

IMPLEMENTATION OF A RASPBERRY PI-BASED PRIORITIZED POWER DISTRIBUTION SYSTEM FOR INDUSTRIAL APPLICATIONS

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Abstract

The proposed idea introduces an advanced approach to govern power allocation within a complex institutional framework comprising multiple edifices. Employing a sophisticated smart panel in conjunction with a switching module, the system amalgamates both hardware and software components to establish a network of interconnected communication apparatus. The overarching objective of this innovation is to optimize power distribution within individual structures, demarcated into two segments: the main electricity board (EB) + auxiliary power source, and the EB exclusively. Each commercial and institutional edifice is equipped with an electronic control system enabling customizable prioritization based on specific exigencies. Integration with a central smart panel, functioning as the nerve center of the power distribution network, is facilitated through a comprehensive feedback mechanism. Utilization of power detection sensors facilitates precise measurement of current influx into each building segment. Subsequently, the switching module is activated based on these measurements, ensuring meticulous regulation of power output distribution in accordance with predefined preferences. A user-friendly application with an intuitive interface has been developed to enhance user accessibility and control. This web-based platform offers real-time monitoring and control capabilities for the entire smart panel and switching module system. Additionally, users are provided with manual control options through the web interface. Incorporating smart panels into the decentralized electricity control system represents a pivotal technological advancement in the field. This transformative technology not only enhances operational efficiency and minimizes wastage but also enables dynamic adaptation of power distribution to meet evolving demands through intelligent allocation while furnishing real-time control. The efficacy of such a system within an institutional milieu has been substantiated in this investigation, underscoring its potential to redefine power management protocols and propel the utilization of sustainable energy sources.

Keywords

Smart panel, switching module, power distribution, electronic control system, power detection sensor, user interface, real-time monitoring, technological innovation.

1. Introduction

In contemporary industrial and institutional landscapes, the significance of electrical energy cannot be overstated. It serves as the lifeblood for diverse sectors including manufacturing, education, information technology, agriculture, and commerce. The ever-expanding scope of energy utilization across new ventures, residential properties, industrial operations, and emerging projects underscores the criticality of robust power distribution systems. As economies progress and agrarian regions transition towards industrialization, the demand for electrical energy escalates correspondingly. However, the reliability of electrical energy supply faces challenges, particularly during periods of grid instability or fluctuating power availability. To mitigate the risks associated with energy deficits, various backup measures such as generators, batteries, and provisional UPS systems have been traditionally employed. Yet, these solutions often lack the agility and precision required to optimize power allocation according to specific operational priorities.

In response to these challenges, the proposed model introduces a novel paradigm for monitoring and prioritizing power distribution, known as priority-grounded power distribution. This approach revolutionizes the conventional methods by integrating sophisticated hardware and software elements, including smart panels and switching modules, into a cohesive network of communication devices. Priority-grounded power distribution operates on the principle of assigning precedence levels to individual loads, ensuring that critical loads receive preferential treatment during power allocation. This system enables meticulous regulation of power output, wherein loads with higher precedence levels are served first, while lower precedence loads may experience reduced or intermittent supply depending on available power resources. The implementation of priority-grounded power distribution represents a significant advancement in modern power management systems. By aligning power allocation with predefined priorities, organizations can achieve heightened reliability, improved energy efficiency, and greater control over their power distribution networks. This transformative technology not only addresses the diverse requirements of different loads but also facilitates real-time monitoring and manual control through user-friendly interfaces. Through empirical validation and analysis, this study elucidates the potential of priority-grounded power distribution to revolutionize power management practices and accelerate the transition towards sustainable energy utilization in institutional settings.

2. Literature Review

Design and Implementation of a Low-Cost Power Monitoring System for Residential Applications@ S.K. Panda., et al. The authors present a cost-effective power monitoring system for residential energy management. The system employs smart meters at each residence to measure real-time voltage and current. A Data Acquisition Unit (DAU) processes data through serial communication, utilizing an Arduino microcontroller and RS-485 protocol. A user-friendly web interface, created with HTML, CSS, and JavaScript, enables homeowners to visualize real-time and historical energy consumption patterns. The system, validated under diverse load conditions, demonstrates accurate measurements and low latency. With easy installation and insightful data presentation, the proposed system serves as a practical tool for homeowners to understand and optimize their energy usage, contributing to energy conservation.

