Design and Implementation of an SMS-based Fault Detection System Using Arduino STM32 Microcontroller

Md Lutfur Rahman[1], Rajib Mondal[2], Md Shariar Hasan[3], Md Abu Hena Shatil[4], Md Abdul Mannan[5], Rapsan Amin Anonto[6]

[1]Lecturer, Department of Electrical and Electronic Engineering, RPSU, Bangladesh
[2]Assistant Professor, Department of Electrical and Electronic Engineering, RPSU, Bangladesh
[3]Research Assistant, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[4]Associate Professor, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[5]Associate Dean, Department of Electrical and Electronic Engineering, AIUB, Bangladesh
[6]PhD Researcher, Department of Electrical and Computer Engineering, Morgan State University, USA
Corresponding Author: Md Lutfur Rahman, lutfur_eee@rpsu.edu.bd

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ABSTRACT

The paper deals with safety features and notifies the manager of any industrial load. It includes sensors to monitor current, voltage, and temperature data continuously if something goes wrong. This study uses Arduino as a microcontroller to check sensor data and execute appropriate actions for the load. Upon detection of a fault by the sensor, the Arduino will trip the switch and disconnect the load. Additionally, a further feature is the utilization of GSM for fault detection and localization. Upon the occurrence of a defect, the GSM module delivers an SMS to notify and urge rapid action by field operators. In this system, the simulation model is set up into proteus 8.1 professional software.

1. Introduction

Industrial loads are very expensive and heavy. These loads use very high voltage and current to perform. This is the reason there are risks to the machines and workers. There are many ways to protect the machines. Different types of protections are used for different types of loads. Machines are usually damaged by voltage destruction, unstable current, and overheating. Many scientists in various countries work on research to strengthen the protection system. Fault analysis was complex and challenging in the past. Still, in today's scientific and engineering era, it has become advanced and convenient, due to the emergence of various accelerated and reliable computing technologies, such as MATLAB, ETAP, and others. Fast and dependable techniques for multiple problems necessitate an effective and efficient fault analysis method. The exact fault information is not only appropriate for fault recognition algorithms or prototypes but also for proper protective relay operation and the correct resolution of different fault types (R. Ramaswami and P. F. McGuire,1992, R. E. Brown, 2008, M.-S. Choi, S.-J. Lee, D.-S. Lee, and B.-G. Jin,2004, B. Das, 2006). Currently, electrical energy is essential in various industries, including textiles, chemicals, steel, mining petroleum, and manufacturing. The safety and security of electrical power systems are crucial elements that must be addressed to power stations on efficiently generating electricity (S. Ponnusamy, R. Samikannu, B. A. Tlhabologo, W. Ullah and S. Murugesan, 2020).

To prevent this problem a safety device has been implemented. In this paper, Arduino STM32 microcontroller is used to analyze the data from different sensors and take actions if any unwanted problem occurs. All the data will show in the display. The GSM module is used to communicate with the operator about the data. Another important part of this research paper is to protect expensive machines from any type of power issues. If voltage, current, and temperature rise beyond the limits, might be machines will be damaged even if it can cause a disaster.

To prevent the damage of expensive machines from power issues this automated system works as a protection device. The main aim of this paper is to detect the fault using various sensors to protect the machines from over voltage, over current, and over temperature as well as to cut off the power supply of the machine and send an SMS about the fault to the operator by using GSM module. Currently, there are several aspects that make mobile phones appear inseparable from human existence. With this benefit, the detection may be communicated by SMS on mobile phones. The addition of a detecting buzzing alert can make workers more aware of the defect and aid to notify others if everyone is not present at the workstation (C. Adrian and M. Galina, 2019).

2. Literature Review

The protection system was used at the end of the 19th century. The fusible link is used to protect the machines. These fuses were made out of lead, silver, and tin. When voltage or current increases the fuses trip and the circuit is open. Fuses could be used for one time. It should be changed manually after any fault. This was the main disadvantage. For this disadvantage, a circuit breaker was introduced. In the 1900, circuit breaker was oil-filled with a stored-energy spring mechanism. The circuit breaker has the advantage of being used many times. At that time, circuit breakers were a little heavier and bigger. A circuit breaker (CB) interrupts the input currents in the case of overload in the system.

