



IOT based Design and Implementation of Power Quality Management System

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Abstract:-

This paper introduces an Internet of Things (IoT) based approach for designing and implementing an Electric Power Quality Management System (EPQMS) using Arduino microcontrollers. With the growing complexity of power systems, ensuring high-quality electric power is essential for reliable operation. The proposed system integrates various sensors to monitor key parameters such as voltage, current, sudden phase failure & load imbalances. These sensors are interfaced with Arduino boards equipped with Wi-Fi or Ethernet connectivity for seamless data transmission. In this, power quality parameters are monitored and corrected them in order to experience the good power quality. Hence continuously monitor the power quality parameters such as voltage sag, voltage swell and voltage interruption and safe guard the electric appliances by improving the power quality. ARDUINO microcontroller is used for continuously senses the power line parameters and activates the desired compensation circuits in order to maintain good power quality. Also, the entire project is monitored through Internet of Things [IoT] platform. Through IoT connectivity, the PQMS enables remote access to power quality data, facilitating monitoring and management from any location with internet connectivity. The system can generate alerts and notifications in case of deviations from predefined quality standards, allowing for timely interventions to maintain optimal performance. The implementation of the EPQMS using Arduino offers a cost-effective and scalable solution suitable for a wide range of applications, from residential to industrial settings. By leveraging IoT technology, this system contributes to improving the efficiency, reliability, and sustainability of electric power management

Keywords: Internet of Things (IoT), Electric Power Quality Management System (EPQMS), Arduino, Micro controller unit, GSM MODEL (TCP/IP PROTOCOL).

1. Introduction

The increasing complexity and sensitivity of modern electrical systems, coupled with the rising demand for high-quality power, have led to a growing need for effective power quality



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management solutions. Power quality issues, such as voltage fluctuations, load imbalances, voltage sag & swell, sudden phase failure, harmonics, and frequency variations, can have detrimental effects on equipment performance, leading to increased downtime and maintenance costs. To address these challenges, there is a growing interest in developing intelligent systems that can monitor, analyze, and manage power quality in real-time.

Electric power quality refers to maintaining a near-perfect sinusoidal power supply waveform. Deviations in form can adversely affect electrical devices, leading to inefficiency and damage. Common issues include voltage fluctuations, load imbalances, voltage sag & swell, sudden phase failure, harmonics, and frequency variations. Traditionally, managing these quality parameters involved complex and costly setups, making it inaccessible for smaller setups or individual applications. However, the integration of IoT into power quality management democratizes and simplifies the ability to monitor, analyze, and respond to power quality issues. The growing interconnectivity of devices through the Internet of Things (IoT) is drastically reshaping various engineering fields, including electrical power systems. Among the most critical challenges faced by these systems is ensuring high power quality, as poor power quality can result in significant economic losses, reduced equipment life spans, and decreased operational reliability. An IoT-based Electric Power Quality Management System (EPQMS) using Arduino represents a significant step forward in addressing these challenges through advanced technology.

IoT technology offers a scalable and cost-effective solution to power quality management. By using internet-connected devices that can sense, process, and communicate information, IoT enables continuous monitoring and management of electrical systems in real-time. Arduino serves as an accessible, flexible, and cost-effective platform to develop IoT applications, including those for monitoring electric power quality. It has a robust set of features that allow it to gather data from various sensors, process this data, and communicate with other devices or servers. Arduino, a versatile and user-friendly microcontroller platform, is particularly well-suited for building IoT applications including those for power quality management due to its simplicity, accessibility, and extensive support community. Utilizing Arduino involves:

Data Collection: Implementing sensors that measure critical power quality parameters such as voltage, current, and frequency.

Data Processing: Arduino boards process this data, identifying anomalies and assessing power quality metrics against predefined thresholds or conditions.

Connectivity: IoT connectivity is achieved via modules that enable Arduino boards to send data to a cloud server or a local network where further analysis and monitoring can be performed.

Response and Control: The system can initiate automated responses or send alerts for manual intervention based on the analysis, such as adjusting load or activating corrective devices.