Development of a Real-Time Power Monitoring and Control System for Industrial Applications@ M.A. Hossain., et al. The paper introduces a real-time power monitoring and control system designed for industrial applications. Utilizing serial communication, it comprises a Data Acquisition Unit (DAU) for data collection, a Central Processing Unit (CPU) for data processing and actuator control, and a HumanMachine Interface (HMI) for user interaction. Implemented with a microcontroller board, a personal computer, and a web interface, the system underwent successful testing in a simulated industrial setting, demonstrating accurate power monitoring and control capabilities. With benefits such as reduced energy costs, improved efficiency, real-time functionality, and user-friendly installation, the system emerges as a valuable tool for enhancing energy management in industrial facilities

A Serial Communication-Based Energy Management System for Smart Homes@ M.A. Hannan@., et al. The paper introduces a serial communication-based energy management system tailored for smart homes, employing a Data Acquisition Unit (DAU) for sensor and actuator data collection, a Central Processing Unit (CPU) for data processing and actuator control, and a Human-Machine Interface (HMI) for user interaction. Implemented with a microcontroller board, a personal computer, and a web interface, the system underwent successful testing in a simulated smart home environment, demonstrating accurate energy monitoring and control. With advantages such as reduced energy costs, improved efficiency, real-time functionality, and user-friendly installation, the system emerges as a valuable tool for enhancing energy management in smart homes.

A Novel Serial Communication Protocol for Fault Detection in Power Distribution Networks@ J. Wu., et al. The paper addresses the critical need for accurate and timely fault detection in power distribution networks, proposing a novel serial communication protocol designed for this purpose. The protocol employs a master-slave architecture, minimizing data transmission overhead and ensuring efficient communication by analyzing voltage and current measurements from distributed slave nodes. Key features include efficiency, reliability with error detection and correction, and adaptability to various network topologies. The fault detection algorithm combines statistical analysis and threshold comparison, demonstrating high accuracy and low false alarm rates

in simulations and laboratory experiments. The protocol and algorithm collectively present a promising solution for enhancing the reliability and safety of power distribution systems.

A Secure and Reliable Serial Communication Protocol for Raspberry Pi and ESP32-Based IoT Applications@ Y. Zhang., et al. The paper addresses security concerns in IoT applications and introduces a secure serial communication protocol for Raspberry Pi and ESP32-based systems. The proposed master-slave architecture incorporates encryption, authentication, and message integrity features to ensure confidentiality, authenticity, and data integrity. Key features include enhanced security against unauthorized access and tampering, low computational overhead, and adaptability to diverse IoT applications. Evaluation on a testbed demonstrated the protocol's effectiveness in protecting data transmission without compromising efficiency. With its robust security measures, low overhead, and flexibility, the proposed protocol stands as a promising solution for ensuring secure and reliable communication in Raspberry Pi and ESP32-based IoT applications

A Real-Time Data Acquisition and Control System for Wireless Sensor Networks Based on Raspberry Pi and ESP32@ H.Liu., et al. The paper introduces a real-time data acquisition and control system designed for Wireless Sensor Networks (WSNs) using Raspberry Pi and ESP32. Utilizing serial communication, ESP32 sensor nodes collect environmental data and transmit it to the Raspberry Pi for processing and control. The Raspberry Pi acts as the central processing unit, processing data and controlling actuators based on the received information. Implemented with ESP32 microcontrollers, a Raspberry Pi, and a web interface, the system demonstrated accurate data collection, processing, and actuation in a simulated WSN environment. This versatile system serves as a valuable tool for monitoring and controlling various environmental parameters in WSN applications, including temperature, humidity, and light intensity.

