International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Fault Detection of 3 Phase Induction Motor Using Vibration Analysis

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Abstract:
The induction motor is a critical component extensively employed in industrial applications. It is susceptible to various fault conditions during operation. These faults, which can arise due to multiple external factors, include overloading, single-phasing, unbalanced supply voltage, locked rotor, phase reversal, ground fault, under voltage, and overvoltage. To prevent damage and ensure worker safety, it is essential to promptly shut down the machine upon detecting a fault. Numerous types of faults can occur in induction motors, and identifying them often necessitates the utilization of vibration analysis techniques. These techniques require advanced signal processing methods to achieve rapid and dependable fault detection. Leveraging LabVIEW, a versatile and powerful software system for measurement and automation, can facilitate the creation of graphical interfaces for vibration detection.

Keywords. Induction Motor, LabVIEW, Vibration analysis, Faults

INTRODUCTION

The induction motor holds a prominent position in industrial applications, effectively converting electrical energy into mechanical energy. Renowned for its affordability, high performance, and reliability, it stands as the preferred choice for alternating current motors across industrial and commercial sectors. These motors find versatile applications, ranging from small-scale household appliances to massive industrial endeavors like the petroleum industry. While induction motors are generally dependable, operational conditions can expose them to various faults that carry the potential for machine shutdowns, leading to substantial production setbacks [1].

Mitigating unforeseen shutdowns stands as a pivotal objective for industries. To achieve this, a continuous monitoring process of induction motors becomes imperative, aimed at early fault detection. Detecting these faults in their nascent stages empowers maintenance engineers to swiftly implement necessary corrective measures. Among the key external faults that induction motors may encounter are overloading, single phasing, supply voltage imbalances, rotor locking, phase reversals, ground faults, and deviations in voltage levels [2].

A. *Electrical faults*

1. ***Under Voltage:*** An undervoltage fault arises when the supply voltage across the three phases decreases by a specified percentage. This impedes the motor from achieving its rated speed within the designated

time frame, causing increased current flow and overheating of the machine. Traditional systems incorporate low voltage protection relays. Yet, to prevent undesired relay shutdowns due to transient voltage drops, an additional delay mechanism is required for the AC contacts. This supplementary component entails sensitive devices and necessitates calibration [3].

2. ***Over Voltage:*** Over voltage occurs when the three-phase voltages surpass the rated voltage level. This fault leads to heightened current flow, placing excessive strain on motor insulation due to elevated heat generation. Conventional protective systems employ over voltage relays to safeguard the motor during this situation [3].
3. ***Overloading:*** Overload faults manifest when the mechanical torque applied to the motor surpasses a predetermined threshold, subjecting the motor to a mechanical load greater than its full load rating. Overloading induces escalated phase currents and subsequently raises the machine's temperature. In traditional relay protection setups, the over-current relay triggers the motor offline when current transformers (CT) detect overcurrent in the line [3].
4. ***Single Phasing:*** Single phasing represents an imbalanced motor condition that occurs when one of the three phases becomes open. This imbalance diverts excessive current through the remaining two phases, resulting in elevated heat generation within the stator winding. Traditional protection systems incorporate high-set instantaneous trip unit relays. Additionally, single phasing can lead to negative sequence currents, making negative sequence relays a viable protective measure [3].
5. ***Unbalanced Supply Voltage:*** Unbalanced supply voltages arise due to various factors like unbalanced loading, open delta transformers, and uneven tap settings. Such a scenario diminishes motor efficiency, escalates motor temperature, and results in an excessive imbalance in full load current. Protective designs should identify overcurrent conditions during unbalanced supply instances [3].
6. ***Locked Rotor:*** Locked rotor conditions arise when voltage is applied to an immobile motor. This leads to stator currents that may be nearly six times the rated value. Various causes can trigger this fault, such as connecting the rotor shaft to a substantial load, resulting in a locked rotor state. This condition induces high current and subsequent rotor heating. Therefore, locked rotor conditions are unsustainable over prolonged periods. The permissible duration of motor overload during locked rotor events depends on the applied voltage to the motor terminals [3].
7. ***Phase Reversal:*** Phase reversal emerges when either of the two phases deviates from the standard sequence, leading the motor to rotate in the opposing direction. Such reversal can lead to severe motor damage as the motor starts rotating in an unintended direction. Consequently, this state necessitates immediate rectification. Reverse-phase relays and negative sequence relays serve as protective measures against phase reversal [3].
8. ***Ground Fault:*** Ground faults transpire when any of the motor's phases comes in to contact with the ground. These faults are more frequent in motors than in other power systems, attributed to their dynamic operating conditions and frequent starts. Ground faults yield significant consequences, including potential hazards to human safety and interference with communication systems. Detection can be achieved through ground leakage current measurement [3].
9.

