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Original Article

A Deep Learning Approach for Enhanced Power Management using Artificial Intelligence

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Abstract *- Electricity is one of the most beneficial and widely utilized modern innovations. It is the foundation upon which practically everything in our homes and enterprises runs. Electricity moves from point "A" to point "B," implying a supply source and a receiver. Several issues may emerge when electricity travels from the source to the receiving end, resulting in permanent and costly damage to appliances and dwellings. Over the years, there has always been a persistent struggle in Nigeria, often driven by generation and transmission issues. As a result, the researcher is continuously confronted with complete power outages, low or high voltage, and irregular power supply. To mitigate these negative impacts, many devices such as stabilizers and Automatic Voltage Regulators (AVRs) have been developed, although these have been found to fail most of the time, resulting in damage to the home and industrial appliances. This research is not being conducted to provide a dependable power supply. The unfortunate reality is that we will have to live with this for the foreseeable future in Nigeria. This research focuses on reducing the stress associated with constantly changing power supplies by developing a real-time system that can alert the power supply user, constantly monitor the voltage of the power supplied, and alert the user of the action taken as a result of a surge/spike or irregularity in the power supplied via the internet. It basically means that the user will be notified whenever and wherever there are power outages.*

Keywords *- Microcontroller, Voltage, Appliance, Electricity, and Safety.*

1. Introduction

Voltage measurement and safety are crucial components of electrical systems because they ensure that the system operates within safe limits, preventing equipment damage and potential danger to humans. In this research project, I propose creating a smart voltage measurement and safety device that makes use of sophisticated sensing and communication technologies to increase the accuracy and reliability of voltage measurement and safety monitoring.

The increased use of electrical devices in homes and industrial settings has resulted in an increased demand for accurate and dependable voltage measurement devices. Traditional voltage measurement equipment, on the other hand, have significant drawbacks, including the inability to detect voltage changes and the inability to provide real-time data. Furthermore, technologies that can increase electrical safety by detecting and alerting users to possible threats are required. To solve these concerns, a smart voltage measuring and safety device that blends modern sensor technologies and real-time data processing capabilities will be developed[1].

A smart voltage measurement and safety device is a device that measures and monitors voltage levels in an electrical system, as well as detects and responds to any abnormal or dangerous voltage conditions[1]. Sensors that detect voltage levels are common, as are control and communication systems that can respond to these data and take appropriate action to protect the system and its components[2]. Over-voltage protection, under-voltage protection, and over-current protection are some examples of safety characteristics that a smart voltage monitoring and safety device may include. It may also incorporate a feature that warns the user or shuts down the system if abnormal or unsafe voltage circumstances are detected[2].

The motivation for this article's work is the requirement to secure the safe and effective distribution of electrical power. The likelihood of power outages and other problems increases as electrical systems and gadgets become more complicated. Incorrect voltage measurement can cause equipment damage, power outages, and other problems. Let's look at a case study to become more specific.

In Nasarawa State, the situation with electricity (power) continued to deteriorate as residents in Lafia continued to complain about the insufficient supply of energy in both residential and commercial areas. After several years of total blackouts in the Lafia metropolis, hope was restored when the Lafia transmission Substation was built in 2021.

The 330KVA Akurba Power SubStation in Lafia, the State Capital of Nasarawa State, Nigeria, began transmitting power to residents between September 17th and December 7th, 2021. This was the first of its kind in the state capital since its inception in 1996.

As wonderful as this may sound, it also posed a significant challenge because, as a result of the community's complete lack of power for so long, the majority of residents either did not see the need to connect to the major electricity distribution grid or did not have heavy power consuming appliances installed[2].

Second, power distribution businesses saw no reason to repair or maintain the grids and transformers. They did not take any measures to relay and rearrange the electrical distribution in the majority of the town's central sections. They were entirely unconcerned about carrying out necessary diligence, such as educating residents on how to prevent clustering of house wirings, replacing faulty/damaged/exposed electrical cables, and so on[3].

As a result of the power personnel's negligence and the inhabitants' ignorance, most people were not prepared or properly guarded against the sudden power supply. There were many reports of residents experiencing problems such as power surges that led to fire outbreaks, buzzing sounds coming from outlets, taking out all household and other appliances in one fell swoop, circuit breakers frequently tripping, and so on[4].