A Review of Advanced Techniques for Power Distribution System Protection@ A.K.Singh., et al. The paper addresses the escalating complexities of modern power distribution networks by advocating advanced protection techniques. It reviews key categories such as Digital Protection Relays, Communication-Based Protection Schemes, Adaptive Protection Schemes, and Intelligent Electronic Devices. These technologies offer superior fault detection, communication capabilities, adaptability to dynamic conditions, and integrated functions for enhanced reliability. Applications in distribution feeders, radial networks, distributed generation, and smart grids showcase their effectiveness. The continuous development and implementation of these advanced protection techniques are emphasized as indispensable for ensuring the safety, continuity, and efficiency of electricity supply in the evolving power distribution landscape.

A Low-Cost and Efficient Power Management System for Residential Applications@ P.K.Sahoo., et al. This paper proposes an affordable power management system for residential energy conservation. The system integrates smart meters, a Data Acquisition Unit (DAU), and a central server with a user-friendly web interface. Key features include low cost, easy installation, and real-time

monitoring, empowering residents to analyze and control their energy consumption. Benefits encompass reduced energy usage, lower bills, and heightened environmental awareness. The system's simplicity, affordability, and potential for cost savings position it as a valuable tool for residential energy management, supporting residents in their efforts to contribute to environmental sustainability while efficiently controlling electricity expenses

In summary, prioritized power distribution systems are critical in scenarios where power availability is constrained or needs to be allocated across various priority levels. The literature underscores the significance of power prioritization algorithms, load modeling, communication systems, energy storage integration, fault detection, and cost optimization in ensuring efficient and reliable power distribution. However, further research is warranted to tackle challenges pertaining to scalability, real-time monitoring, and renewable energy source integration, thereby enhancing the performance and resilience of prioritized power distribution systems across diverse application domains.

3. System Design and Architecture

System Architecture:

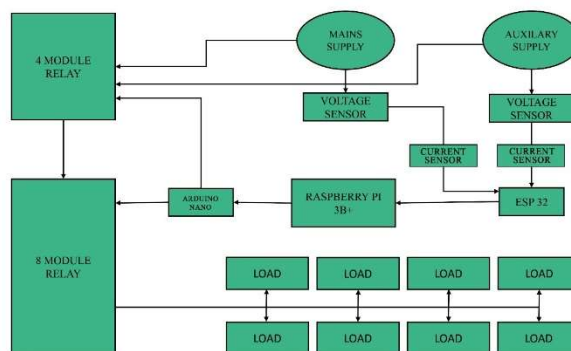


Fig 1. System Architecture

The system architecture comprises four key components: the smart panel, current transformers, switching modules, and the user interface application. The smart panel functions as the central control hub, orchestrating and overseeing the interconnected components. Strategically positioned current transformers facilitate precise measurement of current ingress into individual building power sections, furnishing vital monitoring data. Switching modules enact power output regulation in accordance with predefined building preferences. The user interface application provides comprehensive real-time monitoring, control, and customization capabilities, enhancing system operability and adaptability.

Priority-Based Power Source Selection:

In order to optimize power distribution efficiency, a priority-driven methodology is employed, wherein each building's electronic control system is programmed with a hierarchical preference scheme dictating the selection of power sources (such as EB + Generator or EB alone). This preference hierarchy is meticulously configured to accommodate the specific requirements of the institution, allowing for flexibility and adaptability in power allocation strategies. The sophisticated smart panel, functioning as the central control hub, undertakes continuous surveillance of power source availability and operational status. Leveraging advanced sensing and monitoring mechanisms, the smart panel dynamically orchestrates the seamless transition between available power sources in accordance with the predefined priority order. This dynamic switching mechanism ensures that the institution's critical loads receive uninterrupted power supply, while also optimizing resource utilization and mitigating potential disruptions in power distribution.

