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Identify Faults of Induction Motor through Motor Current Signature Analysis (MCSA) Approach

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Abstract

Induction motors are essential in many industrial applications, and their dependable performance is critical for maintaining productivity and avoiding expensive downtime. Nevertheless, these motors are prone to flaws and deterioration over time, requiring efficient diagnostic methods for prompt intervention. Motor Current Signature Analysis (MCSA) is a method that depends on current monitoring and is used in this study. In order to load unique fault frequencies, it makes use of the machines current spectrum. In order to find problems via measurement, a signal processing method for condition monitoring is used. The motor used in the experiment is a 3-phase, 4-pole, 50Hz model with 0.5 horsepower. One and a half mega-samples per second is the scanning speed. The power spectrum is obtained by the use of LabVIEW software and the Virtual Instrument (VI). To determine the impact of short winding defects under varying loads, experiments are conducted.

Keywords: Current Signature, Induction Motor, Fault Diagnosis, Approach, Motor.

I. Introduction

Induction motors are often used in industrial operations to power a wide range of machines in different sectors. Smooth performance of these crucial components in industrial infrastructure is essential to sustain output and avoid expensive downtime. Induction motors, being electromechanical systems, are prone to flaws and deterioration with time, potentially impacting their performance and dependability. Swift identification and diagnosis of these malfunctions are essential to maintain the uninterrupted and effective functioning of industrial operations. Motor Current Signature Analysis (MCSA) is a potent technique for diagnosing faults in induction motors. It relies on the distinct electrical patterns displayed by motors under various operating situations and problem scenarios. Induction motors are commonly used in industrial settings for their durability, straightforward design, and cost-effectiveness in comparison to other motor varieties. Their operation is based on electromagnetic induction, where alternating current flowing through the stator windings of the motor generates a spinning magnetic field. The rotating field interacts with conductors in the rotor, inducing rotation and driving the linked mechanical load. Induction motors are essential in a wide range of industrial activities, including manufacturing, transportation, HVAC systems, and more.

Induction motors, while dependable, might experience failures and irregularities due to causes including mechanical wear, electrical problems, or environmental conditions. The problems can appear in many forms such as bearing defects, rotor bar breakage, stator winding faults, eccentricity, and others. If left unnoticed, these flaws might worsen, resulting in unforeseen periods of inactivity, expensive maintenance, and even disastrous breakdowns with significant safety consequences. Therefore, implementing proactive maintenance procedures that involve prompt problem identification and diagnosis is crucial for maintaining the dependability, safety, and efficiency of industrial processes.

Motor Current Signature Analysis (MCSA) is a very effective and often used method for detecting problems in induction motors. MCSA is based on the premise that the electrical current used by an induction motor provides important information about its state. Typically, the motor current signature displays certain patterns and frequencies that relate to the motor's design and load features. When defects like broken rotor bars, bearing wear, or winding insulation degradation happen, the motor's electrical signature changes owing to modifications in the magnetic and mechanical interactions within the motor.

The main benefit of MCSA is its non-invasive approach, which involves just monitoring motor current while the system is running, usually done using current sensors or clamp-on ammeters. MCSA may be easily included into current motor control systems without requiring extra sensors or intricate instrumentation. MCSA can detect defects early, enabling maintenance personnel to act proactively and schedule repairs during planned downtime to minimize disruptions and prevent costly unplanned shutdowns.

Recent improvements in signal processing methods, data analytics, and machine learning have improved the capabilities of MCSA for diagnosing faults in induction motors. Sophisticated algorithms can detect fault patterns with increased accuracy by evaluating current signatures, even when there is noise or variable operating circumstances. Online monitoring systems allow continuous real-time monitoring of motor health, enabling condition-based maintenance methods to improve equipment lifespan and save operational costs.

II. Review Of Literature

Geethanjali, M. & Ramadoss, Hemavathi (2019) Due to the fact that they are playing such an important part in businesses, induction motors are sometimes referred to as the horses of modern industry. Moreover, they are straightforward, effective, sturdy, tough, and quite dependable. There is a lower probability of an accident occurring with induction motors; nonetheless, these motors are prone to flaws, the majority of which are not seen by the operator. In order to stop the progression of damage and extend the motor's lifespan, there has been an increase in the amount of focus placed on the identification and diagnosis of problems that are only beginning to manifest. The online condition monitoring of the machine has been applied in a broad variety of ways in order to detect and diagnose the defects. At the moment, the attention is being placed on optimizing techniques for defect detection in induction motors in order to acquire a speedy evaluation at the industry level. A general review of the many different kinds of problems that might occur with induction motors is presented in this chapter. Additionally, the standard (invasive) and new approaches (noninvasive) are discussed, with a particular emphasis on motor current signature analysis (MCSA), which is a methodology for defect identification and diagnosis in induction machines. Additional attention is paid to the research that will be conducted in the future.

