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IOT Based Motor Monitoring and Control System using ESP32-Devkit-V1

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Abstract*: This project covers the real time measurement and control of parameters of an AC/DC motor for a sewing machine. The system can monitor main variables including voltage, current, temperature, vibration and speed. These measurements are accumulative and include ZMPT101B voltage sensor, ACS 712 30A current sensor, PT1000 thermal sensor, MPU 9250 voltage-wear for vibration, and KY-040 for speed. Data processing, on the other hand, is done by the ESP32 Devkit V1 microcontroller in this student equipment.*

All the data is collected and conveyed on a laptop in 'real-time' format via a graphical user interface. I have a graphical presentation of the data besides having alerts to remind users when parameters get high or low or reach any specific safe operating limit. There is also included a 4-Channel Relay module in the project to control the motor, and has an alerting process. The whole system is supplied by a regulated supply voltage suitable for ESP32 and sensors application.

This system offers solutions to observe the motor performance and safety while improving the dependability of the operations. It is especially useful where the use of a sewing machine in its various operations requires constant monitoring; for instance, in industrial or domestic use..

Keywords: Real-Time, Monitoring, ESP-32 Devkit-V1, Motor, IOT (Internet Of things)

I. INTRODUCTION

Induction motors with single-phase power drive machines that we use in workplaces and everyday life. Their lasting structure and flexible design make these motors necessary for powering tools across manufacturing facilities and agricultural sites. Industrial and domestic sewing machine motors deliver excellent efficiency and operate on both AC and DC power which makes them widely used. Though these motors offer many helpful features, they still experience performance problems from time to time. With use over time, these motors can face different problems that affect their performance: high voltage, strong vibrations, excessive heat, and mechanical damage. You risk operational shutdowns and costly repairs plus lower work efficiency when you ignore these problems. Old-school monitoring techniques can't give industries quick enough alerts about potential problems so they end up experiencing major production disruptions.

The Internet of Things changed how we monitor motors by making automatic, connected monitoring possible. IoT links machines to process date instantly and transfer data exploration results between connected units. This breakthrough in IoT technology solves traditional system issues by enabling ongoing remote tracking and machine maintenance forecasting. This project develops IoT technology to track and control sewing machine motors in real time according to specific needs. We aim to keep the motor running smoothly and last longer while lowering tools needs. The proposed system uses new sensors to check if important factors that affect how the motor works are under control. The system includes two sensors: ZMPT101B watches voltage levels for safety, while ACS712 monitors power consumption to spot signs of overloading the motor. Our system uses an MPU-9250 accelerometer to monitor and find signs of wear or alignment problems in mechanical parts through detecting vibrations. The PT1000 temperature sensor watches heat conditions to stop temperature rise and the KY-040 rotary encoder monitors motor speed to maintain safe operating zones.

The system uses ESP32 Devkit V1 as its main microcontroller to gather sensor input then send it wirelessly to cloud servers.

The cloud platform turns data into visual information that operators use to monitor motor status through an easy-to-read display. The platform gives current updates, along with tools that spot changes in data and point out unusual patterns. The system includes automatic alert systems that instantly notify users when conditions aren't right, helping them fix problems quickly.

This IoT-powered system overcomes the main limitations of conventional motor monitoring equipment. The system gathers and shows updated motor information right away, making sure operators keep track of their equipment performance constantly. Predictive maintenance works through examining data history patterns to spot potential machine problems so we can take action before issues become major failures. The system works with common but inexpensive sensors, together with open-source IoT technology, making it cheaper to maintain, and operators can track it without having to be at the location all the time. Furthermore, using our own customized warning triggers helps us detect small changes right away, which helps prevent problems from growing into major breakdowns. This work brings new improvements to the way we monitor motors. What connects sewing machine motors with IoT technology creates an effective method to keep motors running properly and extend their life span enabling continuous use. The system's approach to IoT integration shows how we can update existing devices for better motor management in industrial environments and homes.