2. Methodology

In the proposed system methodology, the power quality parameter is continuously monitored through Internet of Things. Since our system supports scalability, we can be able



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to monitor the system from anywhere without any range restrictions. An automatic power quality improvement technique by adding up the capacitor is used to correct the voltage sag & swell issues. This project continuously monitor the voltage sag, voltage swell and voltage interruption and safe guard the electric appliances by improving the power quality. ARDUINO microcontroller is used in our projects which will continuously senses the power line parameters and activates the desired compensation circuits in order to maintain good power quality. Also, the entire project is monitored through Internet of Things [IoT] platform

In the given block diagram (Fig 2.1) at prior we have a input AC voltage source which a nominal voltage of the range of 230V and 50 Hz from that we are feeding the step down transformer to stepping down the voltage to a volt which we needed to activate the microcontroller which is basically a 5v supply needed for the Arduino board to turn on where we are concluding the 5V with help of bridge rectifier and a capacitive filter. Bridge rectifier gives the dc output voltage from the AC input and the capacitive filter is used to maintain the correct output signal which has the input of distorted wave form of supply.

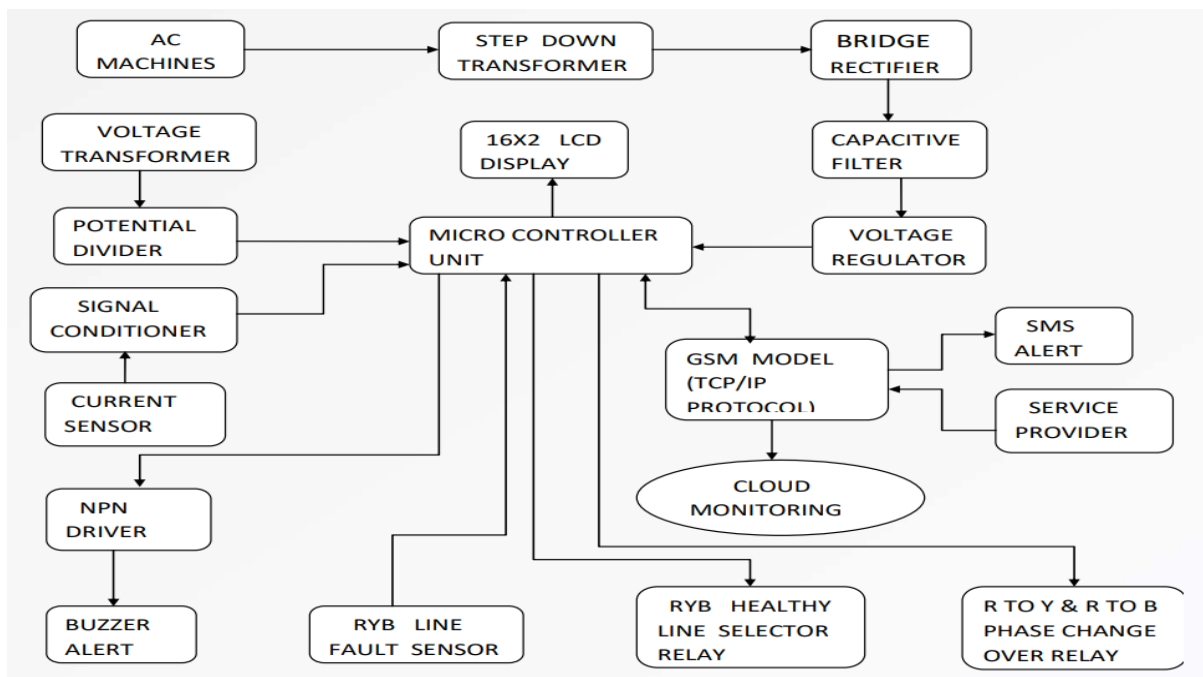


Fig. 1 Block diagram representation of IOT Based Design and Implementation of Power Quality Management System By Using Arduino

Step-down transformers are designed to maintain a relatively constant output voltage under varying load conditions. This is achieved through proper design of the transformer's winding configuration and magnetic core material. A voltage regulator is an electronic circuit or device designed to maintain a stable output voltage regardless of changes in input voltage



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or load conditions. Voltage regulators are essential components in many electronic systems, ensuring that sensitive components receive a consistent and reliable supply voltage.

A voltage transformer, also known as a potential transformer (PT) or voltage sensor, is a type of instrument transformer used to step down high voltages to a lower, standardized level suitable for measurement or control purposes. Voltage transformers provide electrical isolation between the primary and secondary circuits, ensuring that the measuring or control instruments connected to the secondary side are protected from high voltages present on the primary side. The primary function of a voltage transformer is to accurately step down high voltages to a lower level proportional to the primary voltage. This allows for safe and convenient measurement of high voltages using standard instruments. Voltage transformers are designed to provide accurate voltage transformation with minimal error. The accuracy of a voltage transformer is typically specified as a percentage of the rated voltage, such as $\pm 0.5\%$ or $\pm 1\%$.