Haba, Usama et al., (2017) The induction motor, which serves as a primer driver, is the electric component that is used the most frequently in the business and consumes a significant amount of energy annually. The impact of stator winding asymmetry, in conjunction with discharge valve leakage (DVL), causes a considerable increase in temperature, which in turn decreases the efficiency of the motor and shortens its lifespan. Monitoring the status of these machines and the equipment that is downstream of them at the appropriate time not only offers useful information about the machine conditions, but it also helps to maintain the efficiency of the machines, prevents serious damage to the systems, and reduces the amount of energy that is consumed. The purpose of this study is to investigate the utilization of motor current signals information for the purpose of detecting and diagnosing the influence of the stator winding on various common reciprocating compressor (RC) defects that result in varied loads being applied to the induction motor. An oscillator torque is given to the motor by the RC, which causes extra components to be induced in the current signals that are monitored. In addition to this, the current signatures include variations in the torque profiles that are caused by a variety of fault classifications. On the basis of these analytical investigations, the experimental studies investigate a variety of typical RC defects, including valve leakage, intercooler leakage, stator asymmetries, and the compounds of these faults. It is possible to integrate the envelope analysis of current signals with overall current levels in order to conduct model-based detections and diagnoses. This is because the envelope analysis enables reliable demodulation of torque profiles. The findings demonstrate that these simulated defects are capable of being differentiated across all operational pressures.

Faiz, Jawad et al., (2017) Electric motors that use induction are still considered to be among the most dependable and significant electrical equipment. A fault diagnosis is required as part of the maintenance process because of the vast range of their applications, which entail a variety of electrical, magnetic, thermal, and mechanical stressors. The creation of a generic and practical technique that enables industry to properly detect a variety of probable induction motor problems is a goal that has not yet been accomplished or accomplished. Building a comprehensive and structural approach that enables users to pick the appropriate diagnostic technique is the goal of the Fault diagnostic of Induction Motors project, which attempts to address this gap by concentrating on theoretical, experimental, and computer-aided procedures for fault diagnosis.

Dahi, Khalid et al., (2014) Techniques for fault prediction and diagnosis in a three-phase asynchronous system are presented in this study by the authors. This approach will be used for monitoring machine status and will rely on statistical analysis of scalar indicators obtained by the TSA technique (Time Synchronous Averaging). In addition, the stator-current signature MCSA (Motor Current Signature Analysis) employs the Fast Fourier Transform (FFT) method in its spectral analysis to determine the frequency composition of the spectral lines associated with the fault, enabling simultaneous problem identification. In this study, we report our first results in this field and compare the stator current's spectrum representation with that of the residual current obtained using the TSA method. We proved the effectiveness of these solutions by experimental testing and modeling on a wound rotor induction machine. To account for the faulty rotor, we raise the resistance of one rotor phase. Results from both simulations and trials demonstrate the strategy's practical effectiveness.

Krishna, Merugu & Ravi, Kiran (2013) Over the last several years, there has been a significant increase in the rate of research in the field of problem diagnostics of electrical machinery. The use of computer simulation to study the functioning of electric motors is very helpful for developing an understanding of the dynamic behavior and electro-mechanical interaction of these mechanical devices. The use of an appropriate model makes it possible to simulate motor failures and to forecast changes in the parameters that correspond to those faults without the need for actual investigation. The purpose of this work is to discuss a worldwide technique that enables the modeling of squirrel cage induction machines experiencing defects in both the rotor and the stator. This approach derives its foundation from the theory of coupled magnetic circuits. Through the use of winding function theory, it is possible to compute all of the circuit's self and mutual inductances.

