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Arduino-Based Single-Phase AC Current Measurement with Over-Current Protection

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Abstract: The present work aims to design and implement an Arduino-based system for single-phase AC current measurement with integrated over-current protection. The system is intended to enhance electrical safety and improve monitoring by using a low-cost, programmable microcontroller. The system utilizes an Arduino microcontroller, interfaced with a current sensor (e.g., ACS712), to measure AC current in real-time. The Arduino processes sensor data, compares it against predefined threshold values, and automatically triggers protective actions such as disconnecting the load or activating an alarm in case of over-current conditions. This ensures the protection of electrical equipment, preventing potential hazards such as fires and equipment damage. The solution is cost-effective, flexible, and ensures safe operation for residential and small commercial applications. By integrating real-time current measurement and over-current protection, the system ensures the operational safety, efficiency, and long-term reliability of electrical systems.
Index Terms: Arduino, over-current protection, AC current measurement, electrical safety, ACS712 sensor, microcontroller.

I. INTRODUCTION

Monitoring and protecting electrical systems is crucial for maintaining safety and efficiency, especially in single-phase AC circuits commonly found in residential and small commercial settings. The increasing complexity and demand for reliable electrical systems necessitate affordable and easy-to- implement solutions. An Arduino-based system for measuring AC current, combined with over-current protection, offers an accessible, cost-effective method for safeguarding electrical circuits. This system uses the versatile Arduino microcontroller, coupled with a current sensor like the ACS712, to measure real-time electrical current.

The Arduino processes the sensor data and compares it with predefined threshold values. If the current exceeds these limits, the system can activate a protective mechanism, such as disconnecting the load, thereby preventing overcurrent- induced damage to equipment. This approach ensures that electrical devices operate within safe parameters, reducing the risk of fire and electrical hazards. The integration of real-time monitoring with automated protection makes this system an effective and economical solution for enhancing the safety and reliability of electrical systems.

II. LITERATURE SURVEY

The use of microcontrollers for electrical protection and monitoring has been widely studied. Various systems have utilized Arduino for overcurrent and overvoltage protection in both industrial and residential settings.

Bhattacharya et al. [1] proposed a cost-effective overvoltage and overcurrent protection system for simple single-phase circuits using an Arduino Uno. The system monitored real-time voltage and current through analog inputs and activated a relay if thresholds were exceeded.

Kotb and El-Saadawi [2] discussed the integration of Arduino with smart grid systems. They demonstrated the use of an overcurrent relay for backup protection in FREEDM systems, showing high accuracy in simulations.

Majumder et al. [3] focused on the design of an IDMT overcurrent relay using Arduino, incorporating Hall-effect current sensors for fault detection in transmission lines.

Sarker et al. [4] introduced a real-time monitoring system based on Arduino, which collects voltage, current, and frequency data and provides protection through a relay triggered by exceeding set limits.

Khan and Muhtadi [5] proposed an Arduino-based fault protection system for single-phase circuits, using a GSM module and relay to address overcurrent, undervoltage, and overvoltage conditions.

These studies highlight the effectiveness of Arduino in providing low-cost, reliable protection for electrical systems, enhancing both safety and system performance.

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III. SYSTEM OVERVIEW

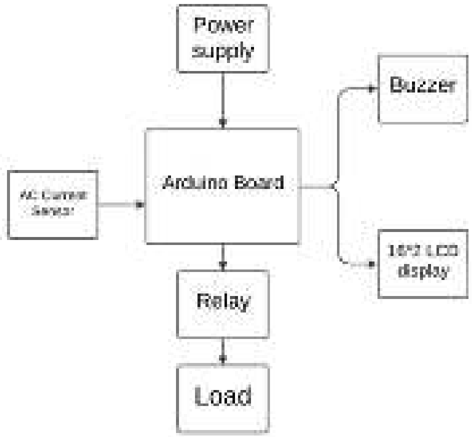

Fig. 1. BLOCK DIAGRAM

The proposed system integrates an Arduino microcontroller with several key components to provide real-time current measurement and overcurrent protection. The block diagram for the system is shown in Fig.1.

