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Fault Detection in DC Motor Using a Programmable Logic Controller

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1.Abstract

Industrial machines and electrical equipment are susceptible to faults such as short circuits, overloads, and high voltage conditions, which can damage machinery, disrupt production, and pose safety hazards. This project presents a Machine Fault Detection and Alarm System using a Wecon PLC, integrated with current and voltage sensors to continuously monitor a motor representing the load. When the system detects abnormal operating conditions—such as undervoltage, overvoltage and overcurrent/Overload—the PLC immediately triggers a buzzer alarm and disconnects the load via a relay, preventing equipment damage and ensuring operator safety.

The system leverages the programmable logic of the Wecon PLC to implement real-time monitoring and decision-making with high reliability. Sensor data is continuously processed, and fault thresholds are pre-configured to respond instantly to unsafe conditions. The project demonstrates an automated, scalable solution for industrial safety, minimizing downtime and maintenance costs. By integrating PLC-based monitoring, current/voltage sensing, and protective relays, this system provides a practical and effective approach to safeguard motors and industrial loads against electrical faults.

Keywords: Electrical Fault Detection, Programmable Logic Controller, Relay, Alarm, INA219 Sensor, Arduino Uno, Buzzer, LCD.

2. Introduction

Industrial machines and electrical systems are exposed to various operational hazards such as undervoltage, overvoltage and overcurrent/ Overload conditions. These faults can lead to equipment damage, production downtime, and safety hazards for operators. Traditional protection methods, like fuses or manual circuit breakers, are reactive and cannot prevent all damage, often requiring manual intervention.

Programmable Logic Controllers (PLCs) offer a reliable and automated solution for industrial monitoring and control. By integrating current and voltage sensors with a PLC, it is possible to continuously monitor load conditions and respond instantly to abnormal situations. This project uses a Wecon PLC to detect electrical faults in a motor load, triggering alarms and automatic load shutdown via a relay, ensuring operational safety and reducing maintenance costs.

3. Literature Survey

Machine fault detection and condition monitoring have become important areas in industrial automation because early identification of abnormal operating conditions can reduce machine downtime, equipment damage, and maintenance requirements. Conventional protection methods generally monitor parameters such as overcurrent, overvoltage, and other electrical abnormalities. Recent developments in electrical machine condition monitoring have expanded these approaches by incorporating different sensing and diagnostic techniques for improving the reliability and safe operation of electrical machines [1].

Programmable Logic Controllers (PLCs) are widely used in industrial automation because of their adaptability, modularity, and suitability for real-time control. However, conventional PLC control systems have limited inherent capabilities for detailed fault diagnosis. Li and Zhou proposed diagnostic models for PLC-controlled flexible manufacturing systems based on logical functions and sequential control processes. Their work demonstrated that PLC signals can be effectively utilized to identify operational faults occurring in manufacturing systems [2].

Ghosh et al. developed an automated PLC Log-Data Analysis Tool (PLAT) for detecting operational faults and behavioural anomalies in PLC-controlled manufacturing systems. The proposed method analyzed PLC signal log data and generated a nominal model of the control process to identify abnormal behaviour in real time. The study demonstrated the importance of utilizing PLC control signals for online fault detection and diagnosis in industrial manufacturing systems [3]. Further development in PLC-based fault diagnosis introduced methods that combine control-process information with electrical power characteristics. Ghosh et al. proposed a fault and anomaly detection system for PLC-controlled manufacturing systems using deterministic finite-state automata and neural-network-based analysis of power consumption profiles. The combination of control-process behaviour and power usage information provided effective detection of different types of faults, including faults that may not be clearly reflected in PLC control signals alone [4].

PLC-based fault detection has also been extended toward fault isolation and remote monitoring. A PLC-based fault isolation and Industrial Internet of Things (IIoT) monitoring system was developed for a three-tank process, demonstrating the use of PLC implementation together with fault detection and remote monitoring technologies. Such approaches indicate the increasing role of PLCs in integrating fault detection with automated control and monitoring functions [5].