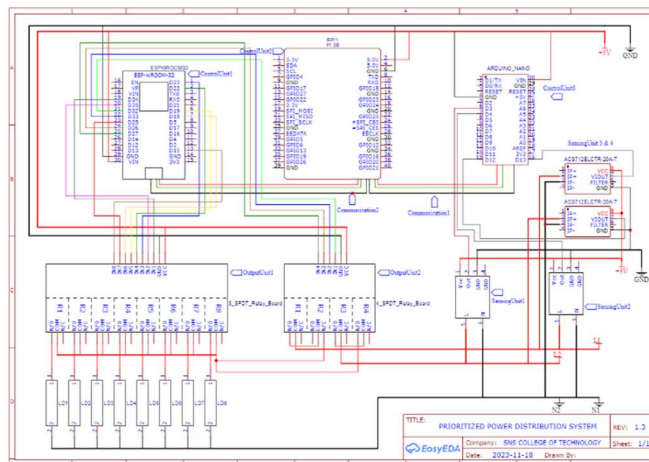


Fig 2. Schematic Diagram

The schematic diagram illustrates the key circuit connections within the prioritized power distribution system. In this setup, the **Raspberry Pi** serves as the master controller, overseeing two devices (ESP32 and Arduino Nano). Arduino Nano monitors the presence of power in both the main and auxiliary sources, relaying this data to the Raspberry Pi through serial communication. Leveraging this information, the Raspberry Pi, in turn, controls power distribution via a relay module through the ESP32, providing an intelligent and responsive system for managing electrical power.

Current Transformer Integration:

Current transformers (CTs) are indispensable components in power distribution systems, strategically positioned at the ingress point of each building's distribution section to precisely measure current influx. These measurements, crucial for system operation, are transmitted to the central smart panel for real-time monitoring and decision-making. Leveraging this data, the system dynamically adjusts power output to align with load demands and available power sources, ensuring efficient and responsive power distribution.

Switching Module and Power Output Control:

The switching modules play a pivotal role in regulating power output to individual buildings within the network. These modules receive signals from the smart panel, which are informed by priority-based power source selection and real-time current measurements. Leveraging advanced switching mechanisms, these modules ensure smooth transitions and efficient power distribution. Through intelligent power management, the system optimizes energy utilization, guaranteeing a stable and reliable power supply to each building, thereby enhancing overall network performance and resilience.

User-Interface Application:

The user interface application serves as a sophisticated platform for overseeing and managing the smart panel-centric control system. Accessible via mobile devices or computers, users can seamlessly monitor real-time data, tailor preferences, and manually toggle power sources when necessary. With its intuitive interface, the application empowers users with complete command and visibility over the distributed electricity management system, ensuring optimal control and operational oversight. The graphical user interface (GUI) plays a pivotal role in the Prioritized Power Distribution System, offering complete control to users. Through the GUI, users can remotely manage the entire distribution system, accessing crucial information such as the status of power in the main and auxiliary sources. Additionally, the interface empowers users with control over power supply to various building sections, providing a seamless and user-friendly experience for remote operation. This section explores the design and features of the GUI for the distribution system, offering insights into user-centric aspects, visual aesthetics, functionalities, and controls. It emphasizes creating an intuitive and efficient user experience within the power distribution framework.

Case 1: Mains ON and Auxiliary Power Source ON

MAINS 248	AUX 246	RASP 3
CUR1(mAh) 2348	CUR2(mAh) 0	CUR3(mAh) 2450
preset1	preset2	preset3
ICU	OT	General
Hallway	Radiology	Reception

Under the condition where both the main power source and auxiliary power source are active, electricity flows unrestricted to all building sections unless manually restricted. In this scenario, both sections denoting MAINS power and AUXILIARY power are visually indicated with a green background. The interface displays real-time voltage readings in the power lines, providing immediate visibility into the system's operational status.