A 16x2 LCD display is a liquid crystal display (LCD) module commonly used for displaying alphanumeric characters. The "16x2" designation refers to the dimensions of the display, indicating that it has 16 character positions in each of its two rows. Monitoring of all the status is by the LCD display which is a 16x2 display where 16 explains a columns and 2 is a row of digits. Here from the voltage transformer we get the lower voltage sine waveform from the higher voltage sine waveform. And the waveform is feed into potential divider. A potential divider, also known as a voltage divider, is a simple electronic circuit that divides an input voltage into a fraction of its original value.

A potential divider, also known as a voltage divider, is a simple electronic circuit that divides an input voltage into a fraction of its original value. It consists of two resistors connected in series across a voltage source, with the output voltage taken from the junction between the resistors.

A current sensor is a type of sensor used to measure the electrical current flowing through a conductor or circuit. Current sensors play a crucial role in various applications, including power monitoring, energy management, motor control, and safety protection. Current sensors operate based on different principles, depending on the specific type of sensor. Here we used the current sensor to sense the current through the signal conditioner and send the values to the microcontroller; this is done because we want to maintain both the current and voltage in the same level.

An NPN driver typically refers to a transistor circuit using an NPN bipolar junction transistor (BJT) to drive a load, such as a motor, relay, or LED. The NPN transistor acts as a switch or amplifier to control the current flow through the load based on the input signal applied to its base terminal.

A buzzer alert system is a simple electronic setup that uses a buzzer as an audible indicator to alert users of certain events or conditions. Buzzer alert systems are commonly used in various applications, including alarms, notifications, reminders, and security systems. SMS alerting is a communication method used to send short text messages (SMS) to notify individual or groups about specific events, incidents, or alerts. SMS alerts are commonly used in various industries and contexts for emergency notifications, service disruptions, system



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alerts, and other critical communications. The system can generate alerts and notifications in case of deviations from predefined quality standards, allowing for timely interventions to maintain optimal performance. Overall, SMS alerting is a valuable tool for quickly disseminating critical information and facilitating timely responses to events and incidents, helping organizations minimize downtime, mitigate risks, and enhance operational resilience. A service provider, in the context of SMS alerting and communication, refers to a company or organization that offers SMS messaging services to businesses, governments, or other entities. Service providers typically operate telecommunication infrastructure, such as SMS gateways, networks, and platforms, to facilitate the sending and receiving of text messages. Overall, SMS service providers play a vital role in facilitating communication and enabling businesses and organizations to reach their target audiences effectively and efficiently through text messaging. Choosing the right service provider is essential for ensuring reliable delivery, scalability, security, and compliance with regulatory requirements.

TCP/IP stands for Transmission Control Protocol/Internet Protocol. It is a suite of protocols that defines how devices send and receive data packets over networks. TCP/IP consists of four layers: application, transport, internet, and network access. Each layer has a specific function and interacts with the other layers to ensure reliable and efficient communication.

Mobile devices, such as smart phones and tablets, rely on wireless networks to access the internet and communicate with other devices. TCP/IP is a set of rules and standards that governs how devices communicate over the internet and other networks.

Finally we give the information through IoT based cloud with the help of GSM and also we can monitor the output of renewable energy sources. The protocol we used in the IoT is TCP (transfer control protocol) with IP (internet protocol). It is a suite of protocols that defines how devices send and receive data packets over networks. TCP/IP consists of four layers: application, transport, internet, and network access. Each layer has a specific function and interacts with the other layers to ensure reliable and efficient communication. Hence we are monitoring all the parameters such as input source, power factor, line faults & load imbalances and send to the respective person with the help of internet of things which made as to enter into the modern world.

3. Results and Discussion

In this project the power quality parameters are not only monitored and controlling the power quality management system. The system uses wireless sensor nodes for communication purpose which has range limitations.

This system monitor the power quality parameters and to correct them in order to experience the good power quality. This project continuously monitor the voltage sag, voltage swell and voltage interruption and safe guard the electric appliances by improving the power quality. ARDUINO microcontroller is used in our projects which will continuously senses the power line parameters and activates the desired compensation circuits in order to maintain good power quality. Also, the entire project is monitored through Internet of Things [IoT] platform.