Salih, Atheer et al., (2012) Thoroughly evaluate both mechanical and electrical issues to ensure optimal performance of the induction motor. This study explains how to diagnose induction motor issues related to unsymmetrical supply voltage and damaged rotor bars using Motor Current Signature Analysis (MCSA) and Fast Fourier Transform (FFT). Studies on the velocity, rotational force, electrical current, and magnetic field strength have been conducted. An research using Fast Fourier Transform (FFT) to analyze the stator current for detecting a problem in the rotor bars was conducted. Vector control is the mechanism utilized for control.

Seera, Manjeevan et al., (2012) This study presents a novel way to discover and classify induction motor defects. A hybrid fuzzy min-max (FMM) neural network with classification and regression tree are used. FMM and CART are combined to categorize and extract rules in the FMM–CART hybrid model. The motor current signature analysis method was used in real trials to establish a database of stator current signatures under different motor conditions. FMM-CART fault detection and classification uses signal harmonics extracted from power spectral density. FMM-CART accurately classified induction motor faults such broken rotor bars, imbalanced voltages, stator winding flaws, and eccentricity concerns. The results match or exceed the literature. Induction motor fault states are assessed using FMM-CART decision tree rules.

III. Experimental Setup

As shown in Figure 1, a test setup was put up to correctly identify the induction motor problem. This setup consists of a three-phase induction motor, a belt pulley, a transformer, NI myDAQ, and a Dell PC with LabVIEW installed. Under load, the three-phase squirrel cage induction machine that was tested had the following specifications: 0.5 horsepower, 415 volts, 1.04 amperes, and 1408 rotations per minute. Signal analysis is performed using LabVIEW software. It is easy to measure using NI LabVIEW. Instantaneous data evaluation and automated measurement from many devices are both possible inside the application.

Figure 1: Configuration for Identifying Stator Winding Short Circuit Faults

Under load, the data collecting device myDAQ takes current samples from the motor. Using cutting-edge technology to improve measurement accuracy, this high-speed multifunction data acquisition (DAQ) device can precisely measure signals at fast sample rates. A built-in OPA1642 amplifier allows for short settling times even while scanning at high rates. Four analogue inputs and eight digital I/O lines are available on this device. Shown in Figure 1 is the NI myDAQ. Both software and hardware parts make up the experimental setup.

A 2 pole selector, a multi-meter, an ammeter that measures current from 0 to 2A, a loading arrangement with a belt and pulley, a current transformer with a 5:1 turns ratio, and a 10Ω resistor for converting current from volts are among the other components. To cause the stator winding to break, flip the switch.

Data Acquisition Parameters and LabVIEW programming are the major components of the software. Fast Fourier Transform Analysis involves digital signal processing.

IV. Results And Discussion

Table 1: Varieties of Short Circuit Situations

Experiments	**Severity of short winding fault**	**Load condition**
1	0% shortened	Nil load
2	7.7% shortened	Nil load
3	23%	Nil load
4	0% shortened	Full load
5	7.7% shortened	Full load
6	23% shortened	Full load

A pulley and belt were used to couple the motor during the test at 7.7 and 23%. A healthy motor's power spectrum under no load is shown in Figure 2. With no load, the motor was running at 1.02 Amp. There are no faulty current components in the spectrum around the main supply frequency, as shown in Figure 2. That rules out stator winding problems with the motor. Here are the testing findings for a 7.7 percent and a 23% winding short circuit:

7.7 % Short-circuited winding

Figure 2 shows the power spectrum of a malfunctioning motor operating under no load conditions with a 7.5% short circuit. At 26 Hz and 75.5 Hz, the fault frequencies are showing up. Fault frequencies of 23 Hz and 76.5 Hz are detected under full load. The amplitude of the fault frequency is -60 dB at no load and -58 dB at full load, as shown in Figure 3. Evidence suggests that fault frequency magnitude increases in relation to load..