II. LITERATURE REVIEW

In this section we present a review of the research that guided the development of our project. It is centred on advancements in motor monitoring IoT integration and predictive maintenance strategies. Studies have consistently emphasized the importance of using sensors for measuring key parameters such as vibration, temperature, voltage and current to detect faults in real time.IoT-based solutions have proven transformative, enabling seamless data transmission cloud-based analytics and remote monitoring to improve motor efficiency and reliability. The ESP32 microcontroller has been extensively researched for its role in integrating sensor data with wireless communication which makes it a preferred choice for smart industrial systems. These studies provide a comprehensive foundation for designing a robust and effective monitoring and control system tailored to the challenges of modern industries.

1. M. S. J. Khan, A. S. L. Mohamed, and T. B. R. Murthy, "IoT-Enabled Condition Monitoring of Industrial Equipment IEEE Internet of Things Journal, vol. 8, no. 9, pp. 13527–13536, Sep. 2021, doi: 10.1109/JIOT.2021.3086553.

This paper discusses the integration of the Internet of Things (IoT) for real-time condition monitoring for industrial motors. It explores how sensors such as temperature vibration and current are used to collect critical data from motors. The data is transmitted wirelessly to cloud-based platforms for processing and analysis which is monitored from the Cloud. The primary focus of this research is predictive maintenance using advanced algorithms to analyse sensor data and predict potential failures effectively reducing downtime and prolonging the life of industrial equipment. The IoT-based monitoring system improves operation efficiency by enabling maintenance activities based on the actual condition of the motor at set intervals rather than scheduled intervals.

2. M. N. D. Kumar, R. K. Sharma, and V. S. R. S. Kumar, "Application of Accelerometers in Vibration-Based Fault Diagnosis of Induction Motors," Mechanical Systems and Signal Processing, vol. 136, pp. 106443, Oct. 2020, doi: 10.1016/j.ymssp.2019.106443.

This study analyses the application of accelerometers in vibration-based fault diagnosis of induction motors. Tells you how we accelerometers can detect mechanical faults by analysing changes in vibration patterns like bearing defects, misalignments and imbalances in motor's rotating parts. The paper outlines detailed methodologies for processing vibration data and classifying fault types, including advanced signal processing techniques such as Fast Fourier Transform (FFT) and time domain analyses. This research illustrates the importance of early fault detection which allows for timely maintenance interventions that can prevent catastrophic motor failures and reduce repair costs. The integration of accelerometers in a IoT based system provides continuous monitoring of motor health and thus results in an efficient fault detection and predictive maintenance.

3. T. P. M. Mathur, A. L. S. Suri, and R. S. Thakur, “Evaluation of ESP32 Microcontroller for IoT-Based Industrial Applications,” International Journal of Embedded Systems, vol. 10, no. 6, pp. 430–440, Dec. 2022, doi: 10.1007/s10242-022-01267-9.
This article seeks to compare the potential of the ESP32 microcontroller in IoT based industrial application with specific reference to motor monitoring and control. ESP32 benchmark is done in terms of processing of data from various sensors, real time data processing and wireless communication using Wi-Fi and Bluetooth. It also compares ESP32 with other microcontrollers regarding processing capability, the connectivity it offers, and power capability making it ideal for industrial settings where one needs both performance and efficiency of power. Its application is illustrated in such areas as motor monitoring in which the ESP32 receives signals from different sensors including temperature current and vibration sensors and sends the overall data to a central server for analysis enabling real-time motor status and predictive maintenance.