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Henceforth, the user can monitor the power quality from any part of the world. Through IoT connectivity, the PQMS enables remote access to power quality data, facilitating monitoring and management from any location with internet connectivity. The system can generate alerts and notifications in case of deviations from predefined quality standards, allowing for timely interventions to maintain optimal performance.

The below fig. 3.1 shown figure is the Simulation Diagram of IOT based design & implementation of Power Quality Management System by using Arduino.

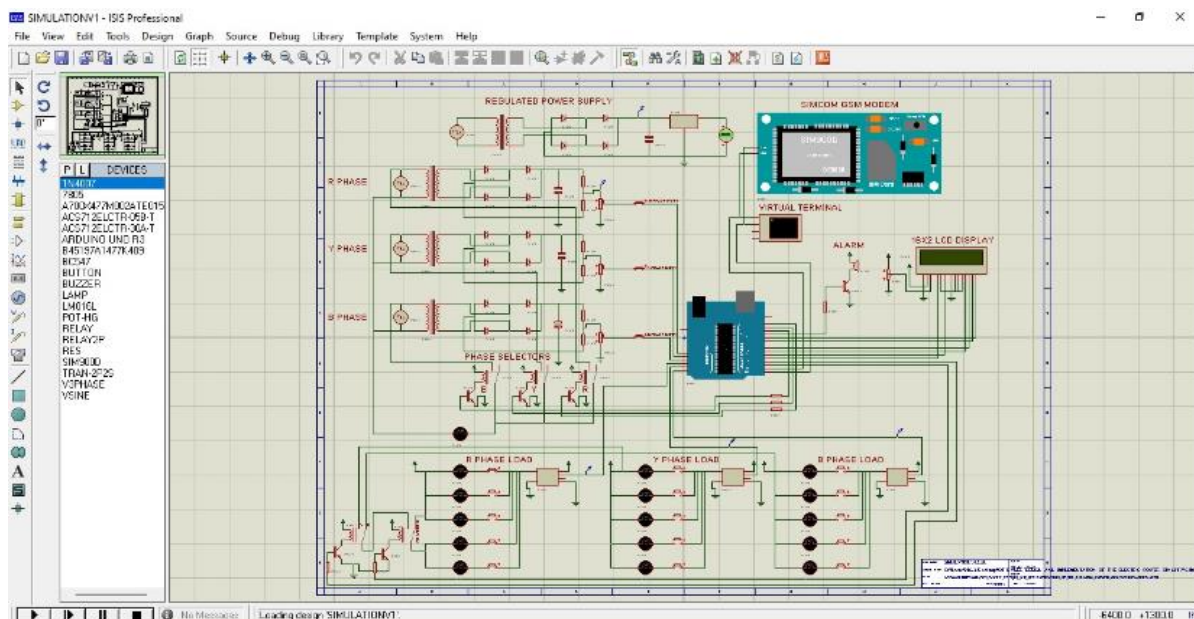


Fig. 3.1 Simulation Diagram of IOT based design & implementation of Power Quality Management System using Arduino

In this project we implemented & monitored the three cases of power quality issues are as follows:

Case-1: R Y B Phase Fault Sensor Activation Mode

Case-2: R to Y, R to B Phase Change over Relay

Case-3: Voltage Variations

These voltage variations are two types. They are

Voltage Swell

Voltage sag

CASE 1 - R Y B PHASE FAULT SENSOR ACTIVATION MODE:



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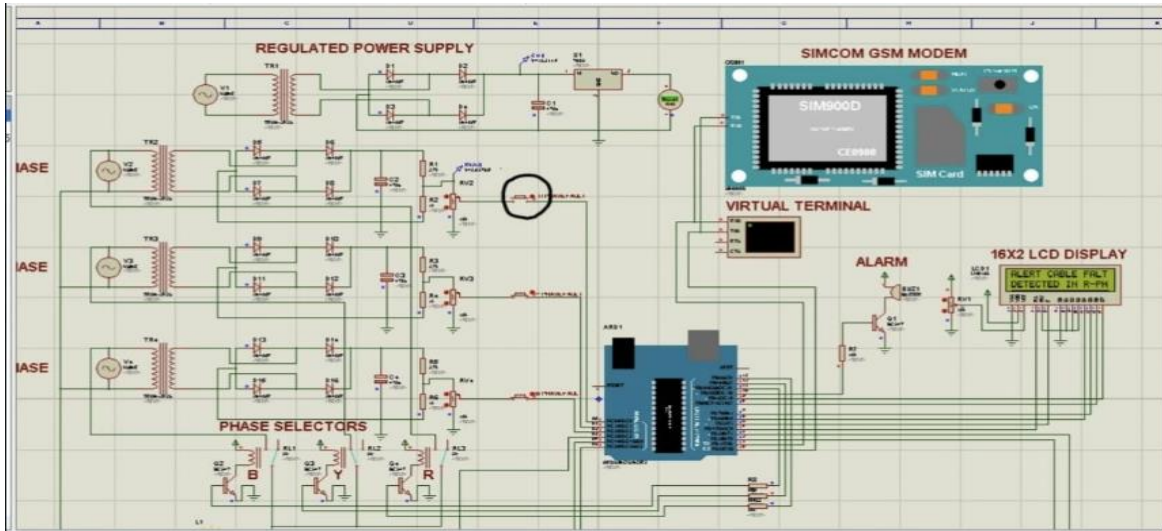


Fig. 3.2 R Phase Fault Sensor Activation Mode

In Case-1, if any fault or phase failures are occurred in any one line of R, Y and B Phases, the sensor will be activated automatically. It will give buzzer sound and also displayed in LCD Display it show alert cable fault detected in the respective faulted phase. In above fig. 3.2 we can observe that fault or phase failure occurred in R Phase, the sensor will be activated automatically. It will give buzzer sound and also displayed in LCD Display it show alert cable fault detected in R phase.

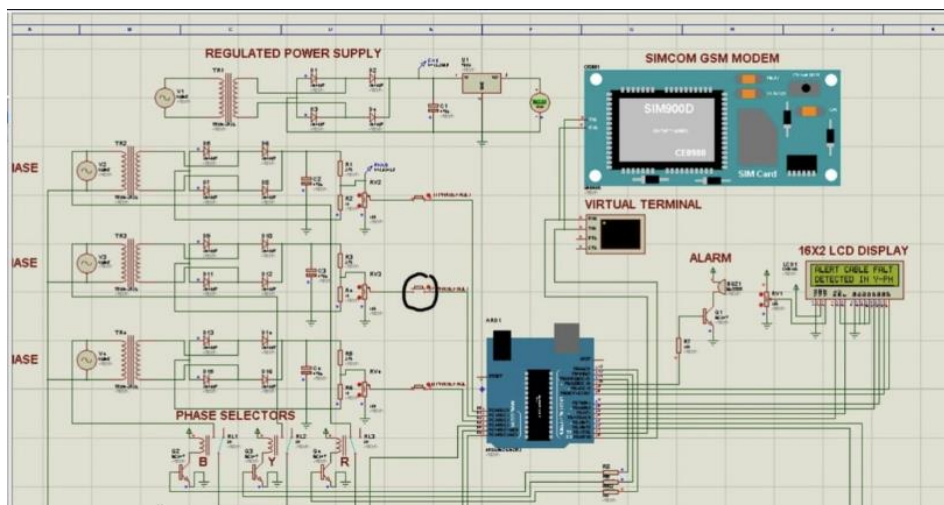


Fig. 3.3 Y Phase Fault Sensor Activation Mode

In above fig. 3.3 we can observe that fault or phase failure occurred in Y Phase, the sensor will be activated automatically. It will give buzzer sound and also displayed in LCD Display it show alert cable fault detected in the faulted Y phase.



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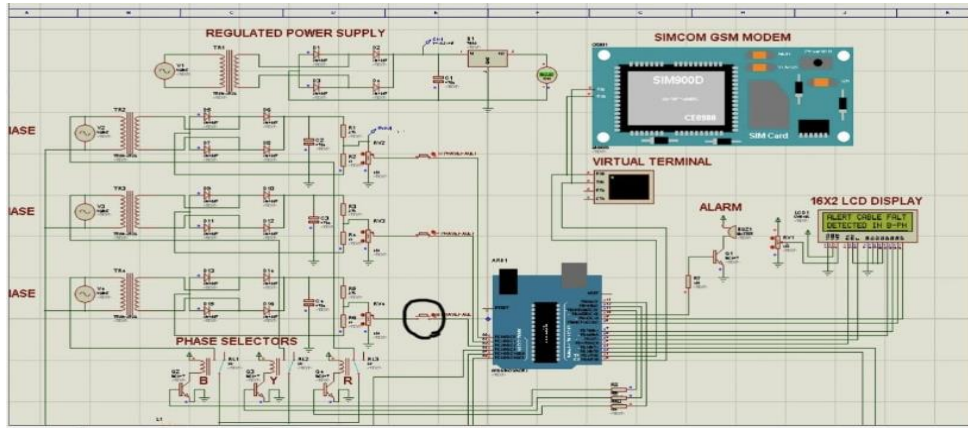


