JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Single -Phase Electrical Machine Health Monitoring Using Sensors And Microcontroller

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***Abstract*—The use of electrical machines is widespread in industrial and commercial applications, and their proper functioning is essential for ensuring operational efficiency and safety. There has been a rise in recent years in demand for continuous monitoring of the health of electrical machines to detect any potential faults and prevent catastrophic failures. This has led to the development of various techniques and technologies for machine health monitoring, including the use of sensors and microcontrollers. The proposed system provides a low-cost and efficient solution for monitoring the condition of single-phase electrical machines in various industrial applications. The system is based on a microcontroller and various sensors that are used to monitor the temperature, current, and vibration of the machine. These parameters are critical indicators of the machine's health and can be used to detect faults and potential failures before they occur. The system is able to detect anomalies in the temperature, current, and vibration of the machine, which can be indicative of faults or potential failures. The results also show that the system is reliable and can provide accurate measurements of the machine's parameters. The system is able to provide real-time monitoring of the machine's condition, which can help prevent downtime and reduce maintenance costs.**

Keywords- Micro-controller, Single-Phase InductionAC motors, Real-time, Interactive Dashboard.

I. Introduction

The usage of single-phase motors is prevalent inindustries because they are constructed with durable and uncomplicated materials, making them robust and reliable. The fundamental principles of their operation are straightforward, and they can function in various environmental conditions. Additionally, these motors require minimal maintenance and do not necessitate an external DC source. The induction motor is self-starting, which means it can start without any additional equipment. Moreover, three-phase motors are relatively inexpensive compared to other motors and have an extended lifespan. These motors also exhibit reduced armature reaction, which reduces their susceptibility to performance degradation over time.

Many mechanical and electromechanical systems depend on electric motors, which are widely utilized in industries.However, prolonged use can lead to damage and reduced lifespan, resulting in financial losses and production interruptions. To address this issue, IoT-based monitoring systems are installed on existing machinery infrastructure in the energy sector to keep track of equipment conditions and predict future results based on collected data. The power sector involves heavy machinery with potential safety risks, but powered monitoring can reduce such risks and enable remote control of the machinery through smart devices. Data is gathered and shown visually on a digital dashboard, which allows users to monitor and analyze the temperature of the motor in real-time,supporting continuing development and improved decision-making. Thermal sensors are used to collect temperature data, similarly vibration, voltage and current sensors are used and the information is processed and displayed on an interactive dashboard with a continuously running graph. Users are alerted if thedesired range of parameters exceeds the threshold value, enabling regular checks to lengthen the life and improve the health of a induction motor with a single phase.

The remaining portions of the paper are organized as follows: A thorough overview of earlier studies is done in part II. The implementation technique is provided in the Section III. The sample outcomes collected are reported in the section IV. The conclusion is provided in the section V, which comes last.

II. Literature Review

This section provides a summary of the work completed, the methods used, and the key literary results.

A strategy that makes use of a model fordisclosure and localization of phase in theinterturn short fault (ISF) in the permanent magnet synchronous generator (PMSG) is put forth by S. Moon et al. [1]. In this, a simple mathematical model of a PMSG with an ISF on the dq-axis is created for the investigation of the fault signature. On the basis of the extended mathematical representation of the permanent magnet synchronous generator, an accurate evaluation of the current residues is carried out by the Luenberger observer. The second harmonics are removed from current residues by utilizing the negative sequence park transformation and integral angular filtering to create the index for fault and flaws detection.

A model-based approach was put forth by H. Lee et al. [2] to identify an ISF defect in a permanent magnet synchronous machine. The discrepancybetween the computed and predicted stator voltages, known asresidual voltage components (RVCs), is used to diagnose faults. The RVC-based fault indicators evaluate the fault's severity. The fault indicators also identify the degree and stage of the ISF defect. The approach that diagnoses the ISCF in various fault conditions is proposed after it has been validated using simulation data from a finite element analysis programme. Using this technique, ISCFs in PMSMs can be prematurely diagnosed.