The relay was invented in 1920. This relay could easily determine thermal overload and the trip-down down the machines. Fuse relays protect the input side against overcurrent and thermal ones protect the electrical machine against overheating. A protective relay is the device, which gives instruction to disconnect a faulty part in the system (Mohamed Rashad, Amer Nasr A. Elghaffar, 2024). Protection relays are the most important aspect of power system protection, facilitating the isolation of faulty sections of the electrical system (Eltamaly A, Amer Nasr A. Elghaffar, et al. 2021).

Relays compare the electrical variables of networks (such as current, voltage, frequency, power, and impedance) with predetermined values (Christophe Prévé, 2006, Ali Eltamaly, Amer Nasr A. Elghaffar, et al. 2019). When the monitored value reaches the threshold, after that the relay sends a tripping command to the circuit breaker when an abnormal scenario has been identified (Ali M. Eltamaly, Amer Nasr A. Elghaffar, et al. 2019, Ali M. Eltamaly and Amer Nasr A. Elghaffar, June 2017).

Different protective relay types such as distance relays, differential relays, overcurrent relays, etc. are available. There are two options on the relay: plug and time. While the plug setting is determined by the amount of current needed to pick up for the relay, the time setting determines when the relay operates (S. A. Shaikh, K. Kumar, A. R. Solangi, S. Kumar and A. A. Soomro, 2018). Currently, microprocessor-based digital and numeric relays are substituting conventional relays across every aspect of power system protection (Z. Q. Bo, X. N. Lin, et al. 2016).

Different types of protections are combined in modern protection systems, but it has taken years of development and research. The earlier protection module works mechanically. Numerous research papers have suggested methods for fault detection that reduces the period of time between the fault occurrence and the fault diagnosis (R. L. de Araujo Ribeiro, C. B. Jacobina, E. R. C. da Silva and A. M. N. Lima, 2003). Now, microcontroller-based protection system is induced. From the modern protection system, we can know what fault occurs and the current reading of the main power supply.

3. Control and Protection System

In new era, equipment protection has become one of the most important aspects of the industry. Without a protection system, industries cannot operate their machines effectively. Sometimes accidents occur in a variety of ways.

3.1. Over Voltage

Overvoltage is a common cause of damage to machines. Every machine operates within a voltage range. When a problem occurs in line voltage, the voltage rises above the range. As a result, overvoltage causes damage to machines. Voltage surges, or spikes, are the inverse of dips, an increase that might be practically immediate (spike) or last longer (surge). A voltage surge occurs when the voltage is 110% or higher than usual. The current invention pertains to variable voltage protection devices used to safeguard electronic devices against over-voltage transients generated by lightning, electromagnetic pulses, electrostatic discharges, ground loop-induced transients, or inductive power surges (Gerald R. Behling, San Jose; James B. Intrater, Santa Clara., 2002). When the circuit gets an overvoltage spike, the variable voltage material rapidly transitions to a low electrical resistance state, shorting the overvoltage to the ground. After the overvoltage has passed, the material instantly returns to its natural condition. In the majority of industrial applications, the machine is powered by a voltage-source inverter. These AC drive systems are sensitive to any voltage failure. When faults arise, the machine should be turned off. Five basic types of loads are used to represent equipment with varied load characteristics: resistive, capacitive, and inductive loads, resistive and capacitive paralleling loads, and resistive and inductive serial loads (J. He, Z. Yuan, S. Wang, J. Hu, S. Chen and R. Zeng, 2010).

Overvoltage and undervoltage can cause harm to the equipment. Each component of the equipment has a minimum and maximum voltage rating. In Bangladesh, the voltage ranges between 220 and 230 volts. In this system, the voltage limit is set at 210 volts to 240 volts. If the supply voltage rises due to a defect in the supply line and exceeds the limit Arduino detects, the machine will shut down promptly and send an SMS to the operator. The innovation provides an arrangement that protects sensitive electrical equipment. For example, voltage transients can affect integrated circuits. A protective feature, such as a voltage regulator or voltage sensor, has been implemented to prevent overvoltage damage to the machine. The feature sends a signal to the microcontroller, causing the power supply to shut down due to an excessively high voltage. Surge suppressors, voltage regulators, uninterruptible power supplies, and power conditioners are all potential solutions. Since, each machine has a voltage rating, and very heavy equipment has overvoltage protection. The machine

can work at a few voltages above the range. This suggested protective device can restrict the output voltage. The limit can be set based on the machine's rated voltage. This device can turn off the supply voltage if the line voltage exceeds a certain level. This device functions automatically and will turn on after the error is solved.