Fig. 3.4 B Phase Fault Sensor Activation Mode

In above fig. 3.4 we can observe that fault or phase failure occurred in B Phase, the sensor will be activated automatically. It will give buzzer sound and also displayed in LCD Display it show alert cable fault detected in the faulted B phase.

CASE 2 - R to B, R to Y PHASE CHANGE OVER RELAY:

When over load or fully load is applied on any phase of R, Y and B phases, then the fully loaded phase is disconnected it will changed to lightly loaded phase, which means the load balancing or load sharing will be takes places automatically. Also this is displayed in LCD display.

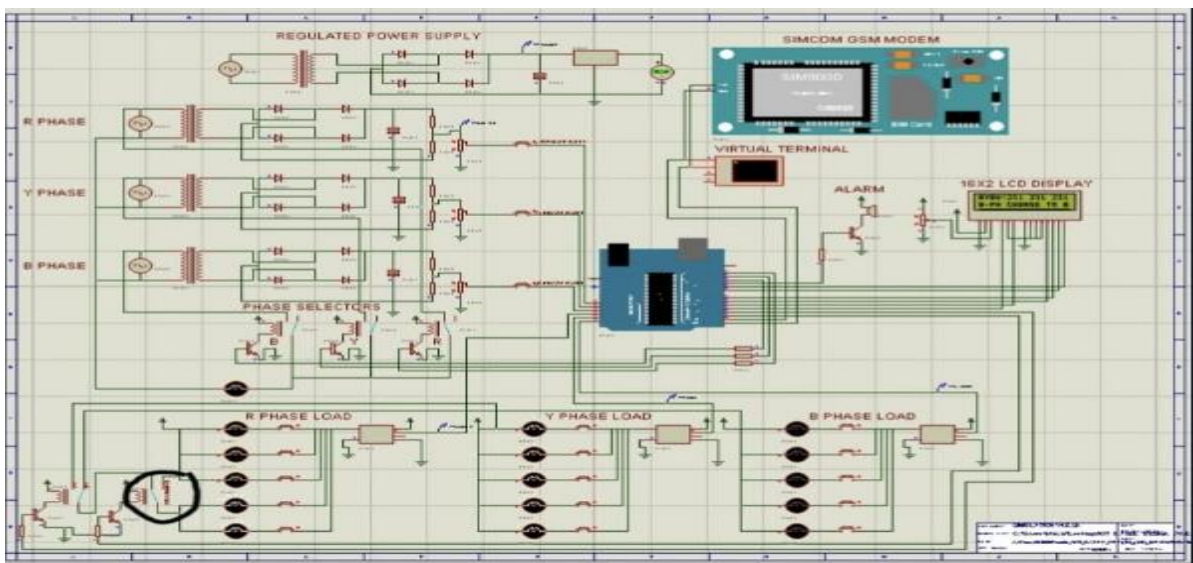


Fig. 3.5 R phase is fully loaded then it will changed from R to B Phase change relay

When R Phase is fully loaded and Y Phase or B Phase are low loaded then R Phase will automatically disconnected & phase is changed to low load phases. From the above fig. 3.5



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we can observe that R Phase is fully loaded and Y Phase is more loaded compared to B Phase, then the R Phase is automatically changes into B phase. In display also it will show R Phase changes to B.