Faults and Diagnosis techniquesfor PMSM were proposed by M. Zafarani et al. [3]. In this procedure, the introduction of PMSM motor electrical, magnetic, and mechanical flaws is done first. The techniques utilized forcommon defect identification, model-based fault diagnostics, for instance, variousprocessing techniques for signals, additionally to data-driven diagnostic algorithms, are estimated later. The performance during a defect, various time-frequency analysis methods, harmonic features, and other research topics are covered in this piece.

With reference tosignature analysis of motor voltage, accuracy of Condition Monitoring in Inverter-Driven PMSMs was the idea put forth by R. Z. Haddad et al. [4] In this work, the analysis of Motor Voltage Signaturetechnique is investigated in both healthy and unhealthy settings. The four fault categories that are assigned are turn-to-turn evade, extremely resistant contacts, static eccentricity, and local demagnetization. The spectrum components that the ordered stator voltage are used as indications for superintended categorization to locate, classify and determine how serious the issues are. It uses classification techniques including support vector machines, k-nearest neighbour analysis, and linear discriminate analysis. The Motor Voltage Signature Analysis-based condition monitoring works effectively in field-oriented control.

Automatic PMSM Fault Diagnosis Using Wavelet Transform and Adaptive Filteringwas the idea put forth by M. Heydarzadeh et al. [5]. This research study develops a defect method of diagnosis depending on the waveform of the current of the stator using discrete wavelet transforms, as well as support vector machines. An adaptive filtering system has been developed for the elimination of the core element of the waveform of currentin order to improve fault diagnostics' precision. Without using an external sensor, the motor's instantaneous rotational speed is approximately computed for this purpose. The accuracy of this defect identification method is 97.67%.

Scalar and analysis of Stator Inter-Turn Short Circuit via Vector Control Impact on PMSM Drivewas the idea put forth by Usman et al. [6]. The study examines howScalar control and vector control are two frequency control mechanisms—operate when a PMSM motor's stator winding sustains damage. In this article, the effects of damage to a PMSM motor's stator winding on the performance oftwo structures for frequency regulation—both scalar and vector control—are presented. The effects of varying the quantity of short bends during the stator winding phase are taken into account by the mathematical model of PMSM, which was provided together with an experimental evaluation.The effects of different factors on the stator winding damage on the motor state variable waveforms effects both in an open scalar control structure and in a closed field-oriented control structure are next examined. The failure signs make it easy to diagnose the stator winding.

For a PMSM which is delta-connected, S. Ding et al. [7] suggested a demagnetization defect detection approach based on unbalanced current components. First, the demagnetization fault model and the PMSM which is delta-connected is established. After that, the presentation of the zero-sequence current components for the delta-connected permanent magnet synchronous machine is produced, and the similar fault severity index may be used to measure the degree of demagnetization. The findings are then displayed.

A complete and appropriate mathematical route was put forth by Z. Liu et al. [8] for an internal PMSMwith known eccentricity. In this, the association between the eccentricity of the air gap and the simulated inductances in various coordinate frames is thoroughly examined. The internal permanent magnet synchronous machine, or PMSM, is then developed using asystematized eccentric rotor high-frequency inductance model.Using this model, an online symptomatic approach is suggested that takes into account assessments ofd-axis inductance at high frequencies and flux in permanent magnets. As a result, eccentricity of the rotor and the partial demagnetization of the permanent magnet may be identified and disclosed.

Demagnetization Modelling and the methods of fault diagnosis of PMSM under Stationary and On-standard conditions was the idea put forth by J. Faiz et al. [9]Techniques for diagnosing demagnetization faults in permanent magnet machines are the main topic of this study. There are some steps in this. First, a discussion is had on the causes of problems and how they affect the performance of the motor. Then, in two distinct parts, the recently established approach for demagnetization faults in stationary and non-stationary situations is described. After the approaches are evaluated and allimportant elements, such as weaknesses and strengths, are documented, recommendations for additional study are made.

A permanent magnet synchronous generator model that is quick and simple and is developed with a novel idea of a graphic interface in the Matlab/Simulink domain was provided by M. Ben Khader Bouzid et al. [10]. This model makes it relatively simple to study various fault types, such as interturn faults also thephase-to-ground faults, and the phase-to-phase faults, as well as the faults that occur at the same time. Comparing the simulated and experimental findings enables one to confirm how the suggested model behaves in both healthy and malfunctioning modes at various running speeds.