The system components are described as follows:

1) Arduino Board: The central controller responsible for processing data from sensors and triggering protection mechanisms.
2) AC Current Sensor (ACS712): Measures the current flowing through the circuit and sends an analog signal to the Arduino.
3) Buzzer: Provides an audible alert when overcurrent conditions are detected.
4) 16x2 LCD Display: Displays real-time current measurements and system status.
5) Buzzer: An audible feedback mechanism that triggers when abnormal readings are detected. The buzzer serves as an immediate warning for maintenance personnel.
6) LCD Display (16x2): Displays real-time sensor readings (current) and provides feedback on the status of the system.
7) Relay: The relay is used to disconnect the circuit in case an over current condition is detected. If current sensor detect an over current condition (such as an imbalance or unsafe condition), the relay is activated to disconnect the electrical circuit, preventing further damage or potential hazards.
8) Reset: The reset functionality is built into the system to allow operators to reset the Arduino and sensor readings after a fault has been addressed or after the system has been disconnected. This could be a manual reset through a button or automatically triggered after a certain condition is met, ensuring that the system is back in a safe and functional state after any faults have been cleared.

IV. METHODOLOGY

Fig. 2. KIT PHOTO

1) AC Current Sensor (ACS712)

The ACS712 is a Hall-effect-based current sensor that provides a precise, non-invasive method for measuring both AC and DC currents. It outputs an analog voltage proportional to the current flowing through the sensor. The sensor comes in various current ranges, such as ±5A, ±20A, and ±30A, making it versatile for different applications. It is easy to interface with the Arduino, providing accurate and reliable current measurements.

2) Arduino Uno Board

The Arduino Uno is a microcontroller platform based on the ATmega328P chip. It is widely used in hobbyist and industrial projects due to its simplicity and versatility. The Uno has 14 digital I/O pins, 6 of which support PWM output, and 6 analog input pins, making it ideal for current monitoring and protection tasks. The Arduino Uno is powered either through a USB connection or an external 7-12V supply and communicates with external components via a range of interfaces, including I2C, SPI, and UART.

3) Solid-State Relay (SSR-40DA)

The SSR-40DA is a solid-state relay that controls high- voltage AC loads using low-voltage DC signals. With a triggering voltage range of 3-32VDC and the ability to switch 24-380VAC at up to 40A, this relay is ideal for disconnecting the load in the event of overcurrent conditions. The SSR eliminates the mechanical components found in traditional relays, providing greater durability and faster switching times.

4) LCD Display (I2C 16x2)

The I2C 16x2 LCD display simplifies communication with the Arduino by using only two data lines (SDA and SCL) for data transmission. This reduces wiring complexity and allows for easy monitoring of real-time current measurements and system status. It provides clear, legible feedback for system operators.

5) AC DC Power Supply

The system requires both AC and DC power supplies. The AC power supply provides power to the load (e.g., motor or appliance), while the ACS712 sensor monitors the current. The Arduino and other components (LCD, relay, etc.) are powered by a DC supply, typically 5V, either from a USB connection or a dedicated power adapter.

6) Relay:

The relay serves to interrupt the circuit when an earth fault is detected. When the voltage or current sensors identify an imbalance or dangerous condition, the relay is triggered to cut off the electrical flow, preventing further harm or risks.

7) Reset:

The reset function is integrated into the system to enable operators to restart the Arduino and refresh sensor readings once a fault is resolved or the system has been disconnected. This reset may be initiated manually via a button or automatically under certain conditions, ensuring the system is restored to a safe and operational state after addressing any issues.

8) Code Logic:

The system monitors the current drawn by the load using an ACS current sensor, controls a relay based on overcurrent conditions, and provides feedback via a Liquid Crystal Display (LCD). It also includes a buzzer for alarm purposes. Here's a breakdown of the logic:

a) Hardware Setup:

- ACS current sensors (ACS_Pin_A0, ACS_Pin_A1): These sensors measure current. One is connected to a "PI" (positive input) and the other to a "NI" (negative input). The readings from these sensors are processed to calculate the RMS (Root Mean Square) value of the current.
- Relay (RELAY_PIN): A relay is used to disconnect or connect a load, based on the current reading. If the current exceeds a set threshold, the relay is turned off.
- Reset Pin (RESET_PIN): This pin is used to reset the system if the button is pressed.