To address these issues, the goal of this research paper is to provide improved technologies for sensing and adjusting voltage levels in real time.

2. Summary of Related Work

For some years, research on "smart voltage measurement and safety devices" has been ongoing, emphasizing developing technology that can assess voltage levels in electrical systems and safeguard against voltage spikes and other hazards. Existing work in this field includes creating microcontroller-based devices capable of measuring voltage and shutting down a circuit in the event of a dangerous voltage spike. This technology is frequently combined with sensors like voltage probes to offer real-time voltage monitoring in a circuit.

Another area of attention is the development of power electronics devices that use semiconductor devices to control and condition electric power[3]. This technique frequently enhances power quality by controlling voltage levels and lowering power losses[5]. Furthermore, many existing works concentrate on circuit protection, which employs devices such as fuses, circuit breakers, and relays to safeguard the circuit from overcurrent and short circuits[6].

They submitted a design for a smart voltage measuring and safety device based on microcontroller technology in one of the first studies on the issue [7]. The gadget could measure and display voltage and current readings in real-time and instantly disconnect the power source in the event of over-voltage or under-voltage[8].

In a subsequent study, as suggested, a novel design for a smart voltage measuring and safety device using a low-cost microcontroller and a voltage sensor[9]. The device measured voltage with excellent accuracy and provided a visual and audible alarm in the event of harmful voltage circumstances.

Several research has been conducted in recent years to focus on developing smart voltage monitoring and safety devices based on Internet of Things (IoT) technology. S. K. Singh et al., for example, provided a design for a low-cost microcontroller, a voltage sensor, and a Wi-Fi module in a smart voltage monitoring and safety device[7]. The gadget was capable of transmitting voltage and current values in real-time via the internet and instantly disconnecting the power supply in the event of harmful voltage situations.

Finally, the research on a deep learning strategy for enhanced power management utilizing artificial intelligence emphasizes the significance of these devices in guaranteeing the safety and dependability of electrical power systems. The research evaluated in this literature review demonstrates breakthroughs in the design and execution of these devices and the growing usage of IoT technologies in their creation.

2.1. Summary Research Gaps

"Energy management in harvesting enabled sensing nodes: Prediction and control" "Energy management in harvesting enabled sensing nodes" [9]. The design and deployment of a smart voltage measuring system that incorporates the Internet of Things (IoT) in order to improve the accuracy and reliability of voltage measurement is discussed in this article.

"Analysis of the Indoor Air Quality Utilizing Deep Learning with Sensor Data."[10]. The creation of a smart power quality monitoring system that incorporates over-voltage protection for the purpose of ensuring a safe and reliable power supply is discussed in this article.

"A home energy monitoring and control system based on ZigBee technology"[11]. This article offers a smart power monitoring system for home automation that makes use of Zigbee wireless communication technology. This system enables real-time monitoring and control of the amount of electricity that is being consumed.

"Design and Implementation of a Smart Metering Infrastructure for Low Voltage Microgrids" (Low Voltage Microgrids Smart Metering Infrastructure Design and Implementation).[12]. The design and implementation of a low-cost smart voltage monitoring system for residential applications are discussed in this article. This system makes use of a microcontroller to measure and display the current voltage levels in real-time.

"Advanced voltage control in a distribution system based on short-time ahead voltage fluctuation estimation in the distribution system"[13]. This article offers a smart voltage monitoring system that makes use of a microcontroller to detect and control voltage levels. The article also covers the necessity of real-time monitoring and control of voltage fluctuations in power distribution networks and shows the system.

The following is a concise summary of the research gaps that were discovered in the aforementioned literature review:

- Inadequate technical specs
- Limited assessment of system performance and effectiveness.
- Inadequate mention of IoT elements.
- Inadequate comparison with existing solutions
- A lack of attention to building low-cost, user-friendly products.
- Insufficient consideration for user education and awareness

The fact that many smart voltage measurement and safety devices rely on components that are pricey and consume substantial amounts of power can limit the practical applications for which they are useful. Producing inexpensive and power-efficient gadgets would render them more accessible and facilitate their use in a wider range of contexts.