B. Mechanical faults

1. ***Bearing Fault:*** In a three-phase induction motor, a pair of bearing sets are positioned within the motor housing to support the motor shaft. These bearings serve two primary functions: facilitating smooth motor shaft rotation and minimizing friction. They comprise an outer and inner ring, known as races,

along with a set of rolling elements called balls. These balls are situated between the inner and outer rings to mitigate shaft friction, which can be further reduced through proper lubrication. However, instances may arise where the balls, outer ring, or inner ring of the bearing sustains damage due to physical factors. This condition is referred to as a bearing fault, leading to motor jamming or immobilization [4].

2. ***Broken Rotor Bar Fault:*** In squirrel cage induction motors, the rotor assembly comprises rotor bars and shorted end rings. When these bars suffer damage or develop partial cracks, the resulting fault is termed a broken rotor bar fault. Although several factors can contribute to this fault, it is often traced back to manufacturing defects. Non-uniform metallurgical stresses can emerge within rotor bars during the brazing process, increasing the likelihood of rotor bar failures during rotor rotation [4].
3. ***Rotor Unbalance Fault:*** Delving into the construction of an induction motor reveals the rotor's placement within the stator bore. The rotor rotates coaxially with the stator, maintaining a centered alignment. In high-torque (HT) motors, this alignment is also maintained with the geometrical axis of the stator. The air gap between the stator's inner portion and the rotor's outer surface remains consistent. However, if inconsistencies arise in this air gap, an eccentricity situation can occur. This eccentricity can lead to a rotor fault known as rotor unbalance fault [4].

VIBRATION ANALYSIS

Vibration pertains to the response exhibited by the mechanical elements of a machine when subjected to internal or external forces. During vibration analysis, attention is directed toward two attributes of the vibration signal: its amplitude and its frequency. The concept of overall vibration involves quantifying the complete energy associated with vibrations occurring across a designated frequency spectrum. By gauging the overall vibration encompassing a machine, its constituents, such as a rotor in relation to the machine or the machine's structural framework, and subsequently contrasting this measurement with its established baseline value (norm), insights into the present condition of the machine can be gained. An elevated overall vibration reading, surpassing the established baseline, signifies the presence of factors intensifying the vibration of the machine or its components [5].

LABVIEW

LabVIEW, short for "Laboratory Virtual Instrumentation Engineering Workbench," stands as a platform and developmental environment designed by National Instruments, featuring a visual programming language. Originally introduced for the Apple Macintosh platform in 1986, LabVIEW serves as a prominent tool for tasks such as data acquisition, instrument manipulation, and industrial automation. Its scope extends to multiple operating systems including Microsoft Windows, UNIX, Linux, and Mac OS. At the core of LabVIEW's functionality lies a distinctive programming language referred to as "G," characterized by its dataflow nature. The manner in which program execution unfolds is governed by the configuration of a graphical block diagram, which constitutes the LabVIEW source code. Within this diagram, the programmer establishes connections between diverse function nodes by drawing lines, thereby dictating the sequence of execution [6].