The most common failures in PMSM, stator interturn faults, were described by S. S. Moosavi et al. [11]. This study presented an enhanced wavelet packet transform-based time-frequency approach foridentification of interturn faults in the stator winding of synchronous permanent magnet motors. In this, both the signal of stator current and the signal of vibration are employed to detect short circuit defects. Examining the experimental results demonstrates the viability of this approach.

To be able to identifyinter-turn short circuit defect of a PMSM, H. Jeong et al. [12] suggested a novel method. This approach starts by using the measured command current and voltage from every phase is woundas the first signal. The delay signal, which contrasts with the first signal, is then derived by the Hilbert transformation. Each phase's current reactive poweris then computed usingeach phase's orthogonal voltage and current signals. Finally, a comprehensive investigation of how the interturn short circuit defect has an impact on each phase's generalized instantaneous reactive powerunder various operating situations is conducted.It is possible to determine whether a phase winding has an interturn short-circuit defect by examiningthe fluctuation of each phase's generalized instantaneous reactive power.

A technique to incorporate comparable damper windings in the winding function technique for modelling was presented by M. Ojaghi et al. [13]. The simulation findings demonstrate how the interturn fault’s frequencies are proportional to the integer multiples of the rotor speed, causes the development and inflation of certain frequency components in both the rotor field and stator line currents. The fault current which is in circulation in the shorted turns contains the frequency components.

In a work that J. Faiz et al. [14] proposed, they discussed how to diagnose demagnetization defects in permanent magnet synchronous motors as well as how to extract the right indices for these motors. The benefits, drawbacks, and considerable uncertainties of index-extracting approaches are discussed in this study. And talked about the methods for solving these challenges.

A PMSM’s stator winding problem is primarily addressed in detection of faults in thePMSM’s stator windings presented by L. Otava et al. [15]. Open-phase faults and interturn faults in one phase are taken into consideration in this. In light of this, it has been assumed that a defective symptom exists whenever there is a difference in stator resistance. This technique has been thoroughly offline-verified.

III. RESEARCH METHODOLOGY

The depiction of an electrical machine health monitoring system is shown in the block diagram below. This system demonstrates how connecting several crucial parts will result in the desired goal being accomplished. This describes the monitoring system's circuit. It displays the components so that we can see that the ESP-32 microcontroller was used, which is capable of processing more. Additionally, we employed a variety of sensors, including vibration, current, temperature, and the voltage sensors. We will receive an alert message on the mobile application when the sensor detects and anticipates a potential malfunction. The mobile app displays the defect that has happened, and since the machine is always being watched outside, all of the data may be stored in the cloud.

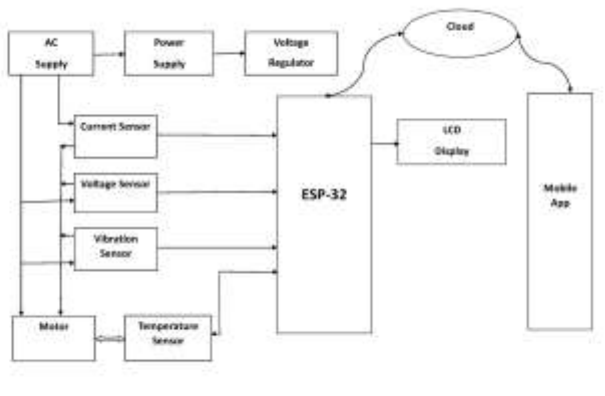


Fig.:- Block diagram of proposed system

A. Single-phase AC motor :-

An AC motor of single-phaseis employed, as seen in the image. The electrical, mechanical, and environmental aspects of the motor affect how well it performs. The motor parameters affect AC motors greatly. All of the induction motor's electrical, mechanical, and environmental parameters, such as current, voltage, temperature, vibration, and external noise, are crucial for a drive system. The aforementioned factors have a direct impact on an induction motor's performance.

