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Research Paper

IOT-BASED POWER OUTAGE DETECTION AND ALERT SYSTEM USING GSM

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ABSTRACT

Power outages can disrupt daily life, damage appliances, and lead to financial losses if not detected and addressed promptly. This project proposes an **IoT-based power outage detection and alert system** using **Arduino and GSM technology** to monitor electricity supply in real-time and notify users via SMS when a power failure occurs.

The system consists of an **Arduino microcontroller** connected to a **voltage sensor** to detect the presence or absence of AC mains power. When a power outage is detected, the system triggers a **GSM module (SIM800/900)** to send an SMS alert to predefined mobile numbers. Additionally, the system logs outage events and can be integrated with IoT platforms for remote monitoring and historical data analysis.

Key Features:

- **Real-time power monitoring** using a voltage sensor.
- **Instant SMS alerts** via GSM when power fails.
- **Low-cost and energy-efficient** design using Arduino.
- **Expandable** for integration with IoT dashboards (e.g., Blynk, ThingSpeak).
- **Battery backup** to ensure functionality during outages.

This system provides a **reliable and automated solution** for homes, industries, and critical infrastructure to mitigate the impact of unexpected power failures.

Keywords: *IoT, Arduino, GSM, Power Outage Detection, SMS Alert, Voltage Sensor*

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I. INTRODUCTION

The continuous availability of electrical power is a fundamental requirement for modern society. Electricity powers households, industries, healthcare facilities, transportation networks, and communication infrastructures. Any disruption in its supply—commonly referred to as a power outage or blackout—can have serious consequences, ranging from inconvenience to critical safety hazards and substantial economic losses. In many regions, particularly in developing countries, power outages are frequent due to inadequate infrastructure, natural disasters, equipment failures, or load-shedding practices. Even in developed nations, extreme weather events, grid instability, or accidental faults can lead to sudden interruptions in power supply. This universal vulnerability highlights the need for reliable systems that can detect outages promptly, provide immediate notifications, and facilitate rapid responses to minimize associated risks.

In residential settings, unexpected power failures can cause food spoilage, disruption of essential appliances, and security system downtime. Industrial and commercial environments face even greater stakes; an unmonitored power outage may halt production processes, damage sensitive machinery, and cause financial losses that escalate with each minute of downtime. Critical infrastructures—such as hospitals, data centers, and transportation hubs—are particularly susceptible, as they rely heavily on uninterrupted electricity to maintain life-saving equipment, patient monitoring systems, and essential services. Consequently, a proactive power outage detection and alert mechanism is not merely a convenience but a necessity in ensuring safety, operational continuity, and economic stability.

Traditional approaches to monitoring power availability have relied largely on manual observation or periodic checks, which are inefficient and incapable of providing real-time notifications. In many cases, individuals or organizations become aware of outages only after experiencing their effects, leading to delays in initiating backup solutions like generators or alternative energy sources. This delay can be detrimental in environments where even brief interruptions are unacceptable. Therefore, there is a pressing need for automated systems capable of continuously monitoring power status, instantly detecting failures, and notifying users or maintenance personnel without requiring human intervention.

The rapid advancement of the Internet of Things (IoT) has created new opportunities for addressing these challenges. IoT refers to a network of interconnected devices that collect, transmit, and process data from the physical world, enabling intelligent decision-making and automation. By integrating IoT principles into power monitoring systems, it is possible to achieve real-time detection, remote accessibility, data logging, and even predictive analytics to identify patterns that may lead to future outages. IoT-based solutions are cost-effective, scalable, and versatile, making them suitable for a wide range of applications—from small households to large industrial complexes.

In the context of power outage detection, an IoT-enabled device typically includes sensors to measure voltage or current, a microcontroller to process the data, and a communication module to transmit alerts to end users. Among various communication technologies, GSM (Global System for Mobile Communications) stands out due to its wide coverage, reliability, and ability to function in areas lacking Wi-Fi or broadband connectivity. GSM modules allow systems to send Short Message Service (SMS) alerts directly to mobile phones, ensuring that users are promptly informed regardless of their location. Unlike internet-based notifications, which may be disrupted during network failures caused by the same outage, GSM remains operational as long as the cellular network is active. This makes GSM an ideal choice for power outage alert systems in both urban and rural settings.