EXPERIMENTAL SETUP

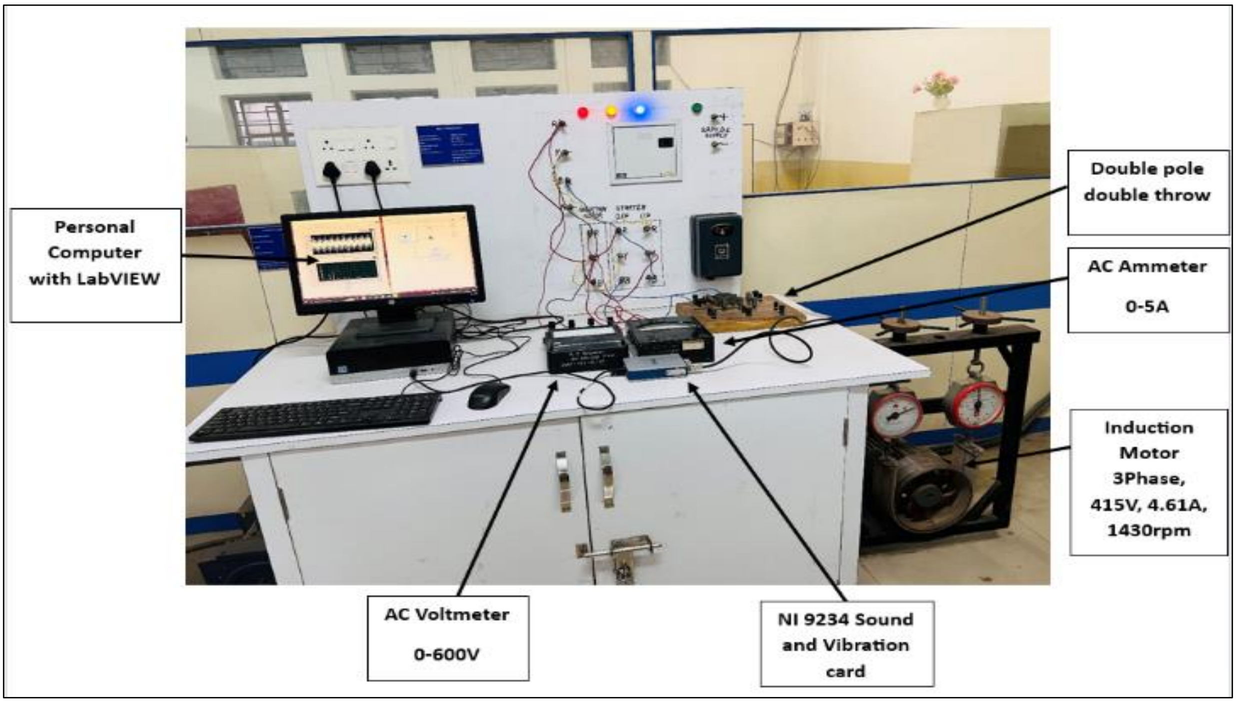

FIGURE 1. Electrical setup for vibration analysis of three phase induction motor

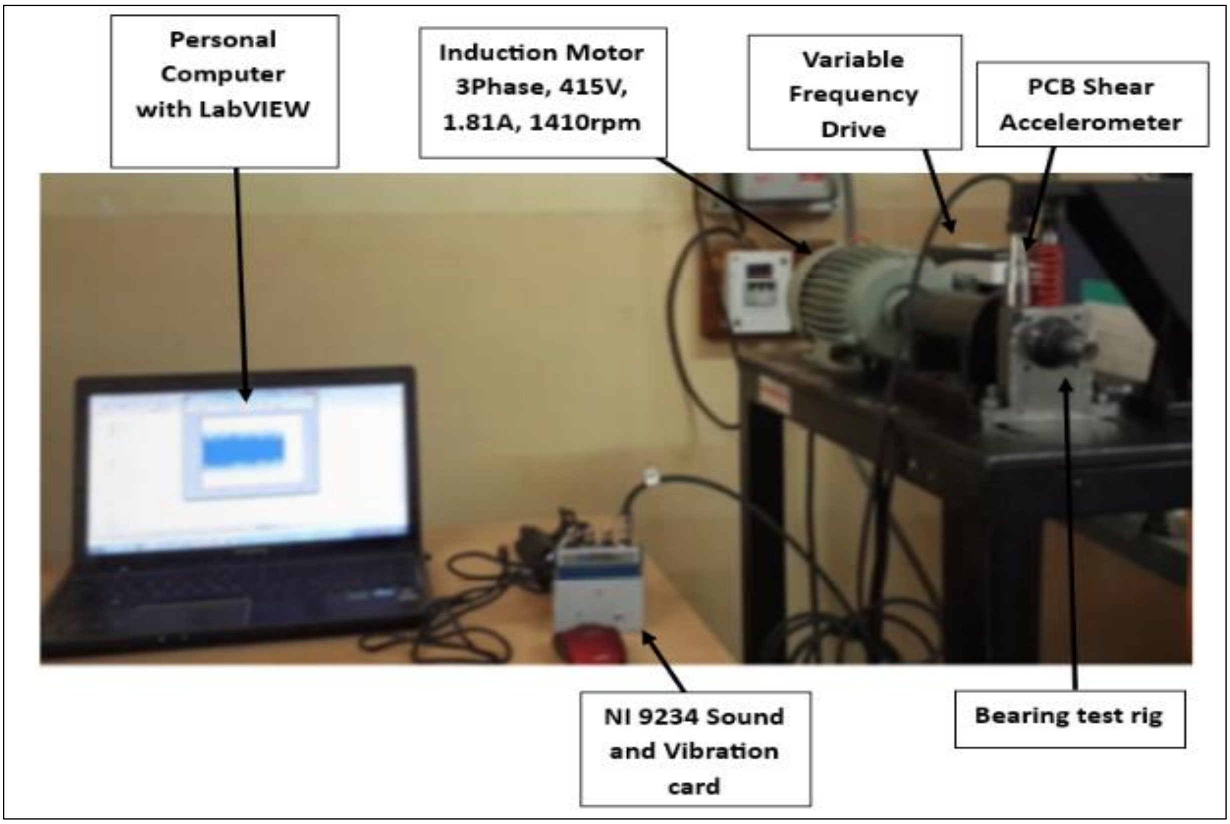

FIGURE 2. Mechanical setup for vibration analysis of three phase induction motor

FAULTS DETECTED USING VIBRATION ANALYSIS

1. *Overloading*:

An overload fault is encountered when the mechanical torque surpasses a specific threshold point due to the application of a mechanical load on the motor that exceeds its designated full load rating [3]. Within the context of this project, a three-phase induction motor (rated at 415 V, 1430 rpm, and drawing 4.61 A) is utilized alongside a mechanical loading setup to investigate vibrations associated with overload faults. To facilitate this investigation, vibrations are captured through a PCB shear accelerometer (a vibration sensor) and subsequently relayed to an NI 9234 vibration card. This hardware combination enables the acquisition of time-domain signals linked to these fault conditions, which are subsequently displayed utilizing the LabVIEW software. The experimental setup involves operating the motor under various conditions: no load, full load, and overload, allowing for the observation and analysis of resulting vibrations.

TABLE 1. Observation table for overloading condition

Cases	Voltage	Current	Skewness	Kurtosis
No load	415V	2.6A	-0.1069	2.6081
Full load	415V	4.6A	0.0895	2.4615
Overload	415V	5.5A	0.0077	2.7414

2. Single Phasing:

Single phasing arises when one of the three electrical phases becomes disconnected or open. Consequently, a greater amount of current diverts through the remaining two operational phases, leading to elevated heat generation within the stator winding [3]. For the purpose of analyzing vibrations linked to single phasing faults, an induction motor rated at 3 phases, 415 V, 1430 rpm, and drawing 4.61 A is employed. A methodical approach involves the utilization of a knife switch to deliberately sever one of the motor's phases from the power supply, thus simulating the conditions associated with single phasing. This experimental setup allows for the acquisition of single phasing fault readings under both no-load and full-load operating scenarios.

TABLE 2: Observation table for single phasing condition

Cases	Voltage	Current	Skewness	Kurtosis
Full Load	415V	4.6A	0.0545	2.3788
No Load	415V	3.5A	0.0873	2.4631

3. Bearing Fault:

A bearing fault encompasses any form of physical damage inflicted upon the inner or outer race of a bearing or the surface of its ball components. In a specific experimental configuration, an AC motor powered by a Variable Frequency Drive (VFD) imparts motion to the shaft. The experimental setup involves positioning a test bearing within a bearing housing located at the non-drive end of the shaft. This test bearing is subjected to a radial load by means of a screw and nut mechanism. The vibrations emitted by the test bearing are captured through a PCB shear accelerometer, which interfaces with NI's sound and vibration card. The acquired vibration signals are subsequently processed utilizing LabVIEW software, leveraging the hardware and software combination to delve into the time-domain aspects of the signals [7].