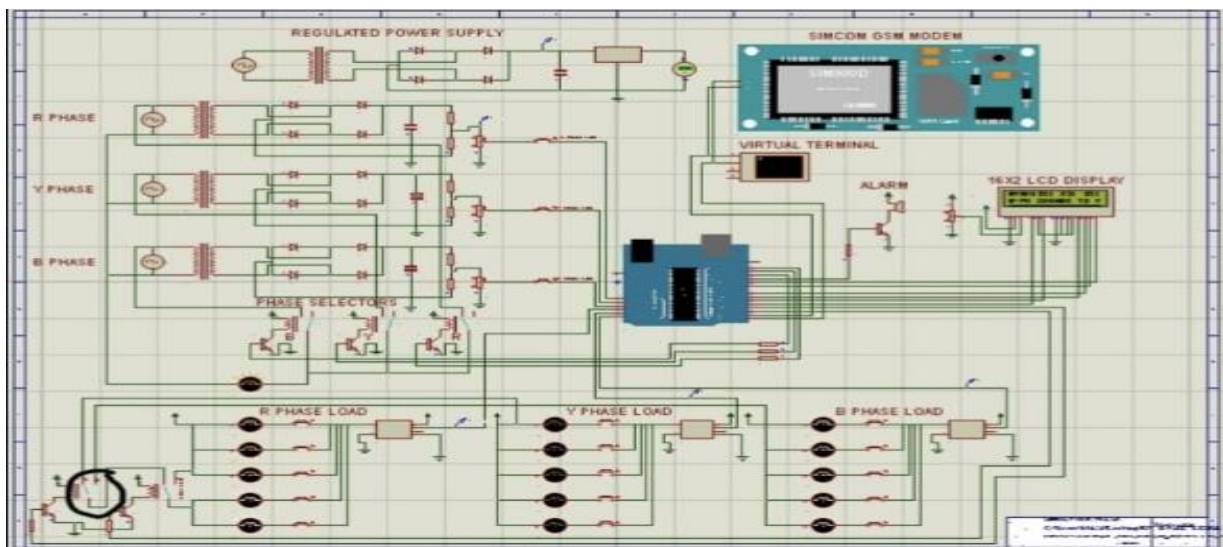


Fig. 3.6 R phase is fully loaded then it will changed from R to Y Phase change relay

When R Phase is fully loaded and Y Phase or B Phase are low loaded then R Phase will automatically change or connects to low load Phases. From the above fig. 3.6 we can observe that R Phase is fully loaded and B Phase is more loaded compared to Y Phase, then the R Phase is automatically changes into Y phase. In display also it will show R Phase changes to Y.

CASE 3 - VOLTAGE VARIATIONS (SWELL/SAG):

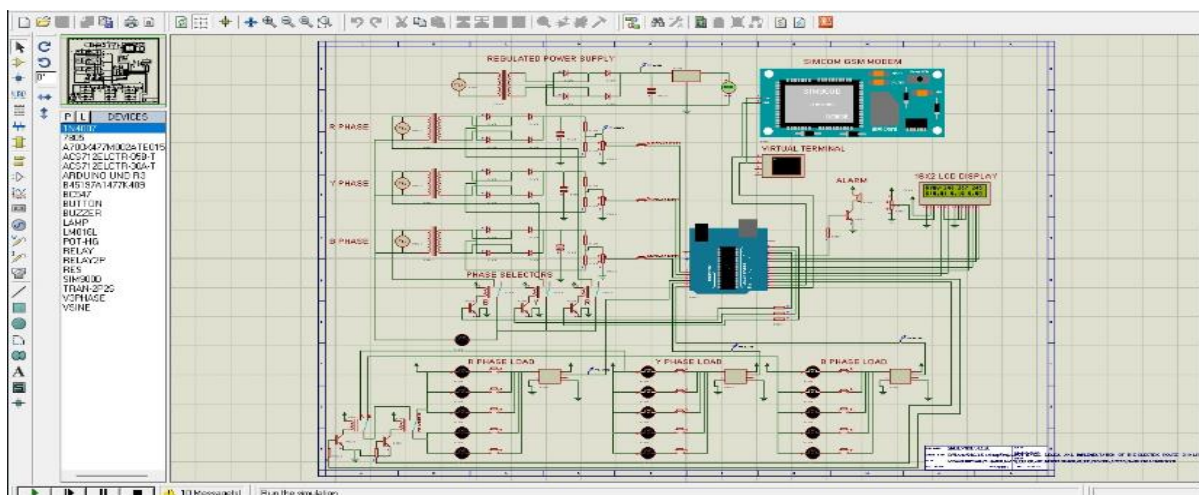
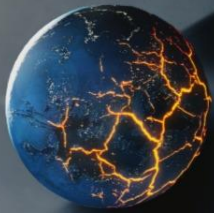


Fig. 3.7 Voltage Swell



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If the voltage is increase in any three phases the swell will be occurred. In these situations the equipment's will be damaged. When swells are occurred in circuit or network it shows the high voltage levels (i.e. more than normal supply voltage) in LCD Display as shown in above fig. 3.7.