The proposed IoT-based power outage detection and alert system using GSM leverages a simple yet effective architecture to meet these needs. At its core, a voltage sensor continuously monitors the status of the AC mains supply. When power is present, the system remains idle; when power is lost, the voltage sensor detects the absence of electrical input and immediately signals an Arduino microcontroller. The microcontroller processes this information and triggers a GSM module to send SMS notifications to one or more predefined phone numbers. To ensure that the system itself remains operational during an outage, it is powered by a battery backup. This approach guarantees that even in the absence of grid electricity, the detection and communication functions continue without interruption.

Beyond immediate notification, IoT integration allows for additional functionalities that extend the utility of the system. For instance, the device can log historical outage data, including the frequency, duration, and timing of each event. Such data can be transmitted to cloud-based IoT platforms like Blynk or ThingSpeak, enabling users to analyze patterns, evaluate the reliability of their power supply, and make informed decisions regarding backup power solutions. Over time, data-driven insights can help utility providers identify weak points in the distribution network, prioritize infrastructure upgrades, and improve overall service quality.

Another significant advantage of IoT-based monitoring is scalability. A single household may require only one detection unit, while larger facilities—such as hospitals, campuses, or industrial plants—may deploy multiple devices across different power circuits or buildings. These devices can be centrally managed, creating a networked system that provides comprehensive visibility into the entire electrical infrastructure. Furthermore, integration with existing automation frameworks can allow the system not only to notify users but also to automatically activate backup generators, switch to renewable energy sources, or shut down sensitive equipment safely when an outage is detected.

Despite its clear benefits, the implementation of such systems faces certain technical and practical considerations. These include ensuring low energy consumption to maximize battery life, protecting the system from electrical surges or sensor faults, and securing communication channels against unauthorized access. Cost optimization is also critical for making the technology accessible to a broad user base, particularly in rural or resource-limited regions where power outages are more frequent but financial resources may be constrained. Addressing these challenges requires careful design, component selection, and testing to balance reliability, affordability, and ease of use.

In summary, the increasing dependence on electricity in modern society underscores the importance of proactive outage detection and notification systems. Traditional manual methods are insufficient in meeting the demands of real-time monitoring, while IoT-based solutions offer a powerful alternative by combining sensor technology, microcontroller processing, and GSM-based communication. The proposed IoT-powered power outage detection and alert system represents an automated, low-cost, and efficient approach to safeguarding homes, industries, and critical infrastructures from the adverse effects of unexpected power failures. By delivering instant SMS alerts and enabling integration with data analytics platforms, this system contributes not only to immediate response and risk mitigation but also to long-term improvements in energy management and reliability.

Overview of Power Outages and Their Impact

Power outages are a common occurrence in both developed and developing countries, often caused by factors such as extreme weather conditions, equipment failures, grid overloads, or maintenance activities. These disruptions can have severe consequences, including:

- **Economic Losses:** Businesses and industries rely heavily on uninterrupted power supply. Outages can halt production, damage sensitive equipment, and lead to significant financial losses.
- **Household Inconvenience:** Homes depend on electricity for lighting, heating, cooling, and powering essential appliances. Prolonged outages can disrupt daily life and even pose health risks in extreme temperatures.
- **Critical Infrastructure Risks:** Hospitals, data centers, and emergency services require constant power. Failures can endanger lives and compromise critical operations.

Given these challenges, there is a growing need for **real-time power outage detection and alert systems** that can promptly notify users and authorities, enabling swift corrective actions.

Evolution of Power Monitoring Systems

Traditional power outage detection methods often rely on manual reporting or delayed notifications from utility companies. However, advancements in **Internet of Things (IoT)** and **wireless communication technologies** have revolutionized this field. Modern systems now offer:

- **Automated Detection:** Using sensors to monitor voltage levels in real-time.
- **Instant Alerts:** Leveraging GSM (Global System for Mobile Communications) to send SMS notifications the moment an outage occurs.
- **Remote Monitoring:** Integration with IoT platforms for data logging and analysis.