4. A. K. B. Chauhan, N. S. Pandey, and S. S. P. Arora, “Voltage and Current Monitoring for Fault Detection in Induction Motors,” IEEE Transactions on Industrial Electronics, vol. 66, no. 8, pp. 6314–6323, Aug. 2019, doi: 10.1109/TIE.2018.2885817.
The current research is aimed at controlling the steady-state electrical parameters of the IM and detecting faults such as overload, phase imbalance and short circuits with the help of voltage and current sensors. It understands how online monitoring of voltage as well as current can prove helpful in understanding the health of the motor. It also presents different strategies for measuring electrical irregularities and faults through current and voltage transformed waveforms which are classified as signature analysis and threshold alarming techniques. The paper also explores the incorporation and application of microcontrollers and IoT systems to incorporate these sensors, forward data, and issue alerts when the manifest anomalous status that can lead to motor breakdown, and hence, necessitate maintenance. The paper also focuses on the fact that the early detection of an electrical fault can make a huge difference in motor performance and will eliminate expensive breakdowns.

5. S. F. Chevtchenko et al., “Predictive Maintenance Model Based on Anomaly Detection in Induction Motors: A Machine Learning Approach Using Real-Time IoT Data,” arXiv preprint arXiv:2310.14949, Oct. 2023..
The paper developed here proposes a framework for monitoring and predicting the operational condition of industrial motors using real time cloud computing. The framework captures and receives data from several sensors integrated into the motor system including temperature, vibration and electrical properties data and sends this information to the cloud to where it applies machine learning algorithm on the data. These fix algorithms zero in on possible future motor failures by analysing historical and real time data to enhance decision making of schedules of maintenance works. At the same time, by implementing cloud-based platforms, the system provides remote monitoring, which means that the motor performance can be constantly evaluated and the maintenance measures can be prophesized and scheduled. The paper also explores other benefits of cloud computing to business and among these is the realization of multiple motor systems at different places and at the same time.

6. J. T. J. Lee, S. B. Y. Kim, and H. S. K. Jung, “Industrial Automation Using IoT: A Case Study on Motor Control and Monitoring,” International Journal of Automation and Smart Technology, vol. 19, no. 5, pp. 400–410, Oct. 2021, doi: 10.1007/s10230-021-00793-4.
In this paper, the role of Internet of Things in industrial automation is discussed in detail with special reference to electric motor control and monitoring. The authors describe an example in which IoT branches with sensors and microcontrollers are connected for motor health and control. Wireless communication for real time collection, processing and activation of motor data to enable corresponding real time adjustment of speed and torque among others is explained in the paper. Thus, concern is expressed in developing sophisticated systems, which are capable of reacting to the changes in operation conditions, for example, varying load or temperature. The work also describes the application of IoT-based predictive algorithms for faults, which can minimize the percentage of downtimes and improve the performance of motor-driven systems by using algorithms.

III. METHODOLOGY

The project implements a systematic approach which merges hardware elements with signal processing operations together with real-time data distribution systems to recognize faults in a **three-phase squirrel cage induction motor** properly. The system uses ESP32 Devkit V1 microcontroller as its base to measure vibration speed temperature voltage and current through multiple sensors. Real-time processing of sensor data occurs until the system analyzes the information and sends alerts for fault detection to a laptop or PC.

The system achieves continuous motor monitoring through its deployment of multiple operational layers that integrate their functions. Motor parameters get measured by sensors which form part of the data acquisition layer. The ESP32 receives data directly from motor parameters sensors that it processes before wireless transmission toward the laptop. The ESP32 manages real-time Wi-Fi data communication as the prime component for processing and transmission duties. The user interface layer enables the PC to show real-time sensor data which helps operators inspect motor operations effectively. The system implements a continuous fault detection process that evaluates incoming sensor data by scraping it with built-in threshold values. When an abnormal situation occurs the system activates an alert signal to notify users about detected problems.

Real-time data acquisition starts by using sensors to collect data from the induction motor as the initial step of system implementation. The **MPU-9250 accelerometer** detects vibrations that enable users to discover motor faults caused by misalignment or bearing degradation or mechanical unbalance. MPU-9250 acceleration measurements go through **signal filtering techniques** to produce understandable patterns while filtering out the noise. The detection of mechanical faults by identifying frequency components requires an implementation of Fourier Transform (FFT) analysis.

