There are a number of simple steps that can be used for analysis using MCSA. The steps are as follows

1. Map out an overview of the system being analyzed.
2. Determine the complaints related to the system in question. For instance, is there reason for analysis due to improper operation of the equipment and other data that can be used in an analysis.
3. Acquire data.
4. Review data and analyze:
    - Review the snapshot of current for 10 second to view the operation over that time period.
    - Review low frequency demodulated current spectrum to view the condition of the rotor and identify any load-related issues.
    - Review high frequency demodulated voltage and current in order to determine other faults including electrical and mechanical health.

- ***Data Acquisition system***

This method is based on the spectral decomposition of the steady state stator current which can be acquired with simple measurement equipment and under normal operation of the machine. In the MCSA method, the current frequency spectrum is obtained with the use of data acquisition module and specific frequency components are analyzed by the software tools such as LABVIEW and MULTISIM installed in the PC. These frequencies are related to well-known machine faults. Therefore, after processing the stator current, it is possible to infer about the machine's condition.

- ***Analysis with MULTISIM and LabVIEW***

The MULTISIM is an electronic workbench simulation program for the designing the proposed MCSA based fault detection system as illustrated in Figure 3.4. With the advanced analysis and design capabilities it simulates the system to provide optimized performance, reduce design errors, and shorten time to prototype.

The protection devices such as MCB, MCCB, OLR and RCCB are used in the industrial factory field. These protection devices are not shown in the simulation design in order to avoid complexity and time consumption factors. By using LABVIEW virtual instruments all the performance parameters of the induction motor in the real world is converted into digital data and be processed by computer.

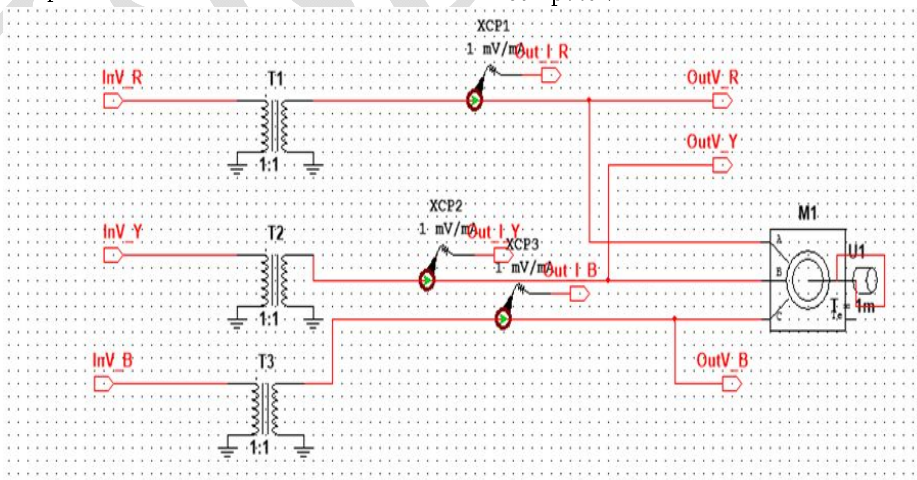

Fig 4. Multisim model for signature acquisition

The performance parameter here is the current spectrum or signature will appear at monitor. The simulation model for the proposed system is shown in the Figure 4.A PC based DAQ system is plugged in for the combination of the computer with the signal from induction motor. It shows the real time characteristic of the experimental induction motor during its operation. Beside give the graphical views to the user, LABVIEW also give a good analysis capabilities about the measurements on the induction motor in the proposed system.The current signature of the induction motor is acquired from

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each phase of the power supplied to the IM. Analysis of the current signature is carried out as a co-simulation in LabVIEW.

Simulation of healthy and faulty motors and comparison of their respective signatures is accomplished with the help of labVIEW tool [9]. In order to create faults in motor the Multisim software has been utilized [12].

6. SIMULATION RESULTS

The faulty motor designed with different fault types are simulated by clicking on the Simulation button. The output current spectrum or signature of the motor with each of open circuit, short circuit and leakage faults are presented here.

i. ***Open Circuit fault***

Due to aging, high speed applications and mechanical stress cut off of any of the winding presented in the stator side the open circuit fault occurs. The opened phase directly goes to zero and other phases are affected by noise shown as fluctuations. With each phase opened the following waveform shown in Figure 5 depicts the faulty current spectrum.