RESULTS AND DISCUSSION

1. Overloading:

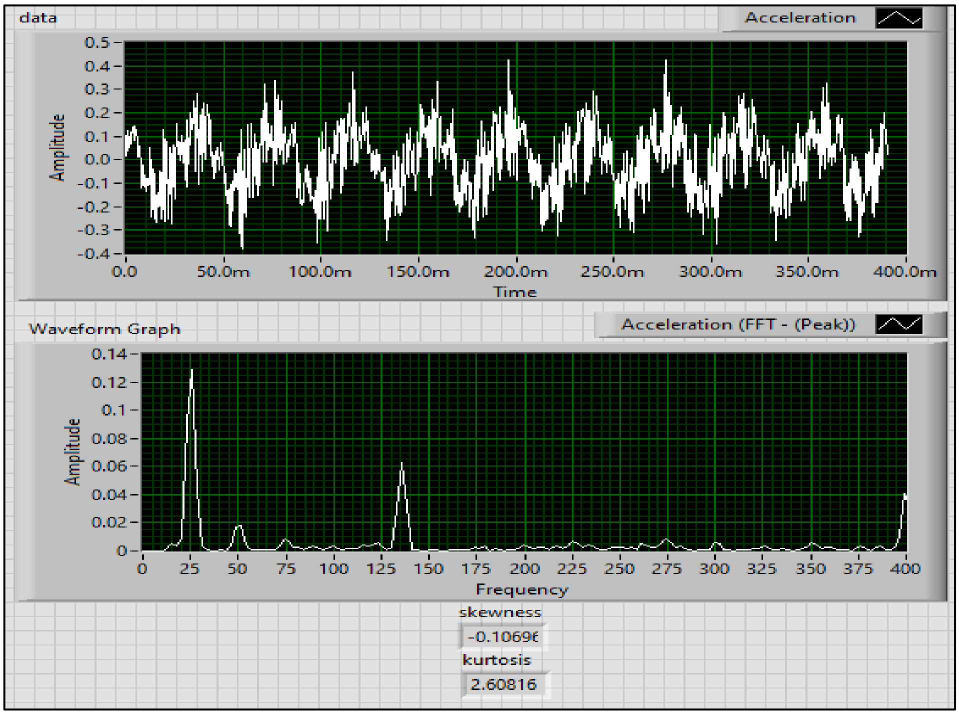

FIGURE 3. Vibration results under no load condition

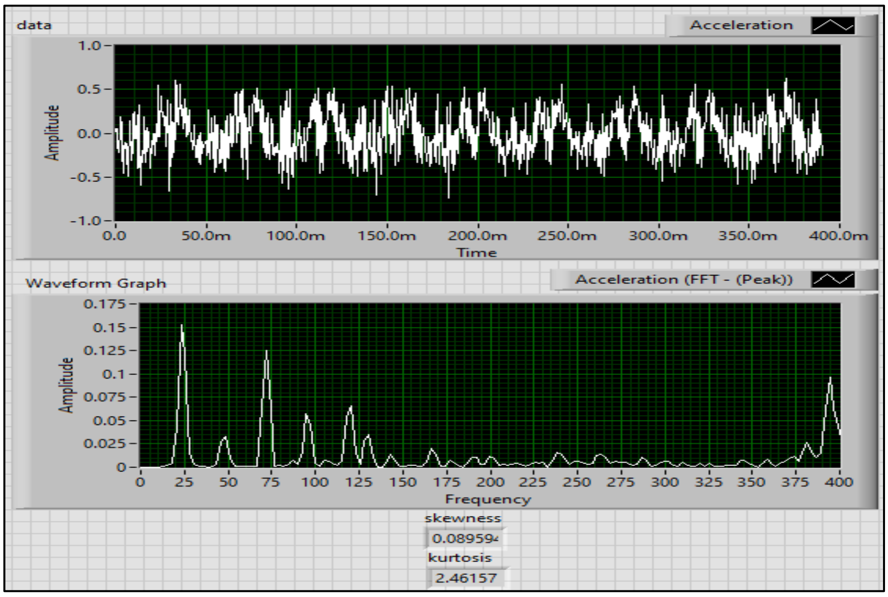

FIGURE 4. Vibration results under full load condition

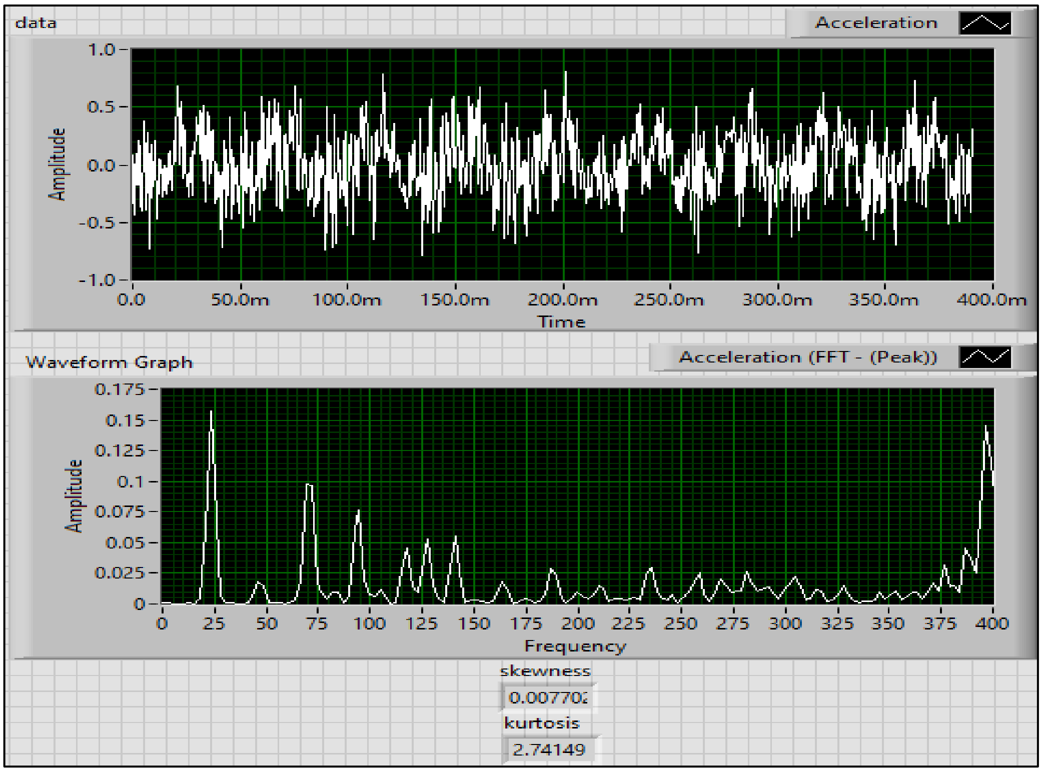

FIGURE 5. Vibration results under overload condition

2. Single Phasing:

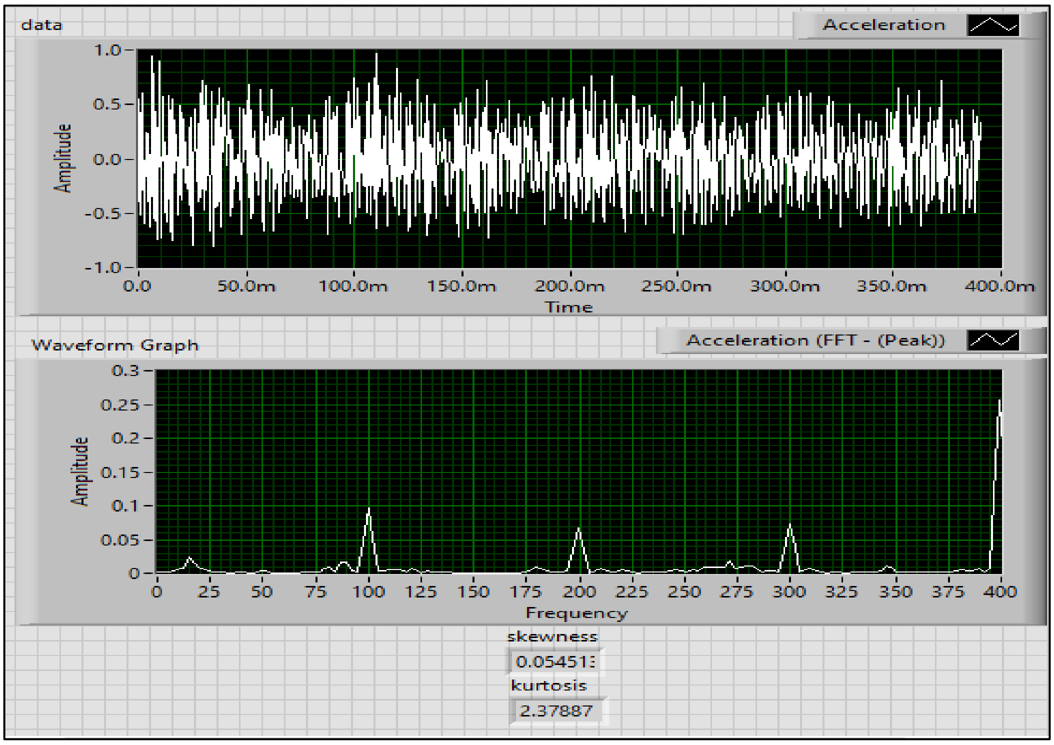

FIGURE 6. Vibration results for single phasing under full load condition

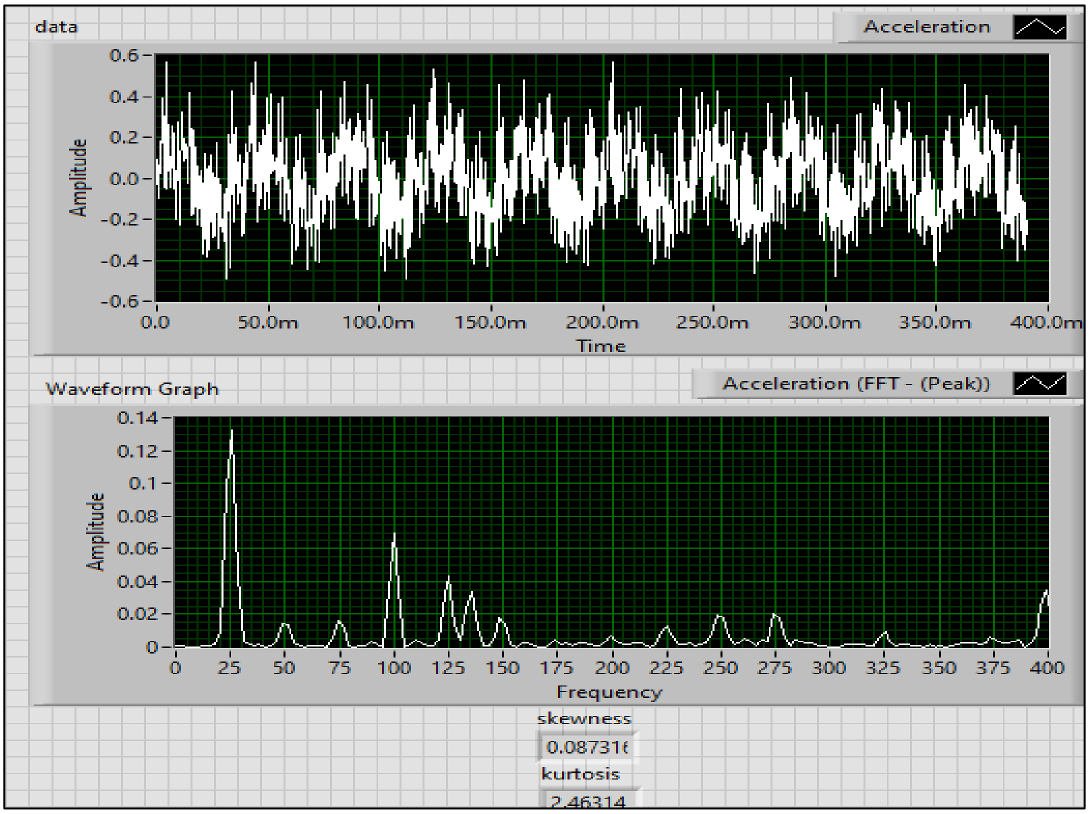

FIGURE 7. Vibration results for single phasing under no load condition

3. Bearing Fault:

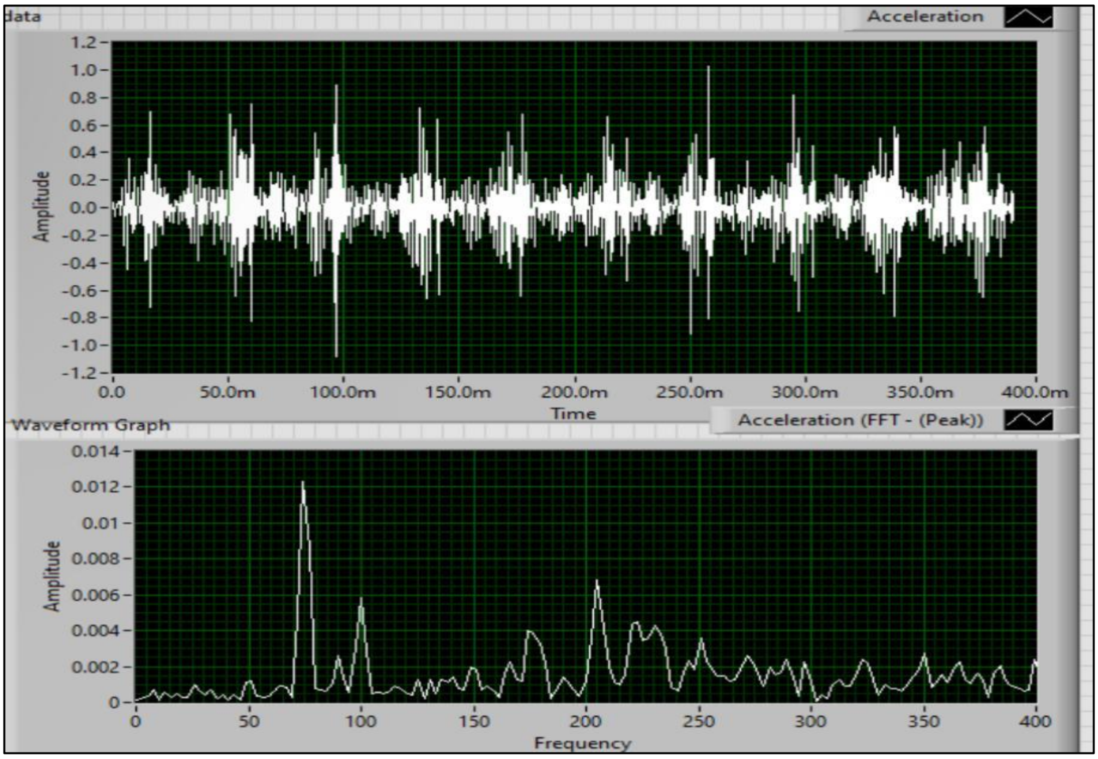

FIGURE 8. Vibration results for bearing fault condition

CONCLUSION

In this project, the aim is to conduct vibration analysis for a three-phase induction motor to detect various faults such as under voltage, over voltage, overloading, and