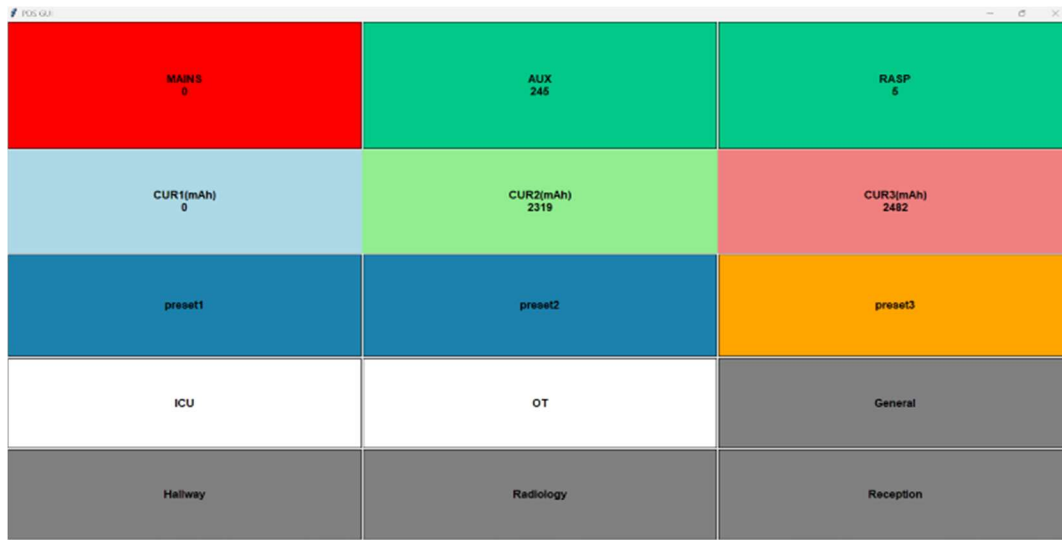
Case 2: Mains OFF and Auxiliary Power Source ON Preset 1



In the second scenario, with MAINS power unavailable, the system seamlessly shifts to the auxiliary power source. During this transition, areas of lower priority may witness diminished or no power supply. The MAINS indicator reflects this shift by turning red, accompanied by a power reading of 0, symbolizing the absence of power. Simultaneously, sections subjected to power restrictions exhibit a distinctive grey background, visually indicating the reduced power availability. Within this context, users possess the flexibility to manually tailor power distribution across various building sections. Alternatively, the system offers the convenience of utilizing pre-defined presets, especially advantageous in large buildings where individually managing each section could prove time-intensive. This dynamic feature empowers users to efficiently adapt to varying power scenarios, ensuring optimal control and utilization of available resources.

Case 3: Mains OFF and Auxiliary Power Source ON Preset 2

In the third scenario, with MAINS power unavailable, the system seamlessly shifts to the auxiliary power source. During this transition, areas of lower priority may witness diminished or no power supply. The MAINS indicator reflects this shift by turning red, accompanied by a power reading of 0, symbolizing the absence of power. Simultaneously, sections subjected to power restrictions exhibit a distinctive grey background, visually indicating the reduced power availability. Within this context, users possess the flexibility to manually tailor power distribution across various building sections. Alternatively, the system offers the convenience of utilizing pre-defined presets and the change in preset conditions is correlated with the power consumption of the auxiliary power source i.e., as the power drains out the preset value jumps to the higher priority order (Preset 2).

Case 4: Mains OFF and Auxiliary Power Source ON Preset 3

In the fourth scenario, with MAINS power unavailable, the system seamlessly shifts to the auxiliary power source. During this transition, areas of lower priority may witness diminished or no power supply. The MAINS indicator reflects this shift by turning red, accompanied by a power reading of 0, symbolizing the absence of power. Simultaneously, sections subjected to power restrictions exhibit a distinctive grey background, visually indicating the reduced power availability. Within this context, users possess the flexibility to manually tailor power distribution across various building sections. Alternatively, the system offers the convenience of utilizing pre-defined presets and the change in preset conditions is correlated with the power consumption of the auxiliary power source i.e., as the power drains out the preset value jumps to the highest priority order (Preset 3).

4. Data Acquisition and Analysis

Data Acquisition:

Data acquisition entails systematically gathering and capturing data from diverse sources. Within the ambit of the smart panel for distributed electricity control, data acquisition encompasses meticulous monitoring and capturing of pertinent information concerning power sources, line statuses, and relay modules. This process involves employing sensors, meters, and communication protocols to ensure comprehensive data collection, facilitating precise analysis and informed decision-making in power distribution management. With the help of Current and Voltage sensors and the acquired data from the institution the data acquisition is done.

Power Source Monitoring:

The central controller continually gathers telemetry from both the primary electricity board (EB) and auxiliary generator power sources, encompassing critical parameters like voltage, current, and frequency. Through real-time monitoring of these parameters

using various sensors, the system conducts comprehensive assessments of power source availability and quality, ensuring dynamic and informed decision-making regarding power allocation and load management strategies.