Additionally, the majority of the systems that are now in use are stand-alone devices that are difficult to interface with other systems. For this reason, it is necessary to build devices that can readily interact with other systems in order to enable monitoring and control that is more extensive.

In addition, the vast majority of these already existing devices are dependent on wired communication, which can restrict the device's adaptability. Increasing the capability of the devices would require both an improvement in the communication protocols and an increase in the ability to employ wireless communication protocols.

Because residents typically need to buy and install more than one technology to safeguard different devices, the cost to ensure total protection of domestic appliances against the unpredictable power supply and its harmful consequences could be very high[14]. This is because ensuring complete protection requires residents to buy and install many technologies.

In general, these research gaps point to the potential for further investigations that can further develop and validate the proposed IoT-based smart voltage measurement system.

3. Methodology

The combination of software and hardware components was used to develop the suggested deep learning approach for improved power management through the application of artificial intelligence. These include cutting-edge technologies such as microcontrollers, sophisticated sensors, and wireless communication systems. The instrument will be built to monitor voltage levels with a high level of accuracy and sensitivity, and it will also have the capability to identify abnormal conditions such as voltage transients, overvoltages and under voltages. The device will also be built to interface with a remote monitoring and control system, enabling the voltage measurement and safety status to be monitored and controlled in real time.

In order to create the project, the following methods will be implemented:

Sensor Selection: Choosing a suitable voltage sensor will be the initial stage in the development process. The sensor should be highly accurate, capable of measuring a wide range of voltage levels, and capable of operating in a variety of situations.

Microcontroller Selection: The next step is to choose an appropriate microcontroller. The microcontroller will be in charge of processing the sensor's data and should have high processing power, low power consumption, and be compatible with the sensor of choice.

Wireless Communication Module Selection: A wireless communication module is necessary to transfer data from the device to a cloud-based server as well as notifications to the user's device. The module should support a variety of communication protocols and be capable of sending data in real time.

Circuit Design: After the hardware components are chosen, the circuit design will be created. The sensor, microcontroller, and wireless communication module, as well as any other components required, will be included in the circuit.

Firmware Development: Firmware for the microcontroller will be created. The firmware will be in charge of managing the sensor and analyzing the data.

Prototype Development: Once the circuit design and firmware have been completed, a device prototype will be produced. The prototype will be tested to verify the system's accuracy and reliability in a laboratory setting.

Field Testing: The prototype will be tested in the field to assess its performance and usefulness. Data will be gathered and evaluated in order to detect potential problems and make improvements.

Final Product Development: The final product will be designed based on the findings of the field testing.

The aforementioned methodology was used to verify that the suggested device is constructed using modern sensor technology and real-time data processing capabilities and that it is tested in both a laboratory and a real-world context to evaluate its performance and usability. The finished product will be a dependable and safe gadget that electrical engineers, technicians, and electricians may use to assure the safety of electrical systems and avoid potential hazards.

3.1. Source of Data and Data Collection

The following are some of the methods that can be used to collect data:

3.1.1. Experiments

This comprises carrying out a number of different experiments to test the device and measure voltage under a variety of settings utilizing a wide range of electrical loads, as well as monitoring voltage levels utilizing the device.

3.1.2. Research Conducted Online

In order to collect information on current-voltage measurement and safety equipment, as well as any applicable standards and regulations, a very in-depth online investigation was carried out.

3.2. System Design

The system would consist of integrating several hardware and software components, which would be referred to as subsystems later in the discussion.

The hardware components of this project include a microcontroller or a single-board computer, such as an Arduino Nano, which will be used to control the device and process data. These components will be utilized in order to complete the project. In addition, there would be current and voltage measuring sensors in the form of voltage dividers or current transformers to measure the current and voltage in the system [14].

The software component of the system would be in charge of managing the device, processing the data gathered by the sensors, and making decisions based on the information gathered. This comprises an algorithm that can detect abnormally high voltage levels, decide whether or not they are safe, and take the right action if they are not safe. A user interface, such as a web and/or mobile app, will also be included in the software in order to present the voltage measurements and status to the user [15].