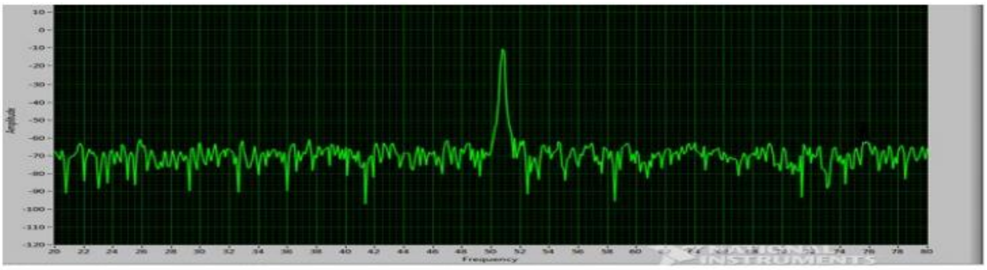

Figure 2: Healthy motor's power spectrum when not loaded

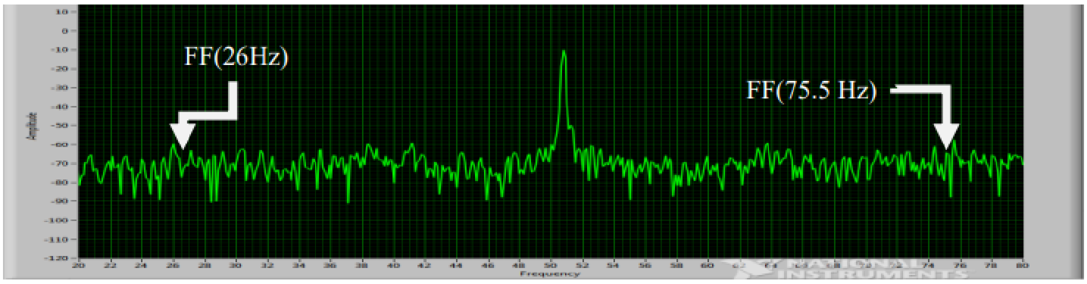

Figure 3: Power spectrum of a sound motor operating in a no-load state with a 7.5% shortened end

23% Short-circuited winding

An induction motor's power spectrum is shown for both no load and full load operating conditions, revealing a 23% rise in failure severity. A faulty motor with a winding short circuit of 23% when not loaded is shown in Figure 4 as a power spectrum. At 26 Hz and 75.5 Hz, the fault frequencies are observed. The results of the calculations and the experiments are confirmed by this. For both LSB and USB, the amplitude of the fault frequencies ranges from -56 dB to -50 dB. Even if the problem's severity is just 7.7 percent, the frequency of faults has increased significantly. The magnitude of the fault frequency increases as the fault becomes more severe. If you want your induction machine to work well, you should avoid increasing the current component's magnitude. Under full load circumstances, the results were comparable, as shown in Figure 7. The 23 Hz and 76.5 Hz fault frequencies that were observed are in agreement with the projected value when the load is fully applied. Higher loading conditions and fault severity have led to a considerable increase in fault frequencies.

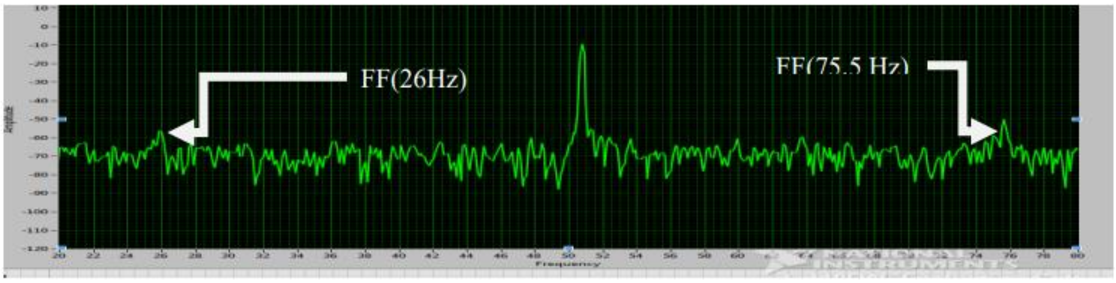

Figure 4: Power spectrum of a healthy motor is reduced by 23% during no-load conditions