B. Voltage regulator :-

`The graphic illustrates the use of a voltage regulator. An uncontrolled voltage is transformed into a steady, regulated voltage by a voltage regulator. The AC voltage regulator generates a controlled AC voltage output from a variable AC voltage input.

C. Voltage sensor:-

To measure AC voltage, we use a voltage sensor.In this instance, ZMPT101B is the voltage transformer for measurement of the AC voltage. Using this gadget, wecan detect voltages of up to 250 volts. Analogue signals come out of this sensor. The output voltage will change if the input voltage is altered. This sensor calculates, monitors, and establishes the voltage supply.

D. Current sensor:-

In order to detect electric flow through a wire and to produce a signal proportionate to the current, we use a current sensor. SCT-013-030which is an unobtrusive AC current sensor., or current transformer, that may be used to detect AC current which is 100 amperes or more in this project. This non-invasive current sensor, which is clamped around the supply line, can monitor loads up to 30 amperes and determine how much current flows through them.

E. Vibration sensor :-

Comparator vibration sensors accustomed to measure the acceleration and vibration of devices or systems. Here, we employed a vibration sensor to measure the AC motor's vibration. Industrial equipment can vibrate, sometimes as a natural element of functioning and occasionally as a symptom of trouble. Because of this, a crucial component of this project is the monitoring of the vibration in the AC motor. This sensor's accessible lower and upper sensitivity ranges typically fall between 2 and 10,000 Hz.

F. Temperature sensor:-

Here the temperature sensor is used for measuring the temperature of the motor.Many applications, including HV, AC environmental controls, and automobile under-the-hood monitoring systems, employ temperature sensors.Here we used DS18B20 digital temperature sensor which follows the single wire protocol and it can be used to measure temperature in the range of -67°F to +257°F or -55℃ to +125℃. The range of received data from one wire can range from 9-bit to 12-bit.

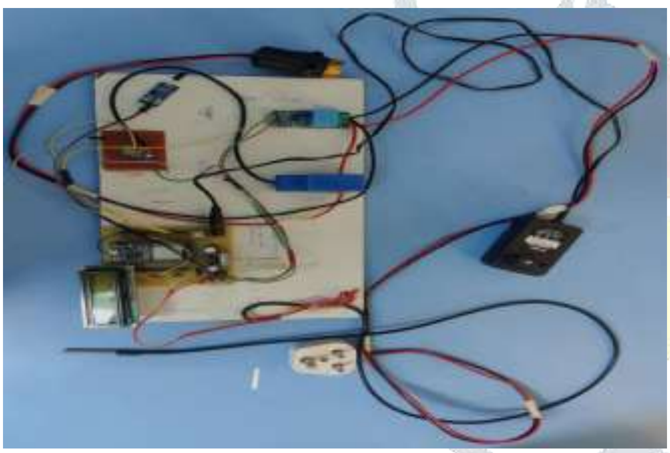
G. ESP-32 microcontroller (ESP8266EX):-

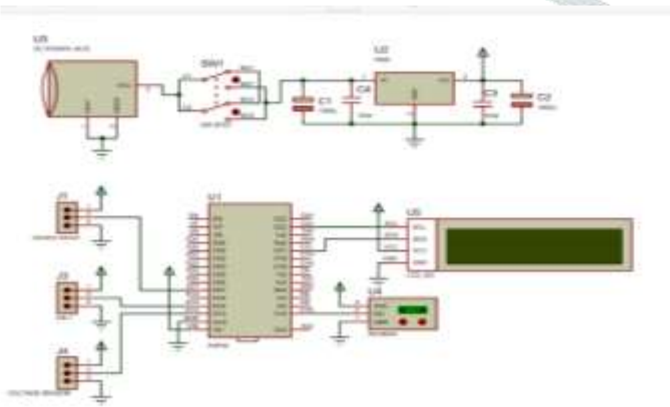
The ESP8266EX microcontroller has the Tensilica L106 32-bit RISC processor, which uses incredibly little energy andhas a top speed of 160 MHz..Thanks to the real-time operating system and WiFi stack, there can be over 80% of the computing power available.for creating applications and programming.The ESP8266EX can work dependably in industrial situations thanks to its wide operating temperature range.The ESP8266EX uses a combination of many proprietary methods to achieve its low power requirements. The power-saving architectural feature has three operational modes:the sleep mode, the sleep mode, and the deep sleep mode. Therefore, battery-powered equipment could run for longer.