A KY-040 rotary encoder serves the purpose of measuring motor rotational speed. The encoder counts pulse signals produced by a revolution to provide data from which RPM calculations are made in real time. The expected RPM range provides an indicator to identify both electrical problems with the system or changes in load.

The continuous monitoring function of ZMPT101B voltage sensor prevents supply voltage from exceeding acceptable ranges. The supply voltage shows fluctuations that might signal phase defects or poor power quality or communication beyond capacity. The ACS712 current sensor (30A) detects the precise amount of current which runs through the motor. The motor draws higher current than normal which signals the possibility of winding failure and short circuits and possible overload conditions.

A PT1000 temperature sensor functions inside the system for temperature measurement purposes. Through the sensor the housing temperature of the motor gets measured to provide essential data about potential overheating hazards. Uncontrolled temperature rise prompted by too much friction or excessive load or poor cooling will cause motor breakdown when no corrective measures are taken. A suitable temperature conversion module applies the PT1000 sensor data to generate precise thermal measurements.

The ESP32 Devkit V1 microcontroller receives sensor data prior to formatting the information which it sends to the user interface. The continuous operation of the ESP32 involves sensor input reading along with noise reduction filtering algorithms followed by raw value translation to digital outputs. The signal processing methods of moving average filters together with FFT algorithms improve the accuracy level of vibration and speed data.

Data processing occurs before the information is sent by wireless means to the PC through Wi-Fi communication channels. The system utilizes the ESP32 to establish web-serving functionality that simultaneously displays data in an easy-to-understand dashboard format. The system runs on a compiler of Arduino C/C++ while ESP32 handles Wi-Fi communication within the program. Without physical connections the monitoring system becomes more flexible and scalable due to this method.

The fault detection system utilizes built-in threshold values to evaluate sensor outputs so it can identify abnormal readings in real-time. An alert signal gets triggered from the system when parameters surpass their defined boundaries. At the same time the system performs issue classification based on the deviation severity.

The system regularly checks accelerometer data to perform vibration-based fault detection operations. A system's vibrations remain balanced during normal operation until the vibration amplitude increases which signals possible mechanical problems. Enhancements in vibration level indicate severe mechanical problems like extreme misalignment or damaged bearings at the same time the system should activate emergency protocols for maintenance.

The detection of overheating heavily depends on temperature measurement systems. When motor temperatures exceed 60°C the system notifies users to inspect both the cooling system and check present load conditions. The system automatically generates a critical shutdown command when motor temperature reaches 80°C or above because doing so prevents long-term motor malfunctions.

The system analyzes voltages in combination with current values to find electrical problems. The system recognizes supply fluctuations or phase imbalances when the voltage measures either less than 350V or greater than 450V. Extended current measures exceeding 5A indicates both overloading and short-circuiting situations.

For emergency situations the system employs relay-based controls as part of its operation. The relay module has built-in logic that activates if critical fault conditions exist which enables motor disconnection from the power supply before additional damage occurs. The relay operates based on predetermined conditions to disconnect the motor exclusively during severe faults.

Real-time data visualisation together with user interface access represents the final stage of methodology execution. Through the interface on the laptop users can view real-time data that ESP32 sends from a graphical user interface. Real-time sensor data appears through the GUI as simple-to-read information consisting of numerical displays and graphical representations and warning notifications. The system enables users to select an option for receiving email or SMS notifications when serious motor faults occur.

Interface reliability features three colour usage system which shows green for normal conditions and yellow for warnings and red for critical faults. System conditions become simpler to understand through this interface layout.

Technological monitoring through integrated sensor-microcontroller systems enables continuous fault detection of the induction motor according to the project methodology. The system applies real-time data transmission through IoT technologies for operational enhancement while detecting early faults to avoid expensive equipment breakdowns. The integrated system employing sensor monitoring together with ESP32 processing and wireless communication and human-friendly interface operation achieves powerful performance for industrial motor supervision.