Electrical parameter monitoring using microcontroller-based systems has also been investigated for machine condition monitoring. Triwong et al. developed a low-cost remote condition monitoring system for three-phase induction motors using an Arduino-based embedded system. The system monitored parameters including voltage condition, stator current, and winding temperature under different operating conditions. The study demonstrated that a microcontroller-based platform can be used for real-time electrical machine monitoring and protection at relatively low cost [6].

Recent research has further explored the use of electrical power signals for early fault detection in PLC-controlled systems. A power and fault behaviour monitoring approach was developed using Boolean and analog signals, with current and voltage monitoring incorporated for identifying fault conditions under different operating scenarios. This indicates that monitoring electrical parameters such as voltage and current can provide useful information for detecting abnormal machine or process conditions [7].

Based on the above studies, it can be observed that PLCs provide a reliable platform for industrial control and fault response, while microcontroller-based systems provide a flexible and economical approach for sensor interfacing and real-time parameter monitoring. However, many existing approaches focus either on advanced fault diagnosis algorithms, remote monitoring, or individual machine parameters. Therefore, the present work proposes a comparatively simple integrated system in which an INA219 sensor measures voltage and current, an Arduino Uno performs threshold-based fault detection, and a PLC performs the industrial control action. The INA219 provides digital voltage and current monitoring through an I²C interface, while the Arduino Uno provides the required microcontroller platform for processing the acquired measurements [8].

4. Experimental Setup

Initially, the SMPS provides the required DC supply to the experimental system. The LM2596 buck converter is used to adjust the supply voltage using its potentiometer. The adjusted voltage is applied to the motor or connected machine load.

The INA219 sensor continuously measures the voltage and current associated with the load. These measured values are transmitted to the Arduino Uno through the I²C communication interface.

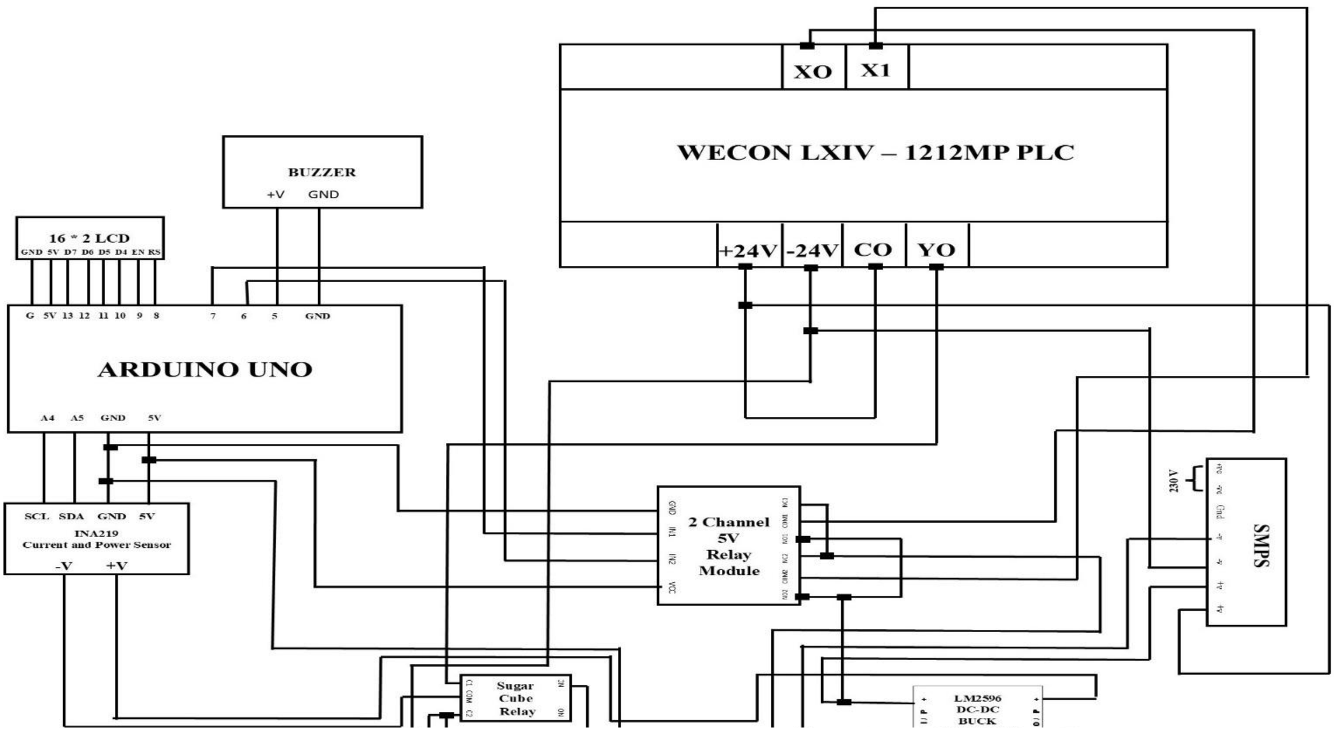
The Arduino compares the measured voltage with the predefined limits of 8 V and 11 V. If the voltage falls below 8 V, an undervoltage fault is identified. If the voltage exceeds 11 V, an overvoltage fault is identified. Similarly, if the current exceeds the predefined threshold, an overcurrent fault is detected.