H. LCD display:-

LCD display is used to display the output of the system. 16x2 LCD meansit contains 2 rows and 16 columns.Numerous combinations are possible like, 8x1, 8x2, 10x2 etc. But 16x2 LCD is mostly used one and the same is used for our project.

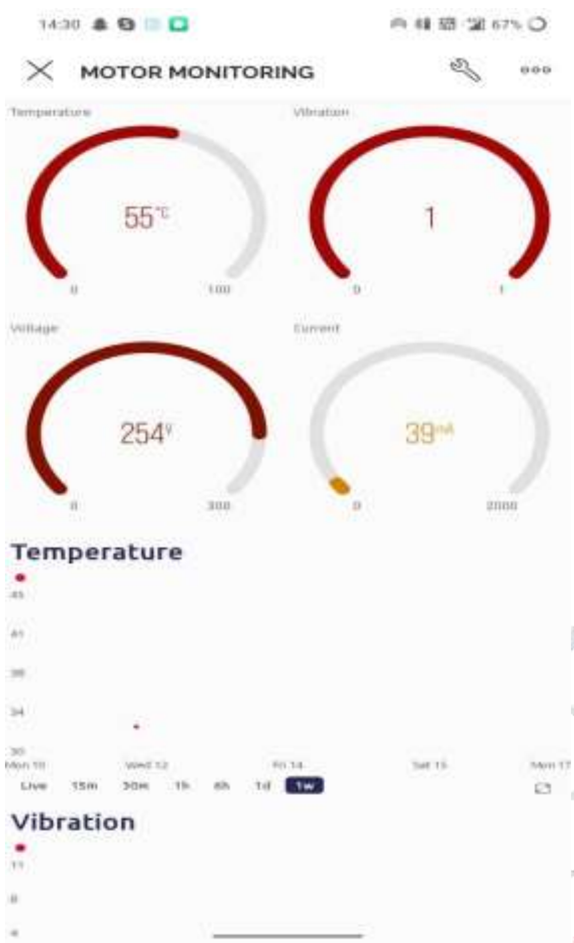
IV. EXPERIMENTAL RESULT





The circuit diagram of the above system provides a detailed representation of the connections between the different components of the system. It shows how the ZMPT101B Voltage Sensor,SCT-013 Current Sensor, DS1820 Temperature Sensor, and Analog Vibration Sensor are connected to the ESP32 Wi-Fi module. The circuit diagram also shows the power supply unit, which provides power to all the components of the system.Step-down transformer,bridge rectifier,filter capacitor, and the voltage regulatortogether form the power supply unit.. The circuit diagram provides detailed information on the connections between the different components of the system, making it easy for users to understand how the system works. It also provides a clear and concise representation of the power supply unit, which is critical to the proper functioning of the system.
Overall, the circuit diagram provides a detailed view of the system architecture, making it easier for users to understand the different components and their roles in the system. It also serves as a guide for users who want to build their own system based on the same architecture.

The below figure shows the analog values of parameters and shows graphical representation for 100W bulb. This dashboard is operated on mobile app. At once, all parameters are seen.



V. CONCLUSION

This project focuses on the machine's health monitoringresulting in the continuous and constant inputs.There has been a detailed analysis on the fault detection methods of induction motors. The induction motor's error-free and exact health monitoring method can increase dependability and lower maintenance expenses.The system may combine different detected parameters in real time to increase the accuracy of defect identification in motors. The measurement of several characteristics, including motor vibration, temperature, supply voltage, and current, is presented by the motor system monitoring. As a result, this system has a greater number of fields than others that can identify errors.Here, concept of cloud is offered for remote motor monitoring and control. Every electrical system, including EV vehicles and the automation of sectors where higher levels of safety are required, can benefit from the project. The system's unique benefits include minimum and least maintenance, quick and simple operation, and remote data access. Experimental findings support the system's viability for deployment.

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