II. LITERATURE SURVEY

1. Sathish Kumar D, Dinesh C, Hariharan U, Kamalakkumar S (2022)

Title: *IoT Based Three Phase Power Monitoring and Failure Using SMS Alerts*

Conference: ITSPWC 2022, EAI

Abstract: This system detects a 'single phasing' event (loss of one of three phases R/Y/B) due to lightning strikes, broken lines, or mechanical faults. It displays the voltage on an LCD and sends SMS alerts via GSM to authorized personnel about phase failure and restoration. Notification continues via text on power restoration.

2. Leoderic P. Serami & Thelma Palaoag (2020)

Title: *Innovative Power Outage Detection Model for Electric Power Monitoring System*

Journal: *Test Engineering & Management*, Vol. 83, Mar/Apr 2020

Abstract: Proposes a Power Outage Detection Model (PODM) for electric cooperatives in remote areas using IoT, AI, cloud computing, LoRa RF and mesh-networked sensor nodes. Designed to help administrators detect outage locations and support decision-making through improved communication tech.

3. L. R. Prade, V. A. Uberti, A. R. Abaide, P. R. S. Pereira, R. M. de Figueiredo & C. B. Both (2020)

Title: *LoRa Mesh Architecture for Automation of Rural Electricity Distribution Networks*

Journal: *Electronics Letters*, 9 July 2020

Abstract: Presents a communication architecture for rural smart grids using LoRa mesh topology with packet prioritization and MIMO. Demonstrates low-latency, reliable routing suitable for DNP3/Modbus over rural distribution networks. It's more deployable and cost-effective than LPWAN or cellular alternatives.

4. Mauricio C. Tomé, Pedro H. J. Nardelli & Hirley Alves (2018)

Title: *Long-range Low-power Wireless Networks and Sampling Strategies in Electricity Metering*

Platform: arXiv (Mar 2018)

Abstract: Investigates the use of LoRa for smart-metering communications, comparing time-based vs event-based sampling strategies. Studies interference impacts on outage probability and link bitrate, and assesses gateway range for reliable signal reconstruction. Though focused on metering, it underscores LoRa's suitability for outage/timeseries monitoring.

5. Xiaofan Jiang, Heng Zhang, Edgardo A. Barsallo Yi, Nithin Raghunathan, Charilaos Mousoulis, Somali Chaterji, Dimitrios Peroulis, Ali Shakouri & Saurabh Bagchi (2020)

Title: *Hybrid Low-Power Wide-Area Mesh Network for IoT Applications*

Platform: arXiv, June 2020

Abstract: Proposes a hybrid LPWAN combining LoRa (long-range radio) and ANT (ultra-low-power short-range) in a mesh for wide-area IoT, enhancing coverage and reducing energy. Real-world deployment across campus and farm demonstrates benefits over standard LPWAN. Valuable architecture reference for scalable outage sensing systems.

III. EXISTING SYSTEM AND PROPOSED SYSTEM

Existing System

Current power outage monitoring solutions often include:

1. **Manual reporting methods** – Users notice an outage and report it to utility providers.
2. **Basic alarm circuits** – Some use simple relays or LEDs to indicate a power loss locally.
3. **Utility-side monitoring (SCADA systems)** – Large grids employ

SCADA, but these are costly and primarily focused on transmission/distribution networks rather than individual homes or small facilities.

4. **Smart meters with data logging** – They can record outages but often lack instant user notification (unless integrated with advanced utility platforms).

Disadvantages of Existing Systems

- **Delayed Response:** Manual reporting leads to slower outage recovery.
- **No Instant Alerts to End Users:** Basic detection circuits do not notify users remotely.
- **High Cost & Complexity:** SCADA systems are expensive and not suitable for small-scale deployment.
- **Limited Coverage:** Internet-based systems fail in regions with poor connectivity or during network failures.
- **No Predictive Capability:** Most current systems only detect outages after they occur; they don't analyze trends or predict failures.
- **Lack of Data Analytics:** Outage events are often not stored or analyzed for reliability indices (e.g., SAIDI, CAIDI).