When an abnormal condition is detected, the system first verifies whether the condition persists for consecutive readings. This prevents the system from responding unnecessarily to temporary fluctuations.

After confirmation of a voltage-related fault, Arduino activates the first channel of the relay module, which provides the fault signal to PLC input X0. Similarly, when an overcurrent condition is confirmed, the second relay channel is activated and the corresponding fault signal is sent to PLC input X1.

The PLC continuously checks the status of X0 and X1. The programmed ladder logic performs an OR operation between these two inputs. Therefore, the activation of either X0 or X1 results in the activation of PLC output Y0.

The PLC output then operates the final switching or protection circuit through the relay arrangement. At the same time, the LCD displays the measured electrical parameters and fault status, while the buzzer provides an audible warning.



The proposed PLC-based machine fault detection system was experimentally implemented as explained in the above section. The complete experimental hardware setup is shown in **Figure 1**. The SMPS was used to provide the required power supply for the system.

An LM2596 DC-DC buck converter was incorporated to obtain an adjustable DC output voltage. The potentiometer provided on the buck converter was manually adjusted to vary the supply voltage applied to the load. This arrangement enabled the creation of different operating conditions, including normal voltage, undervoltage, and overvoltage conditions.

The INA219 sensor was connected to the Arduino Uno for continuous measurement of the voltage and current associated with the load. The sensor communicated with the Arduino through the I²C interface.

The Arduino program continuously compared the measured voltage and current values with predefined threshold values. In the implemented system, voltage values below **8 V** were considered as an undervoltage condition, while voltage values above **11 V** were identified as an overvoltage condition. Similarly, current values exceeding the predefined current threshold were considered as an overcurrent condition.

A 16 × 2 LCD was connected to the Arduino to display the measured voltage, current, and corresponding operating status in real time. A buzzer was also incorporated to provide an audible indication whenever an abnormal operating condition was detected.

The fault signals generated by the Arduino were transferred through a two-channel 5 V relay module to the PLC input section. The voltage-related fault signal was connected to PLC input X0, while the overcurrent fault signal was connected to PLC input X1. The PLC was programmed such that the occurrence of either voltage fault or current fault activated the output Y0 according to the implemented ladder logic.

The PLC output was interfaced with the relay-based switching arrangement to perform the required control or protection action for the connected motor. A Sugar Cube Relay was used as part of the final switching interface. Thus, the experimental setup combined Arduino-based sensing and preliminary fault detection with PLC-based industrial control logic.

5. Experimental Results

The experimental results demonstrated that the developed prototype successfully monitored the voltage and current parameters of the connected load in real time.