bearing faults. The presence of a fault can be predicted by analyzing the Fast Fourier Transform (FFT) of the vibration signal. By comparing the peak frequency in the FFT of the vibration signal with the FFT of the motor under normal operating conditions at the rated frequency, the faulty condition can be identified. Additionally, various electrical and mechanical faults and their characteristics will be investigated in this project.

By examining the statistical measures of skewness and kurtosis, valuable insights into the presence and characteristics of different faults can be gained. Skewness is a measure of the asymmetry of the distribution and can have values of zero, positive, or negative. Kurtosis, on the other hand, measures the tailness of the distribution.

In the case of overloading, the motor experiences a current higher than its rated current. The skewness is positive, indicating a positive skew, whereas the ideal scenario would have zero skewness. The kurtosis is less than 3, whereas it should ideally be equal to 3 for a stable system. These characteristics suggest that the system is unstable.

In the case of single phasing under no load, the motor experiences a decline in current compared to its rated current. The skewness is positive, which ideally should be zero. The kurtosis is also less than 3, whereas it should ideally be equal to 3 for a stable system. In the case of single phasing under full load, the motor experiences a rapid rise in current, leading to an instant motor stoppage. Like the previous case, the skewness is positive, which ideally should be zero, and the kurtosis is less than 3, whereas it should ideally be equal to 3 for a stable system.

REFERENCES

1. Prof. P. C. Latane, Punit C. Urolgin. "Fault detection in Electric Motors using Vibration Analysis and DSP processor." International Journal of Innovative Research in Science, Engineering and Technology, Vol.5, Issue 6, June 2016.
2. Katalin Ágiston. "Fault detection of the Electrical motors based on Vibration Analysis." Procedia Technology 19 (2015): 546-553.
3. https://scholarworks.bgsu.edu/cgi/viewcontent.cgi?article=1000&context=ms_tech_mngmt
4. https://goodwillelektrocontrols.com/induction_motor_brousher.pdf
5. http://edge.rit.edu/edge/P14453/public/Research/SKF%20VibrationGuide.pdf
6. National Instruments. "LabVIEW Fundamentals: LabVIEW Manual."
7. P. G. Kulkarni and A. D. Sahasrabudhe. "A dynamic model of ball bearing for simulating localized defects on outer race using cubic hermite spline." Journal of Mechanical Science and Technology 28 (9) (2014): 3433-3442.