3.2. Over Current

The three main components of the electrical power system are distribution, transmission, and generation. A report has been created that shows that 80% of interruptions are observed on the consumer side due to the failure of the distribution system. A fault is an unwanted and unexpected state that stresses the network and increases expenses because of equipment breakdown. Blocking the excessive current flow is a must before harming any equipment.

Overcurrent is also the main issue for damaging machines. Overcurrent can occur for many reasons. If machines get overloaded, then they will drown out more current, which raises the current. When any short circuit happens internally, the line current rises significantly, which is the cause of overcurrent. There are many different kinds of defects, such as symmetrical and unsymmetrical faults.

Three-phase or symmetrical faults are the most serious type of failures that cause the most disruption in network accessories (Myeon-Song Choi, Seung-Jae Lee, Duck-Su Lee and Bo-Gun Jin, 2004). An overcurrent fault causes an extremely high current flow, which needs to be stopped before it harms any network segments. Protective relays and circuit breakers are essential components of the protection system design. Precise fault information is required not only for prototypes or algorithms for identifying faults, but also for the appropriate functioning of protective relays and the accurate correction of various fault kinds.

Every machine has its own current rating. Machines can do the work efficiently with proper and stable current. Overcurrent is very dangerous for machines. This proposed protection device can maintain a limit on output current. The limit can be set according to the machine's current rating. For any fault or short circuit to occur in the line, this device can cut off the power supply when the current gets beyond the limit. The impact of a failure on the system's performance decreases with speed of detection. It is also preferable to minimize the number of extra sensors as employing a significant number of additional sensors for fault detection would raise costs and decrease system dependability. This device is a prototype, so its current range is between 1-2 amps. For any fault, overload, or short circuit, the current will increase. In this situation, when Arduino measures the data and it gets a current reading over the range, it will turn off the load, the operator will be notified by SMS via the GSM module, and it will automatically power on when the fault disappears.

3.3. Over Temperature

Maintaining temperature is our big concern for machines safety. Temperature can rise due to over load or any internal mechanical damage, like bearing or moving parts. Those are reasons for rise the temp and machines get over heated. The main reason causing the motor to burn are current mode failure, a lack of phase, current imbalance, short circuits, leakage, and overcurrent (L. Q. Cartagena, S. E. Barbin and W. J. Salcedo, 2018). Extended over-loading of the motor temperature rise will surpass the permissible value, perhaps resulting in the premature aging of the insulation. When a bipolar power transistor overheats and experiences thermal instability, or runaway, the device malfunctions destructively. In addition, overheating shortens the product's lifespan. The lifespan and efficiency of the gadget will be extended by implementing over-temperature protection. As well as, Fuzzy logic control has demonstrated more efficiency in temperature response management compared to PI control in simulations for a plastic extrusion facility (Ravi S and Balakrishnan P A, 2010). To mitigate signal distortion in monitoring and control, the implementation of intelligent controllers, such as microcontrollers, is advisable (Ravi S, Rajpriya G and Kumarakrishnan, 2015).
Machines work efficiently in optimal temperature. Overheating will damage the machines. Machine can get over heated from over load. An integrated temperature detector is used to monitor the temperature. This protection device can measure the temperature and it can set a limit. Once a certain threshold level is exceeded, the output power is limited (G. Liao and J. Xi, 2011). temperature sensor will continuously measure the temperature. When any internal or mechanical problem occur, the temperature will rise and Excess heat can damage the device so there is a limit set on Arduino, which is 400 °C. when the temperature crosses the limit, the device will cut off the power supply. when it returns on normal, it will turn on the device automatically.

4. Working Principle

This system works are based on Arduino STM32 microcontroller. In this system voltage regulators, current sensors, and temperature sensors are used to detect current data. These sensors are getting actual readings continuously and sending the data to the Arduino. Arduino is programmed to check the data from the sensor and analyze the data. The data from the sensor will be shown on LCD. Arduino has been programmed with a range of data. If data from the sensor gets beyond the limit, the Arduino will send the signal to the relay, which will cut off the power supply of the machine. Then Arduino will send a signal with fault data to the GSM module. It will send a text message to the operator or maintenance department. Arduino will take

data continuously from the sensor so that when the fault is removed, Arduino analyzes the data from the sensor and will again send the signal to relay, which turns on the machines.