5.1 Normal Test Condition

During the Normal test (as shown in Figure 2), the measured voltage was 9.3 V, which was within the predefined threshold of 8V $\leq$V$\leq$ 11V (Current within limit). Consequently, the system displayed the status message NORMAL

5.2 High Voltage Condition

During the High Voltage test (as shown in Figure 3), the measured voltage was 11.0 V, which was equal to the maximum predefined threshold of 8V $\leq$V$\leq$ 11V (Current within limit). Consequently, the system displayed the status message V HIGH

5.3 Low Voltage Condition

During the Low Voltage test (as shown in Figure 4), the measured voltage was 7.9 V, which was lower than the predefined threshold of 8V $\leq$V$\leq$ 11V (Current within limit). Consequently, the system displayed the status message V LOW

5.4 High Current Condition

During the High Current test (as shown in Figure 5), the measured current was 91.5 mA, which was higher than the predefined threshold of 50mA. Consequently, the system displayed the status message I HIGH

6. Discussion

The experimental observations confirmed that the developed prototype successfully differentiated between normal and abnormal operating conditions. During normal operation, the measured electrical parameters remained within the predefined limits, and the LCD displayed the normal system status. When the supply voltage was reduced below the lower threshold, the system identified an undervoltage condition and displayed the corresponding fault message. Similarly, when the voltage exceeded the upper threshold, an overvoltage condition was detected. The system also identified the overcurrent condition when the measured current exceeded the predefined limit. In each fault condition, the corresponding relay interface transferred the fault information to the PLC, where the programmed logic generated the required output response. These results demonstrate the feasibility of integrating sensor-based monitoring, Arduino-based fault detection, and PLC-based control in a single machine protection prototype.

Overall, the proposed system demonstrated effective real-time monitoring and detection of basic electrical fault conditions in a laboratory-scale machine. Although the present system is limited to voltage and current monitoring and uses fixed threshold values, the experimental results indicate that the proposed approach can serve as a foundation for developing an extended industrial machine condition monitoring and protection system.

The proposed machine fault detection system offers several advantages in monitoring and protecting the connected machine or load. The system continuously monitors voltage and current in real time using the INA219 sensor, enabling the detection of abnormal operating conditions such as undervoltage, overvoltage, and overcurrent. The Arduino Uno processes the measured values and compares them with predefined threshold limits, allowing faults to be identified automatically. The integration of the Arduino with the PLC combines sensor-based data acquisition with reliable industrial control logic. The 16 x 2 LCD provides real-time display of voltage, current, and system status, while the buzzer gives an immediate audible warning during abnormal conditions. The relay interface enables the detected fault signals to be safely transferred to the PLC for further control action. In addition, the use of predefined counters in the program helps avoid unnecessary fault activation due to temporary fluctuations. The system is relatively simple, low-cost, and easy to modify, as the voltage and current threshold values can be changed according to the requirements of different machines.
The proposed system can be further improved by incorporating additional sensors for temperature, vibration, and rotational speed monitoring. Communication technologies such as IoT, GSM, or cloud-based monitoring can also be integrated to enable remote fault notification and predictive maintenance.

7. Conclusion

The proposed PLC-based Machine Fault Detection System was successfully designed and experimentally implemented to monitor the voltage and current of a machine load. The system effectively detected abnormal conditions such as undervoltage, overvoltage, and overcurrent using the INA219 sensor and Arduino Uno. The detected fault signals were transferred to the PLC through relay interfaces, where the programmed ladder logic generated the required control response. The LCD provided real-time display of electrical parameters and system status, while the buzzer provided an immediate warning during fault conditions. The experimental results confirmed the successful operation of the system under normal and abnormal conditions. Overall, the proposed system demonstrates a simple, low-cost, and effective approach for real-time machine fault monitoring and PLC-based protection, with potential for further development into a more advanced industrial condition monitoring system.