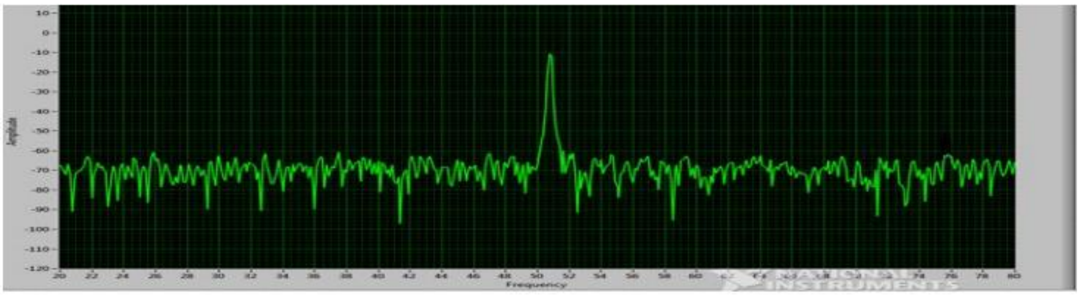

Figure 5: Power spectrum of a healthy motor operating under full load conditions

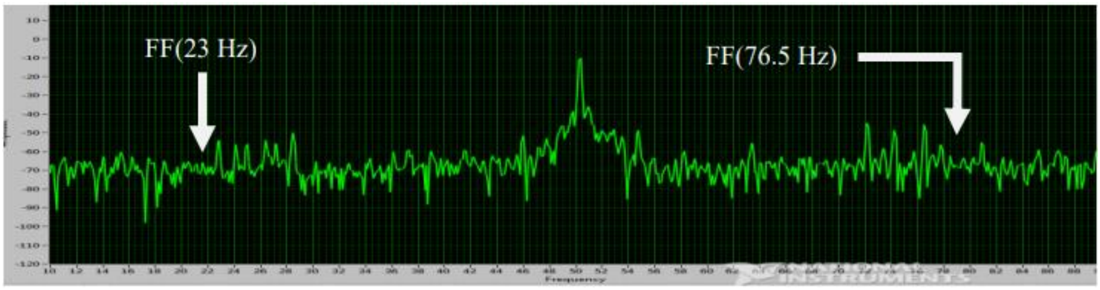

Figure 6: Power spectrum of a healthy motor is reduced by 7.5% at full load condition

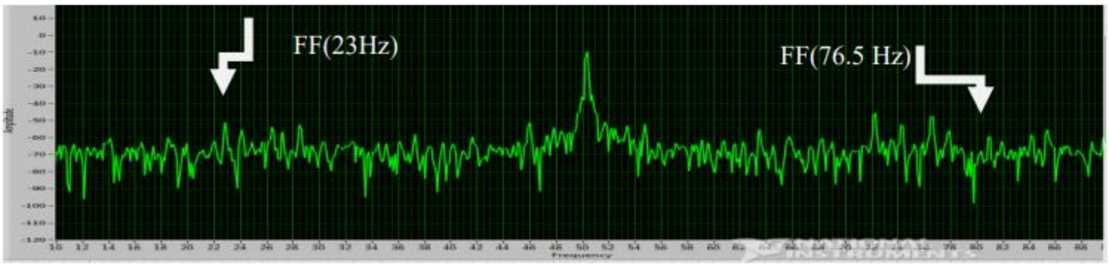

Figure 7: Power spectrum of a healthy motor is reduced by 23% at full load condition

Table 2: Result of the study

Short circuited stator winding	**Load condition**	**Fault frequencies**				**Observation**
		Lower side band		**Upper side band**		
		FF(Hz)	**Mag.(dB)**	**FF(Hz)**	**Mag.(dB)**	
0%	Nil Load	26	-60	75.5	-60	Detectable
7.5%	Nil Load	26	-60	75.5	-58	Detectable
23%	Nil Load	26	-56	75.5	-50	Detectable
0%	Full Load	23	-67	76.5	-66	Detectable
7.5%	Full Load	23	-54	76.5	-46	Detectable
23%	Full Load	23	-50	76.5	-48	Detectable

V. Conclusion

Diagnosing faults in induction motors by Motor Current Signature Analysis (MCSA) is a crucial component of industrial maintenance and reliability management. Induction motors are often used in industrial environments to power various machines, and their continuous functioning is crucial for maintaining production and avoiding expensive interruptions. Issues with these motors may result from a range of variables such as mechanical deterioration, electrical problems, and environmental circumstances, emphasizing the need of prompt identification and assessment. MCSA provides an effective method for defect diagnosis by examining the distinct electrical patterns shown by induction motors under various operating situations and problem states. MCSA can accurately detect and diagnose different flaws such as broken rotor bars, bearing defects, and stator winding issues by measuring motor currents. The non-intrusive characteristic of this technology facilitates smooth integration into current motor control systems, allowing for ongoing monitoring and preventive maintenance approaches.

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