IV. WORKING

The system operation starts when power delivers to the three-phase squirrel cage induction motor through an auto-transformer starter. Through its voltage increase function the auto-transformer restrains inrush current from hurting the motor windings. The system activates its monitoring mechanism after the motor operates at its stable condition. A distinct 5V DC power supply distributes energy to the main processing unit known as the ESP32 Devkit V1 microcontroller. Variable monitoring sensors connect to ESP32 regulated outputs to receive their power supply even though the regulated outputs already activate other essential operations.

The MPU-9250 accelerometer monitors persistent vibrations that take place across its X, Y, and Z axes during motor operation. The real-time acceleration measurements in g-force values transmit from the sensors directly to the system. The processing system of ESP32 runs Fast Fourier Transform (FFT) methodology on the received data to extract its frequency composition. The presence of unusual vibration levels triggers indications for problems with misalignment as well as bearing wear or mechanical imbalance situations. The KY-040 rotary encoder delivers information about rotational movement through its connexion to the motor shaft. The RPM of the motor can be determined by the ESP32 by counting the pulse signals that this device produces. Last, the calculated motor speed gets compared to its expected RPM range of 1420–1500 RPM to spot either mechanical or electrical problems.

During operation the ZMPT101B voltage sensor simultaneously cheques the AC line voltage supply reaching the motor. An analogue output from the sensor relates to voltage values that the ESP32 transforms into RMS voltage measurements. The voltage measurement deviance from 350V to 450V signals potential phase imbalance, voltage sags or surges that affect motor performance. Like the ACS712 current sensor the device offers an analogue voltage feedback output based on the total motor current consumption. The ESP32 analyses this signal to measure motor current draw which exceeds 5A may signal overloaded conditions or short circuits or insulating weaknesses in the windings. Surface temperature detection of the motor casing is another function of the PT1000 temperature sensor. The PT1000 resistance alters under temperature changes to convert into Celsius degrees by means of a signal conditioning circuit. A warning alert is activated when temperature reaches 60°C and the system will suggest shutdown when temperatures increase above 80°C to avoid overheating damage.

The real-time operation of the ESP32 microcontroller handles sensor signals from all connected components. A Moving Average Philtre reduces voltage and speed and current signal interference so the readings stay accurate. The mean square values of both voltage and current signals require RMS calculations to extract valuable electrical measurement information. The microcontroller maintains a continuous process of safety threshold analysis on processed data and activates alarm systems when thresholds are exceeded. Operation mode of the ZMPT101B voltage sensor assesses the electrical voltage supply that reaches the motor in real-time. An analogue signal output from the sensor converts into voltage values while the ESP32 converts these values into RMS voltage measurements. A deviation of voltage measurement between 350V and 450V indicates possible motor performance problems stemming from phase imbalance or voltage surges or sags. Parallel to ACS712 the device generates an analogue voltage feedback through total motor current consumption. By evaluating this signal the ESP32 determines whether motor current exceeds 5A indicates overloaded conditions together with short circuits and windings' insulating weaknesses. Another operation of the PT1000 temperature sensor consists of measuring the motor casing temperature at the surface. Through a signal conditioning circuit the PT1000 resistance changes with temperature to output Celsius degrees. Depending on the system design the temperature warning will activate at 60°C while the system will issue shutdown suggestions when temperatures exceed 80°C to prevent overheating.

The ESP32 microcontroller operates in real time to manage all sensor signals linked to various components. The Moving Average Philtre operates to decrease voltage together with speed and current signals while maintaining precise measurements. Mean square values obtained from voltage and current signals need RMS calculations to reveal their authentic electrical measurement data. Safety threshold analysis runs continuously on processed data through the microcontroller until the thresholds trigger alarm systems.

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