PROPOSED SYSTEM

The proposed system is an **IoT-based power outage detection and alert mechanism using Arduino and GSM**:

- **Real-time voltage sensing** detects outages instantly.
- **Arduino microcontroller** processes sensor input and triggers alerts.
- **GSM module** sends SMS notifications to pre-registered mobile numbers.
- **Battery backup** ensures continued operation during power failures.
- **Optional IoT cloud integration** (e.g., Blynk, ThingSpeak) logs historical outage data for analysis.

Advantages of Proposed System

1. **Instant Alerts Anywhere:** Uses GSM SMS, which works even when Wi-Fi or broadband fail.
2. **Low Cost & Easy Deployment:** Arduino + GSM design is inexpensive and suitable for homes, offices, or rural areas.
3. **Independent Operation:** Built-in battery backup ensures continuous functionality.
4. **Scalable & Flexible:** Can be expanded to multi-phase detection, data logging, or industrial monitoring.
5. **Improved Reliability Indices:** Historical data helps utilities and users understand outage patterns.
6. **No Need for Internet:** GSM works in remote areas where broadband IoT solutions are unreliable.
7. **Potential for Automation:** Could be integrated to trigger backup generators or alert maintenance teams automatically.

IV. DESIGN OF HARDWARE

This chapter briefly explains about the Hardware implementation of authentication of Arduino based smart parking system. It discuss the circuit diagram of each module in detail.

ARDUINO UNO

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. Uno board has a resistor pulling the 8U2 HWB

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line to ground, making it easier to put into DFU mode.Arduino board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Fig: ARDUINO UNO

MAX232 IC:

Max232 IC is a specialized circuit which makes standard voltages as required by RS232 standards. This IC provides best noise rejection and very reliable against discharges and short circuits. MAX232 IC chips are commonly referred to as line drivers.

To ensure data transfer between PC and microcontroller, the baud rate and voltage levels of Microcontroller and PC should be the same. The voltage levels of microcontroller are logic1 and logic 0 i.e., logic 1 is +5V and logic 0 is 0V. But for PC, RS232 voltage levels are considered and they are: logic 1 is taken as -3V to -25V and logic 0 as +3V to +25V. So, in order to equal these voltage levels, MAX232 IC is used. Thus this IC converts RS232 voltage levels to microcontroller voltage levels and vice versa.

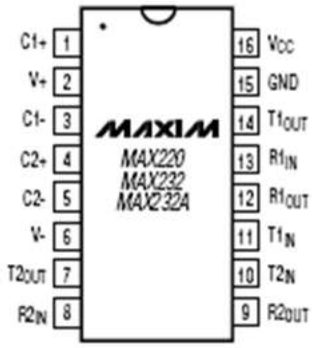


Fig:4.3 Pin diagram of MAX232 IC

POWER SUPPLY

The power supplies are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function. A d.c power supply which maintains the output voltage constant irrespective of a.c mains fluctuations or load variations is known as "Regulated D.C Power Supply".

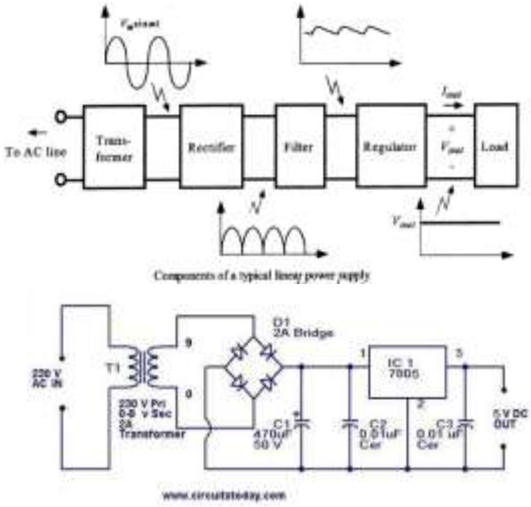


Fig: Schematic Diagram of Power Supply

TRANSFORMER:

A transformer is an electrical device which is used to convert electrical power from one Electrical circuit to another without change in frequency.