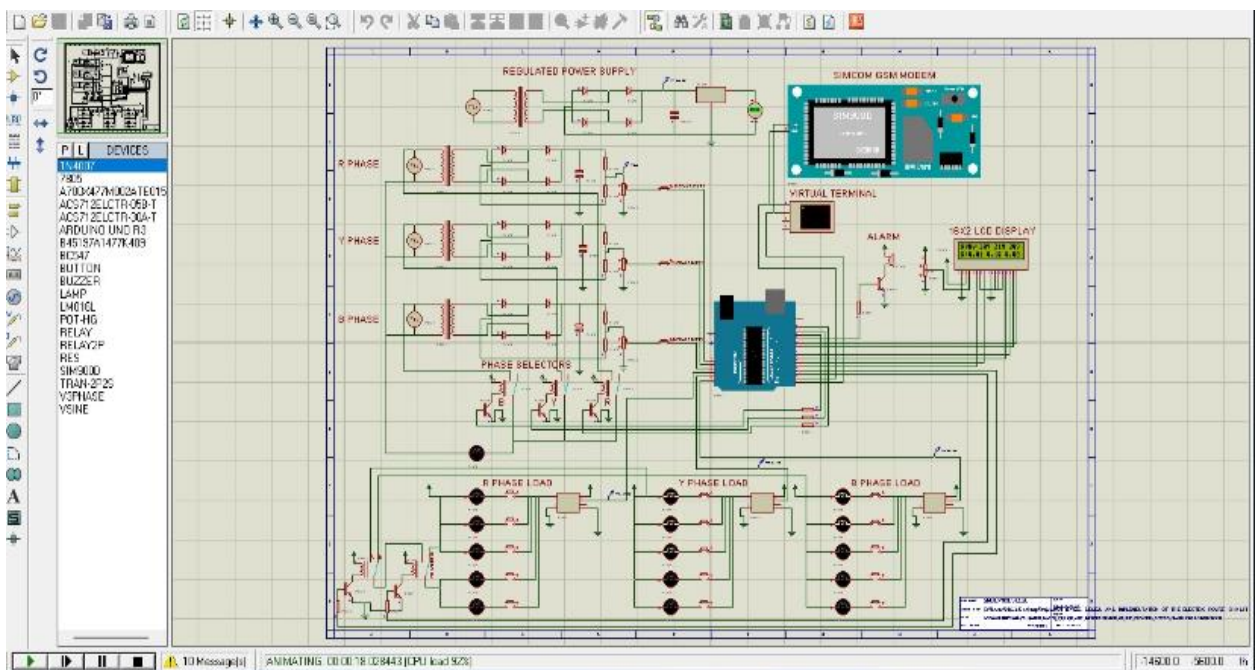


Fig. 3.8 Voltage Sag

If the voltage is decrease in any three phases the sag will be occurred. In this situations the equipment's will runs slow. When sags are occurred in any system it shows the low voltage levels (less than normal supply voltage) in LCD Display as shown in fig. 3.8.

4. Conclusion

IoT-based power quality management system using Arduino microcontroller represents a significant advancement in the field of power distribution and management. Through the integration of IoT technology, intelligent algorithms, and cloud-based logging, the system offers several key advantages over traditional power quality management systems. By providing real-time monitoring, automated anomaly detection, and adaptive response mechanisms, the proposed system enhances the reliability, efficiency, and resilience of electrical power distribution networks. Prompt detection of voltage fluctuations, sudden power failure, sudden load variation, and other power anomalies allows for proactive mitigation actions, reducing the risk of equipment damage and operational disruptions. Additionally, load balancing mechanisms optimize the distribution of electrical loads across phases and improving system performance.



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Cloud-based logging and IoT connectivity enable remote monitoring, analysis, and management of the power distribution system, facilitating proactive maintenance, troubleshooting, and performance optimization. This enhances scalability, flexibility, and accessibility, ensuring efficient power quality management applications. Overall, the proposed system offers a comprehensive and integrated solution for advanced electric power quality management, tending to the advancing needs and challenges of power distribution networks. With its advanced features, the system holds the potential to significantly improve the reliability, efficiency, and maintainability of electrical power distribution systems, contributing to a stronger and responsive energy infrastructure.

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