8. References

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The PLC output then operates the final switching or protection circuit through the relay arrangement. At the same time, the LCD displays the measured electrical parameters and fault status, while the buzzer provides an audible warning

9. Captions

Figure 1: Full Hardware Setup of the Proposed System
Figure 2: Result of the System when Running Normally
Figure 3: Result of the System when High Voltage Detected
Figure 4: Result of the System when Low Voltage Detected
Figure 5: Result of the System when Hight Current is Detected

10. Tables

Hardware Components and their Functions in the Proposed System

Component	Function in Proposed System
Arduino UNO	Acquires Sensor and detects fault conditions
16 * 2 LCD	Display Voltage, Current and System Status
Buzzer	Provides an Audible Warning
2 Channel 5v Relay	Transfers Voltage/Current Faults signals to PLC Inputs
PLC	Processes Fault Signals using Ladder Logic
Sugar Cube Relay	Provides Switching action in the machine control circuit
SMPS	Converts AC Supply into DC Supply
LM2596 Buck Converter	Provides Adjustable DC Voltage for Experimental testing
Motor	Represents the machine under monitoring
INA219	Measures bus Voltage and Load Current

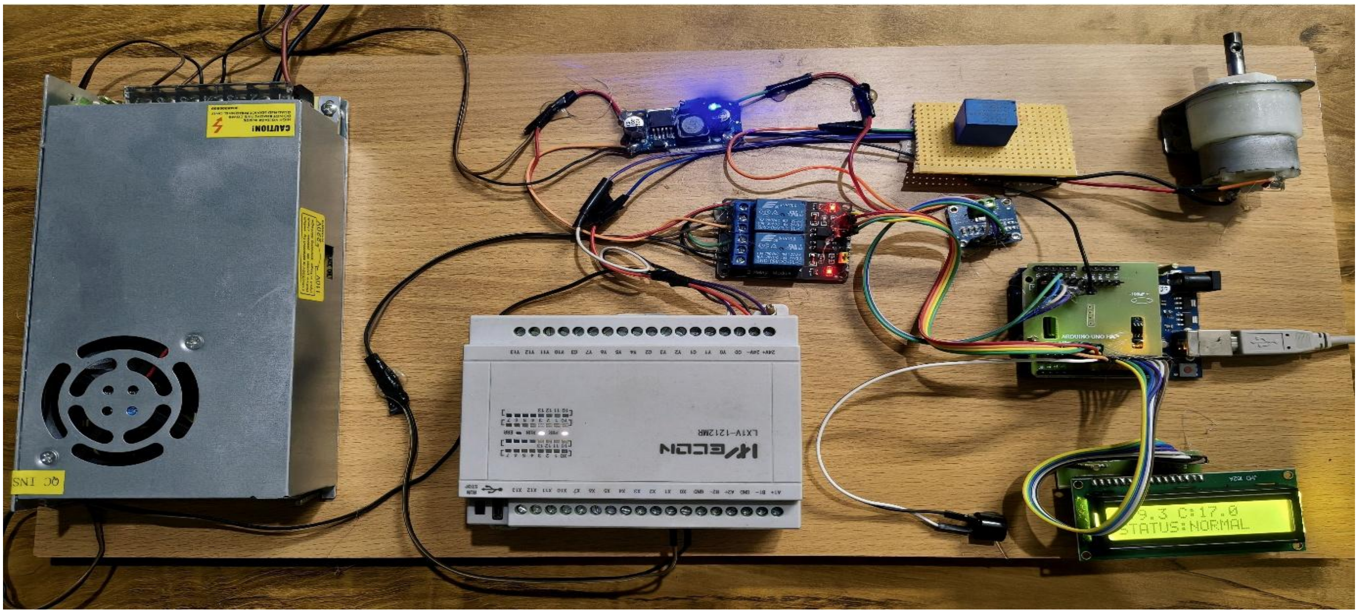

Figure 1: Full Hardware Setup of the Proposed System

Figure 2: Result of the System when Running Normally

Figure 3: Result of the System when High Voltage

Figure 4: Result of the System when Low Voltage Detected

Figure 5: Result of the System when Hight Current is Detected