When AC is applied to the primary winding of the power transformer it can either be stepped down or up depending on the value of DC needed. In our circuit the transformer of 230v/12-0-12v is used to perform the step down operation where a 230V AC appears as 12V AC across the secondary winding.

RECTIFIER:

A circuit which is used to convert a.c to dc is known as RECTIFIER. The process of conversion a.c to d.c is called "rectification.

Bridge Rectifier:

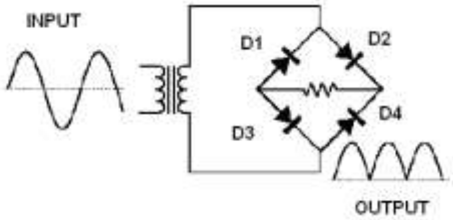


Fig: 4.6 Bridge Rectifier

LED:

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated.[5] When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electroluminescence, and the color of the light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm^2) and integrated optical components may be used to shape the radiation pattern.

Appearing as practical electronic components in 1962, the earliest LEDs emitted low-intensity infrared light.[7] Infrared LEDs are still frequently used as transmitting elements in remote-control circuits, such as those in remote controls for a wide variety of consumer electronics. The first visible-light LEDs were also of low intensity and limited to red. Modern LEDs are available across the visible, ultraviolet,

and infrared wavelengths, with very high brightness.

GSM

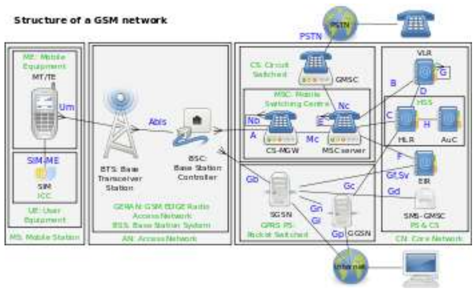
The **Global System for Mobile Communications** (**GSM**) is a standard developed by the European Telecommunications Standards Institute(ETSI) to describe the protocols for second-generation (2G) digital cellular networks used by mobile devices such as mobile phones and tablets. It was first deployed in Finland in December 1991.[2]By the mid-2010s, it became a global standard for mobile communications achieving over 90% market share, and operating in over 193 countries and territories.[3]

2G networks developed as a replacement for first generation (1G) analog cellular networks. The GSM standard originally described a digital, circuit-switched network optimized for full duplex voice telephony. This expanded over time to include data communications, first by circuit-switched transport, then by packet data transport via General Packet Radio Service (GPRS), and Enhanced Data Rates for GSM Evolution(EDGE).

Subsequently, the 3GPP developed third-generation (3G) UMTS standards, followed by fourth-generation (4G) LTE Advanced standards, which do not form part of the ETSI GSM standard.

"GSM" is a trade mark owned by the GSM Association. It may also refer to the (initially) most common voice codec used, Full Rate.

Technical details



The structure of a GSM network

BUZZER

What is a Buzzer : Working & Its Applications

There are many ways to communicate between the user and a product. One of the best ways is audio communication using a buzzer IC. So during the design process, understanding some technologies with configurations is very helpful. So, this article discusses an overview of an audio signaling device like a beeper or a buzzer and its working with applications.

What is a Buzzer?

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

Buzzer Pin Configuration

VOLTAGE SENSOR:

This module is based on resistance points pressure principle, and it can make the input voltage of red terminal reduce 5 times of original voltage.The max Arduino analog input voltage is 5 V, so the input voltage of this module should be not more than 5 V x 5 = 25 V (if for 3.3 V system, the input voltage should be not more than 3.3 V x 5 = 16.5 V).Because the Arduino AVR chip have 10 bit AD, so this module simulation resolution is 0.00489 V (5 V / 1023), and the input voltage of this module should be more than 0.00489 V x 5 = 0.02445 V.

Features

- Voltage input range : **0-25 V DC**
- Voltage detection range : **DC0.02445 V-25 V**
- Voltage analog resolution : **0.00489 V**
- Operating voltage output : **3.3V – 5V MAX**
- 100% Arduino Compatible

Voltage sensor

RELAYS

What is a relay?