5. Block Diagram and Simulation

5.1. Block Diagram of Proposed System

Fig. 1. Shows the block diagram of the proposed system. Arduino STM32 was used as a microcontroller to control the whole system.

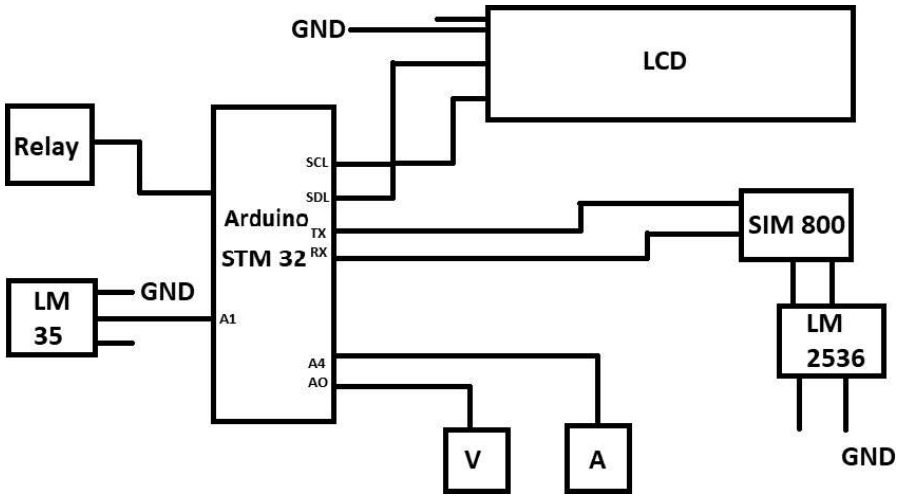

Fig. 1. Block diagram of the proposed system

5.2. Simulation

This project consists of electrical and electronic components. Proteus 8.1 professional software was used for the simulation. Fig. 2. shows the representing the main simulation of the system.

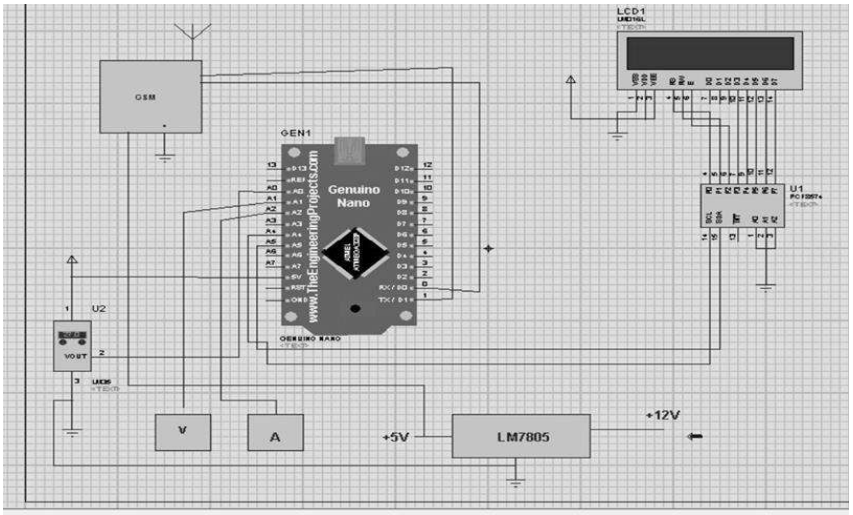

Fig. 2. Simulation of Protection System Proteus 8.1 Professional Software

6. Hardware Implementation and Results

A printed circuit board (PCB) was used to set the full system. On the other hand, A complete instruction of programming language needed to be saved to the microcontroller IC to get the function we want it to. The electronic components of the system were implemented in the printed circuit board (PCB). Fig. 3. Shows the main circuit board of the system.