Line Status Monitoring:

Secondary controllers retrieve data from essential and high-powerlines, encompassing status indicators like activation, disconnection, or default essential line mode. This data aids in real-time monitoring of line conditions, facilitating precise switching and control operations. By analyzing line statuses, the system orchestrates optimal control actions to ensure seamless power distribution and mitigate operational disruptions.

Relay Module Monitoring:

The data acquisition process encompasses real-time monitoring of relay module statuses, including relay states (open/close), voltage levels across relays, and circuit continuity. This meticulous monitoring facilitates fault detection and anomaly identification within the relay modules, ensuring the robustness and reliability of the system. Additionally, advanced algorithms analyze acquired data to discern patterns indicative of potential issues, enabling proactive maintenance and swift response to mitigate disruptions.

Data Analysis:

Data analysis encompasses the intricate process of systematically processing and interpreting acquired data to unearth valuable insights, discern patterns, and facilitate informed decision-making. Within the context of the smart panel framework, data analysis assumes paramount significance, serving as a linchpin in optimizing power distribution strategies and bolstering system reliability. Leveraging advanced analytical techniques such as machine learning algorithms, statistical modeling, and predictive analytics, data analysis empowers stakeholders to derive actionable intelligence, mitigate risks, and enhance operational efficiencies in power management systems.

Power Source Prioritization:

Data analysis of power sources involves assessing their availability, reliability, and load demands. The central controller employs this data to ascertain the primary power source, seamlessly transitioning between the electricity board (EB) and generator sources. This prioritization optimizes power distribution and load handling, bolstering system efficiency and reliability. Utilizing sophisticated algorithms, the controller dynamically adjusts power allocation, ensuring critical loads receive priority while maintaining seamless operation.

Line Control and Customization:

Line status data analysis plays a pivotal role in the precise control of switching modules within the sub-distribution system. This analytical process empowers the system to ascertain the status of critical lines and high-power lines, facilitating prompt and appropriate control actions. Moreover, through detailed data analysis, customization of the ground level is achieved, thereby offering

flexibility in power distribution strategies. This strategic utilization of line status data not only ensures efficient management of power distribution networks but also enhances system resilience and adaptability to dynamic operational demands.

Fault Detection:

Fault detection and anomaly identification are conducted through comprehensive data analysis of relay modules. Parameters including relay status, voltage levels, and continuity are scrutinized to pinpoint potential faults or short circuits. This facilitates swift implementation of protective measures like fault isolation and system operator notifications, thereby upholding system reliability and safety protocols. Advanced algorithms and diagnostic techniques are employed to enhance fault detection accuracy and minimize downtime in critical operations.

5. Control and Optimization Strategies

Power outages pose significant disruptions, underscoring the criticality of a stable energy supply. To mitigate such interruptions and ensure efficient energy management, advanced control, and optimization strategies are essential, facilitated by the evolution of smart power distribution systems. This section delves into pivotal control and optimization mechanisms deployed within smart power distribution networks to enhance power conservation and resilience during outages. Emphasis is placed on elucidating key methodologies aimed at bolstering the reliability and efficiency of energy distribution systems, thereby addressing the pressing need for uninterrupted power supply across diverse sectors of daily life.

1. Demand Response Management

Demand response management is a critical strategy facilitating efficient electricity utilization amid power outages. Advanced metering infrastructure and smart grid technologies empower power distribution entities to monitor real-time electricity consumption and dynamically adjust power allocation based on priority and user preferences. By leveraging demand response programs, consumers can opt to curtail electricity usage during peak demand periods or shift consumption to off-peak hours, thereby optimizing resource utilization amidst blackout scenarios. This proactive approach not only ensures efficient resource allocation but also enhances grid stability and resilience in the face of dynamic demand fluctuations.