We know that most of the high end industrial application devices have relays for their effective working. Relays are simple switches which are operated both electrically and mechanically. Relays consist of a n electromagnet and also a set of contacts. The switching mechanism is carried out with the help of the electromagnet. There are also other operating principles for its working. But they differ according to their applications. Most of the devices have the application of relays.

Why is a relay used?

The main operation of a relay comes in places where only a low-power signal can be used to control a circuit. It is also used in places where only one signal can be used to control a lot of circuits. The application of relays started during the invention of telephones. They played an important role in switching calls in telephone exchanges. They were also used in long distance telegraphy. They were used to switch the signal coming from one source to another destination.

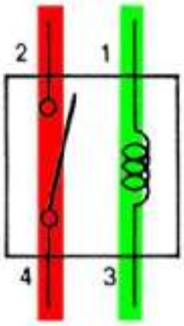
Relay Design

There are only four main parts in a relay. They are

- Electromagnet
- Movable Armature
- Switch point contacts
- Spring

Relay Basics

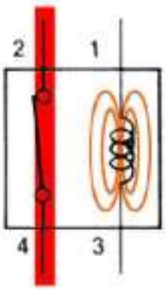
The basics for all the relays are the same. Take a look at a 4 – pin relay shown below. There are two colours shown. The green colour represents the control circuit and the red colour represents the load circuit. A small control coil is connected onto the control circuit. A switch is connected to the load. This switch is controlled by the coil in the control circuit. Now let us take the different steps that occour in a relay.



relay operation

- **Energized Relay (ON)**

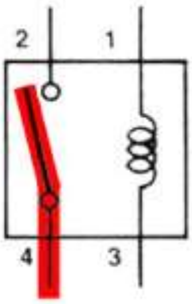
As shown in the circuit, the current flowing through the coils represented by pins 1 and 3 causes a magnetic field to be aroused. This magnetic field causes the closing of the pins 2 and 4. Thus the switch plays an important role in the relay working. As it is a part of the load circuit, it is used to control an electrical circuit that is connected to it. Thus, when the relay in energized the current flow will be through the pins 2 and 4.



Energized Relay (ON)

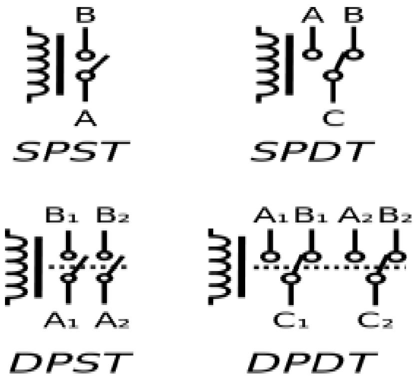
- **De – Energized Relay (OFF)**

As soon as the current flow stops through pins 1 and 3, the switch opens and thus the open circuit prevents the current flow through pins 2 and 4. Thus the relay becomes de-energized and thus in off position.



De-Energized Relay (OFF)

In simple, when a voltage is applied to pin 1, the electromagnet activates, causing a magnetic field to be developed, which goes on to close the pins 2 and 4 causing a closed circuit. When there is no voltage on pin 1, there will be no electromagnetic force and thus no magnetic field. Thus the switches remain open.



V. BLOCK DIAGRAM & WORKING

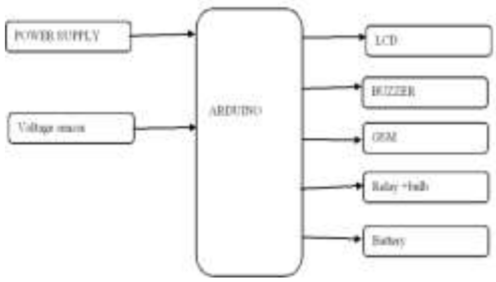


Fig: Block diagram

Working Process

1. Power Line Monitoring Stage

- The system is connected to the AC mains (e.g., 230 V/110 V).
- A **voltage sensor module** reduces and isolates the mains voltage to a safe low-voltage signal.
- The sensor output is fed to the Arduino's analog input pin.
- Arduino continuously checks the voltage signal in a loop.