- Buzzer (BUZZER_PIN): The buzzer sounds when an overcurrent condition is detected.
- LCD: An LCD screen displays the current readings and the relay status.

b) Variables:

- ACS_Value_A0 and ACS_Value_A1: Store the analog readings from the current sensors.
- Amps_TRMS_A0 and Amps_TRMS_A1: Store the calculated RMS values of the currents for the two sensors (PI and NI).
- DI (Difference): The difference between the two current readings, which could be used to detect imbalances.
- RunningStatistics (inputStats_A0, inputStats_A1): These objects keep track of the statistical data (like the RMS calculation) for the two current sensors over time.

c) System Initialization (setup()):

- Pin Setup: Configures pins for input (sensors, reset button) and output (relay, buzzer).
- LCD Initialization: Displays initial messages (like the name of the institution and team members) for a few seconds.
- Running Statistics Initialization: Initializes the RunningStatistics objects for both current sensors.
- Delay: Waits for 10 seconds before starting the current monitoring process.

d) Main Loop (loop()):

- Reset Trigger: If the reset button is pressed (reset pin goes LOW), the system calls resetSystem() to reset the system, which includes resetting the relay and buzzer state and clearing the LCD.
- Current Measurement: Every second, the code reads values from the two current sensors, updates the RunningStatistics objects, and calculates the RMS values of the currents using a linear equation with intercept and slope. The difference between the two currents is also calculated.
- Current Display: The LCD displays the current readings (PI and NI) and the difference (DI). It also shows whether the current is within normal limits or if there is an overcurrent condition.
- Overcurrent Detection:
  - If the relay is ON, the system checks the current every 10 seconds.
  - If the RMS value of either sensor exceeds the threshold (CURRENT_THRESHOLD), the relay is turned off to disconnect the load.
  - A message is displayed on the LCD (e.g., "Overcurrent OFF"), and the buzzer is activated.
- Relay Management:
  - If the relay is OFF, the system waits for 20 seconds before checking the current again.
  - If the current is still above the threshold after 20 seconds, the relay remains OFF.
  - If the current falls below the threshold, the relay is turned ON, reconnecting the load, and the LCD displays "Normal Current ON."
- Serial Monitor: The system prints the current values (PI, NI, DI) and the relay state (ON/OFF) to the serial monitor every second.

e) Reset Function (resetSystem()):

This function is called when the reset button is pressed. It:

- Resets the relay to its initial state (ON).
- Turns off the buzzer.
- Displays a reset message on the LCD for 2 seconds.
- Resets the current monitoring and relay state variables, allowing the system to start fresh.

f) Key Functionality:

- Overcurrent Protection: If the current exceeds a threshold (0.5 A), the relay is turned off to protect the load.
- Relay Control: The system switches the relay between ON and OFF states based on current readings.
- LCD Feedback: Provides real-time feedback of the current and relay status on the LCD.
- Buzzer Alarm: Alerts the user in case of an overcurrent condition.

V. RESULTS AND DISCUSSION

The system effectively monitored and managed overcurrent conditions, providing real-time feedback via an LCD and triggering a buzzer alarm when necessary.

Using ACS current sensors, the system accurately measured the current from the load, with the RMS values calculated for both the positive and negative inputs. The relay control worked as intended, disconnecting the load when current exceeded the set threshold of 1A, ensuring protection against overcurrent. The system displayed the current values and the relay status on the LCD, with clear messages indicating whether the current was within normal limits or if the relay had been turned off due to overcurrent. Additionally, the buzzer sounded when an overcurrent condition was detected, offering an audible warning to the user. The reset functionality was also effective, allowing the system to be manually reset and resume normal operations after any overcurrent event. Overall, the system demonstrated its ability to protect the load while providing immediate and informative feedback, ensuring the safety and reliability of the monitored electrical system.

VI. CONCLUSION

This paper presents an effective and cost-efficient solution for single-phase AC current measurement and over-current protection using an Arduino-based system. The integration of real-time current monitoring, automated protection mechanisms, and user-friendly interfaces makes the system a viable solution for residential and small commercial applications. The use of widely available and affordable components ensures that the system is both scalable and practical. The proposed design enhances electrical safety by preventing damage from overcurrent conditions, ensuring the reliability and longevity of electrical systems.

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