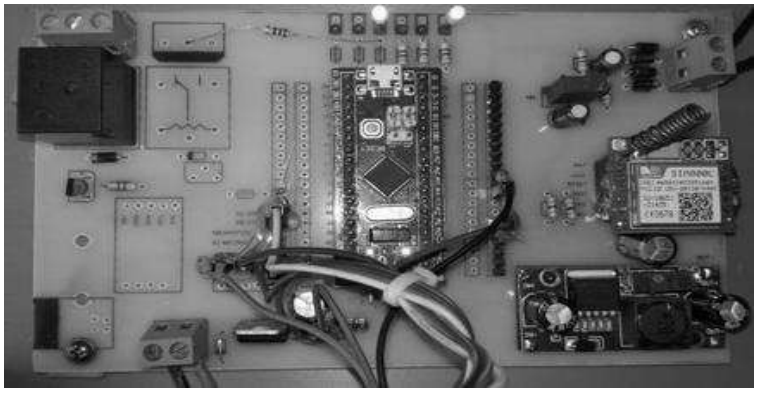

Fig. 3. Main Circuit Board

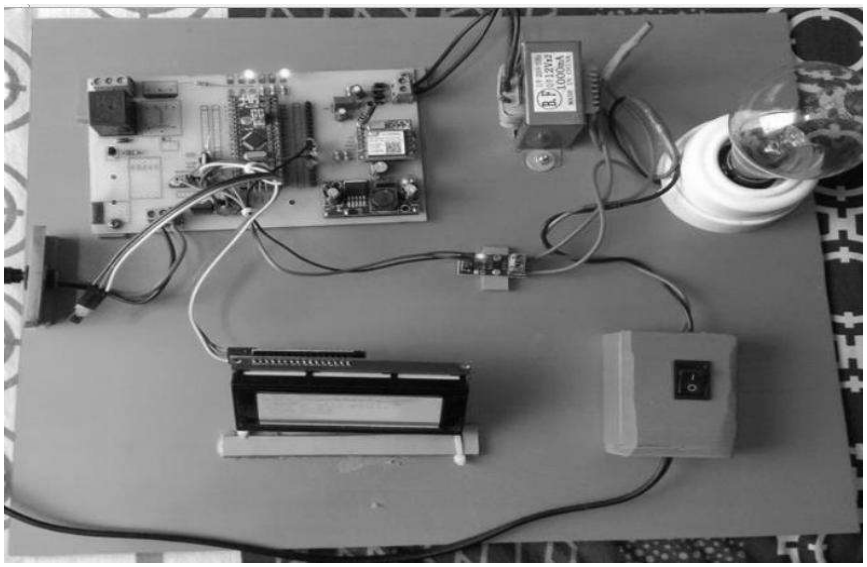

Fig. 4. Hardware Implementation

The whole process of hardware implementation has been described in the segment. Fig. 4. Shows the hardware implementation of the whole system has been given. For hardware implementation here used Arduino STM32, GSM module, voltage regulator, temperature sensor, current sensor, LCD display, transformer, relay, and many other components. Power adapter used to run Arduino and other module. All the component is mounted in a hardboard. Which mainly focuses on representing the whole prototype of the system.

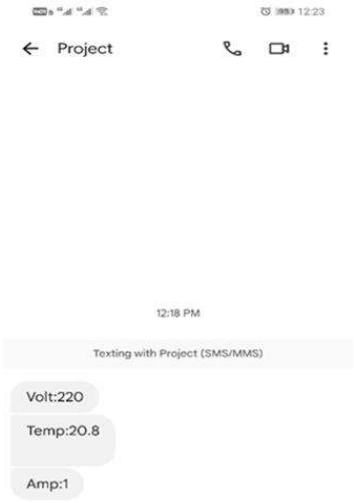

Fig. 5. Display reading **Fig. 6. SMS notification**

Fig. 5. Shows the display reading of the system. Here, a 220-volt AC supply is used to power the main load. A halogen bulb is used to show the current parameter and Fig. 6. SMS notification of the system.

The full system was done by multiple types of operation. Firstly, simulations were done by proteus 8.1 professional software and PCB design was done by express PCB software. On the other hand, the main hardware was implemented with various sensors and electrical components.

7. Conclusion

The main goal of this paper was to reduce the damage to machines or expensive loads from any fault in main power sources. This system works on an Arduino STM32 microcontroller. The most important part of this paper was to read the data from sensors and take immediate action by tripping the relay. Arduino analyzes the data from the voltage regulator, current sensor, and temperature sensor and shows the data in the LED display continuously. Arduino is programmed with code where a limit has been set. If any fault occurs and data from the sensor goes over the limit, the microcontroller will send the signal to trip the relay and send an SMS to the operator about the fault via the GSM module. Arduino will again send a signal to turn the relay on automatically when the fault is removed. The full system has been implemented

with many electrical components. Arduino was used as the brain of the system for getting data from sensors and analyzing the data. The system has been implemented successfully. By implementing this protection system, we can reduce the percentage of damage of expensive machines as well as industrial safety and assets.

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