2. Decision-Making Stage

- **If voltage ≥ threshold:** → System records "power present." → No alert is triggered.

- **If voltage < threshold or zero:** → System records "power outage." → Proceeds to alert routine.

3. Alert Generation Stage

- Arduino sends AT commands to the **GSM module** over serial communication (TX/RX pins).
- The GSM module transmits a **predefined SMS** to the user's registered phone number. Example: *"Alert: Power outage detected at Site A at 10:32 PM."*

4. Backup Power Switching

- During the outage, the system relies on a **battery backup** (e.g., 12 V Li-ion or lead-acid battery).
- A relay or automatic power switching circuit ensures uninterrupted operation of the microcontroller and GSM module.

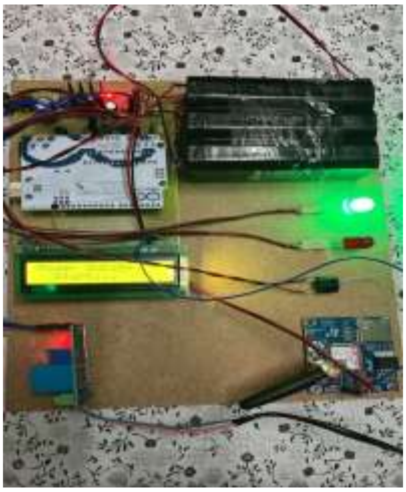
5. Continuous Monitoring during Outage

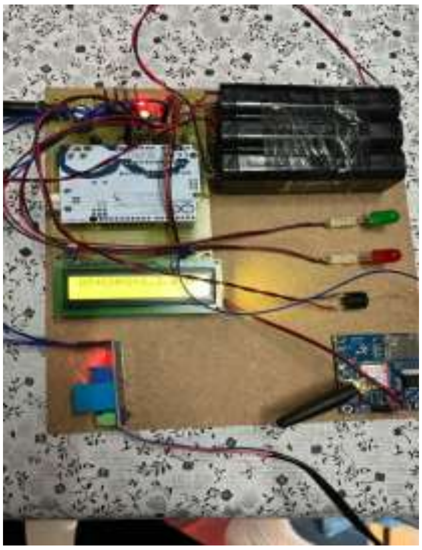
- Even in backup mode, Arduino keeps sampling the mains line.
- This ensures immediate detection when electricity returns.

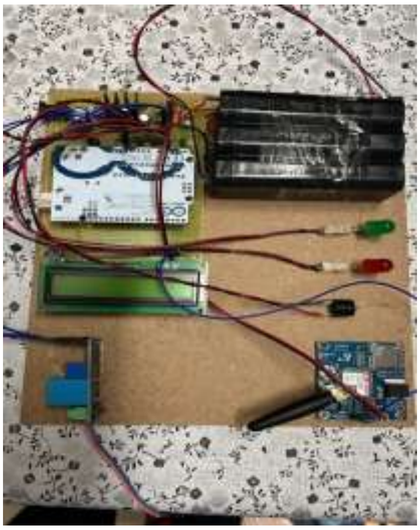
6. Power Restoration Notification

- When voltage is detected again: → Arduino recognizes "power restored." → Sends another SMS: *"Notification: Power restored at Site A at 11:05 PM."* → System switches back to mains power and charges the backup battery.

VI. HARDWARE RESULTS







VII. CONCLUSION

The proposed IoT-based power outage detection and alert system using GSM provides a practical and low-cost solution for real-time monitoring of electrical supply status. Unlike traditional systems, which often rely on manual reporting or complex SCADA infrastructure, this design ensures immediate notification to users via SMS, even in areas without internet connectivity. Its integration of a voltage sensor, microcontroller, and GSM module enables reliable detection of outages, while the inclusion of a battery backup ensures uninterrupted operation during failures.

Furthermore, optional IoT platform integration allows for historical data logging and analysis, which can help identify recurring issues, improve service reliability, and support future predictive maintenance efforts. The system's simplicity, scalability, and cost-effectiveness make it suitable for a wide range of applications—from homes to industries and remote infrastructures.

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