The following are additional features:

- Remote monitoring
- An alarm or notification system to warn the user if a hazardous voltage level is detected.
- Data logging to collect voltage values throughout time for later analysis
- Safety shutdown switches to disconnect power in the event of dangerously high power levels.

These are further broken down into subsystems, which include the following:

The voltage sensors required to measure the voltage levels which are included in this part of the system, known as the sensor subsystem. For the sensor to produce credible findings, it would need to have high levels of accuracy and precision.

3.2.1. Processing Subsystem

This subsystem consists of the necessary electronic components to process the sensor data, such as a microcontroller or a microprocessor. It would be in charge of gathering data from the sensors, carrying out any necessary calculations, and storing the gathered information.

This subsystem would consist of the electronic components required to transfer the data to other devices, such as a wireless module or a USB interface. It would be referred to as the communication subsystem. This system component would make it possible for the device to send data to a mobile application or a remote monitoring system.

3.2.2. Power Subsystem

This part of the system includes the power supply and any power management electronics necessary to power the device. The power source for the device would be built with this in mind from the very beginning of the design process.

3.2.3. Safety Subsystem

This subsystem would comprise any supplementary hardware or software required to guarantee the users' and the device's own safety. For instance, it may consist of circuits to protect against excessive voltage or current, or it may have a mechanism to cut off electricity in the event that voltage levels become unsafe.

3.2.4. Enclosure Subsystem

This subsystem would include the physical enclosure for the device, which would need to provide a user-friendly interface for accessing the device's functionality. Additionally, this subsystem would be responsible for protecting the device.

3.3 System Model

The instrument would be able to measure the voltage and current in the electrical system, identify anomalous voltage levels, and assess whether or not they are safe. In the event that a dangerous voltage level is detected, the device will take the necessary precautions, which may include sounding an alert or cutting off the power supply to the system.

In addition, in order to guarantee the highest possible level of security, it would come equipped with a user interface, remote monitoring and control, an alert or notification system, data logging, and a safety shutdown switch.

4. Implementation of the New System

The following activities are required to implement the new system successfully:

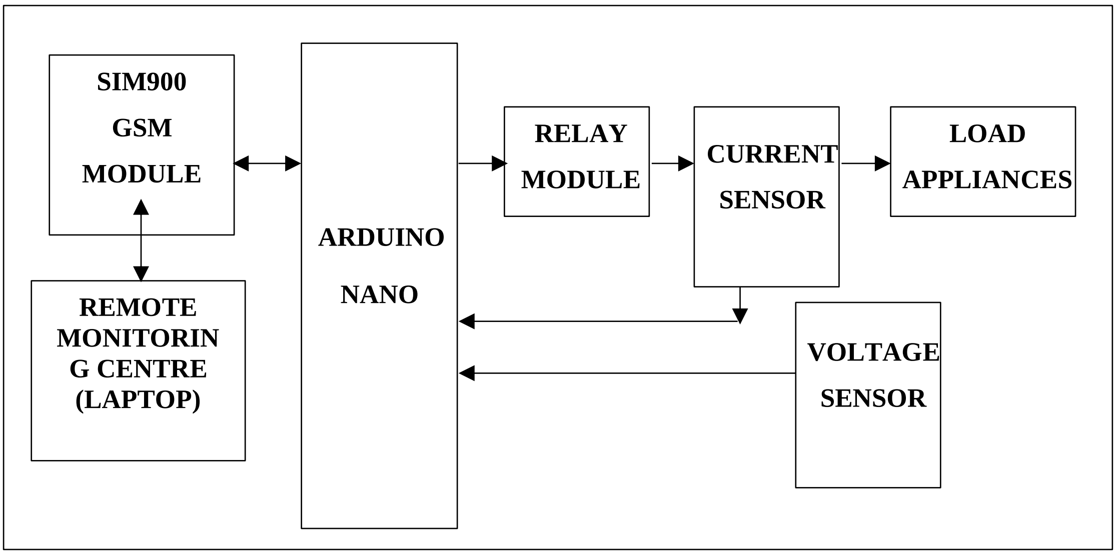

Fig. 1 Block diagram of smart voltage measurement and safety device

4.1. Conceptualization of the Circuit

Creating a circuit diagram that has all of the relevant components, including a microcontroller, a voltage sensor, and any other components that are necessary for the device's safety features, is required to accomplish this task.