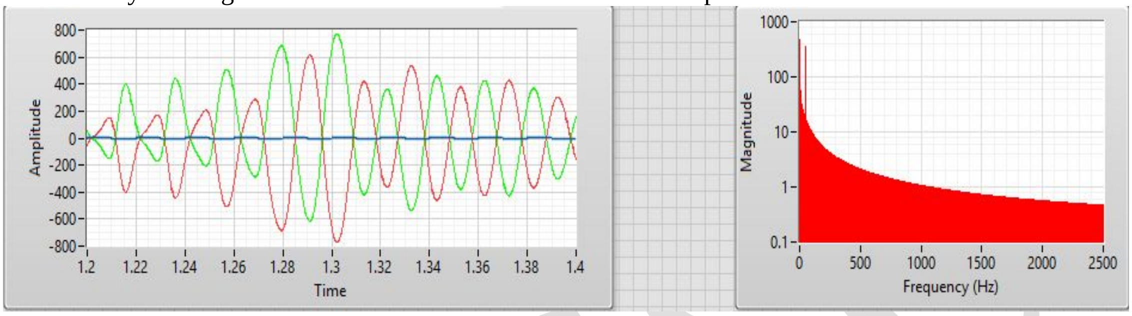

Fig 5 Signature of the faulty IM with Open Circuit fault (A opened)

ii. Leakage Fault

Winding turn-to-turn or turn-to-earth occurrences causes the leakage faults. This is the early fault of open circuit and short circuit of the windings. This result causes the uneven voltage and currents among the three phases and creates noise, heat and variations in the speed. Leakage occurring at any of the stator winding phase causes similar faulty spectrum.

Due to such leakages winding may suffer short circuit whose affected signature is shown in the figure 6.

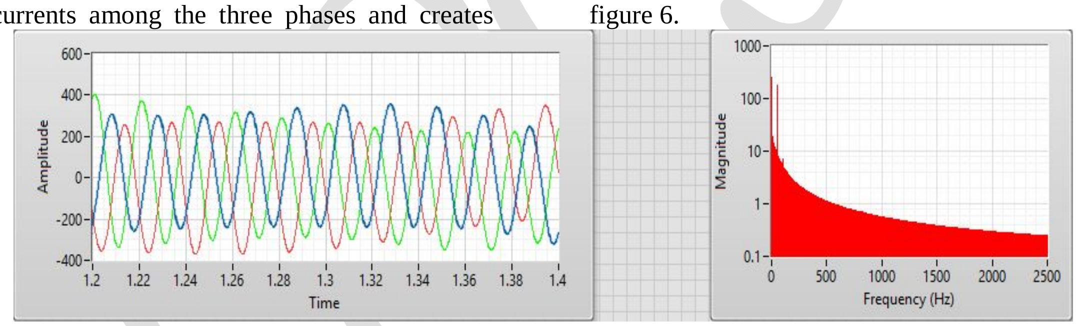

Fig 6 Signature of the faulty IM with Leakage fault

iii. Short Circuit Fault

The shorting between the two different phases in stator windings of the induction motor causes short circuit fault producing enormous flow of current and zero voltage resulting in a faulty current spectrum. By shorting three different combinations of the phases of the induction motor stator winding,the faulty output current spectrums are acquired as in Figure 7.

Thus the current spectrum of the healthy motor for the comparison with that of the faulty motor is obtained from the simulation results. In order to acquire the current spectrum of faulty motor, the internal fault is created with the use of the fault options provided by the LabVIEW simulation tool.

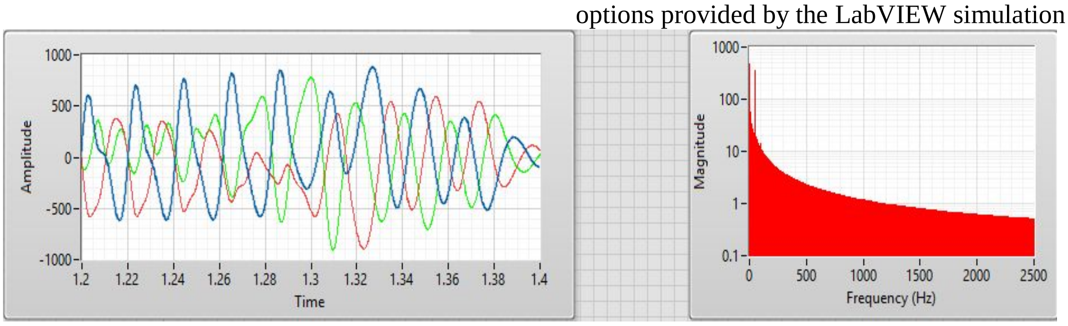

Fig 7 Faulty current Spectrum by shorting A & B phases

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7. CONCLUSION

Thus the efficiency of the MCSA method to detect different stator faults in the IM and to discriminate between them has been proved along with its important advantages such as the simplicity of the data acquisition systems and the required software, along with the robustness of the tools used, which has provided quite satisfactory results. Also, from the stator current spectrum analysis it is possible to detect rotor as well as stator faults. Hence, the simulation presented in the paper establishes the efficiency and effectiveness of this method in area of computer aided condition monitoring of induction machines.

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