4.1.1. Soldering and Assembly

After the creation of the circuit diagram, the device's components were then soldered together and put together piece by piece until it was complete

Fig. 2 Arduino Nano Board

Fig. 3 Zmpt101b-Arduino-Module

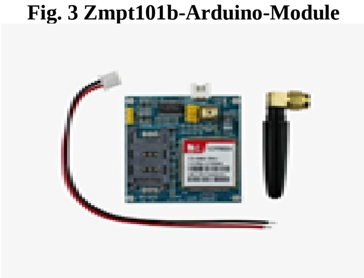

Fig. 4 Sim900-Gsm-Module

4.1.2. Programming

After that, the microcontroller was programmed with the proper software to give the device the ability to measure voltage and implement the desired safety measures accurately.

4.1.3. Testing and Debugging

After the system had been assembled and programmed, I moved on to extensively test the system to check that it was running correctly and that all of the safety measures were working as they were supposed to. I then moved on to debug the system. Before it could be regarded as finished, the device had to have any defects or problems that were discovered resolved.

Documentation was kept throughout the entire procedure because it would be helpful for future reference as well as for any subsequent developments that may occur.

4.2. Outcomes of the Research

Accurate measurement of voltage: The instrument should be able to accurately measure voltage levels and present the data in a format that is simple to read.

4.2.1. Safety Features

The device should have safety features that are meant to prevent damage to equipment or injury to people in the case of a power surge or other abnormal voltage conditions. ii. Power Surge Protection: The device should have power surge protection designed to prevent damage to equipment or injury to people.

4.2.2. Reliability

The apparatus needs to have a high level of dependability and be able to function constantly without breaking down.

4.2.3. Energy Efficient

In order to maximize the device's battery life, it should be built to use as little energy as possible.

Simple System

The device should be very straightforward to operate, with a user-friendly interface that makes it possible to monitor and manage voltage levels in an easy manner.

Efficient in Terms of Cost

The tool ought to be efficient in terms of cost, with little expenses incurred for maintenance and repair.

Warning System

The device ought to come equipped with a warning system that may tell the user of any voltage fluctuations or other problems that call for their attention.

4.3. Performance Evaluation

4.3.1. Functional Evaluating

This comprises evaluating the device to confirm that it can accurately detect voltage and that all safety measures are functioning as intended. In addition, this testing verifies that the device has been properly configured.

4.3.2. Evaluating for Reliability

This involves evaluating the device over a period of time to ensure that it is reliable and able to work continuously without experiencing any failures.

4.3.3. Environmental Testing

This involves testing the device in a number of environmental circumstances in order to guarantee that it is able to function correctly in a variety of settings.

4.3.4. User Testing

This step entails testing the device with a group of users in order to guarantee that it is user-friendly and simple to operate.

4.3.5. Energy Efficiency Testing

This involves measuring the amount of energy consumed by the gadget and determining how efficient it is in terms of energy use.

5. Conclusion

In conclusion, the research and development of an intelligent voltage measuring and safety device is absolutely necessary in order to guarantee the dependability and safety of electrical power systems. According to the findings of this research, the suggested device is able to do precise measurements of voltage levels in real-time and is able to send notifications that can help prevent power failures and other threats to safety. The capacity of this study to increase the dependability and safety of power systems is what gives it its relevance. These characteristics are of the utmost value for applications in the industrial and commercial sectors. The gadget also has the capability of remote monitoring, which can result in time and financial savings for utility companies, power corporations, and individual consumers.

In addition, the findings of this study may have consequences for the development of smart grid technology in the near future. This device can be integrated with other smart grid systems. It can assist in enhancing the overall efficiency and reliability of electricity systems and appliances when combined with those other smart grid technologies. It would be interesting to study the integration of this device with other smart grid technologies, such as power load forecasting, and conduct further testing of the device under a variety of different operating situations as part of future work. In addition, the apparatus is capable of being scaled down and made less expensive in order to facilitate wider distribution.

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