2. Microgrid Integration

Integrating microgrids into existing power infrastructure presents a robust strategy to ensure continuous power availability and mitigate reliance on the primary grid during outages. Microgrids, localized power systems, operate autonomously or in parallel with the main grid, bolstering resilience. Incorporating renewable energy sources such as solar and wind, alongside energy storage solutions like batteries, microgrids provide reliable backup power. Advanced control algorithms facilitate seamless transitions between the primary grid and microgrids, optimizing energy flow and minimizing overall power consumption. This integrated approach enhances grid stability, resilience, and sustainability while reducing vulnerabilities to disruptions.

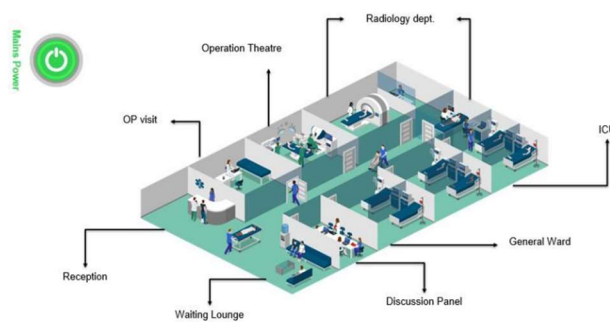


Fig 3. MAIN ON

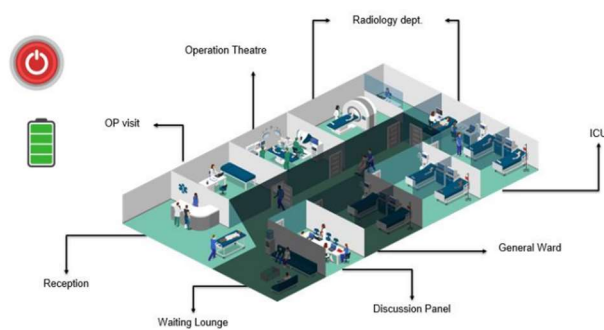


Fig 4. MAIN OFF/AUX ON-PRESET 1

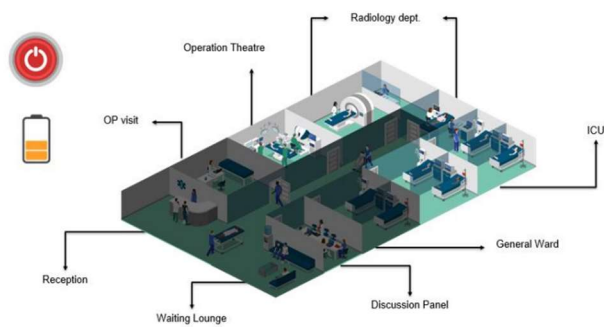


Fig 5. AUX ON-PRESET 2

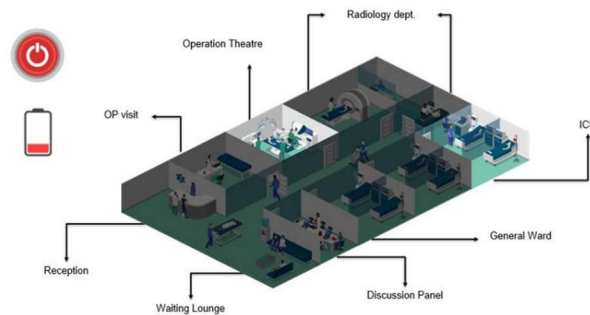


Fig 6. AUX ON-PRESET-3

3. Energy Storage and Load Management

Within smart power distribution networks, energy storage solutions play a pivotal role, particularly in blackout scenarios. The integration of large-scale battery storage systems allows for the storage of surplus power generated during regular operations, ensuring uninterrupted power supply during blackouts. Intelligent load management algorithms prioritize critical loads and dynamically allocate available power to maximize backup time and optimize energy utilization. These optimization techniques enhance system dependability while simultaneously contributing to overall energy conservation and efficiency gains. Moreover, the seamless integration of energy storage systems facilitates grid stability and resilience, thereby bolstering the reliability of power distribution networks.

4. Predictive Analytics and Forecasting:

Employing forecasting and predictive analytics methodologies offers a potent means to mitigate energy loss during power outages and significantly enhance power distribution efficiency. By leveraging advanced algorithms, power distribution firms can accurately anticipate fluctuations in power consumption and potential outage events through rigorous analysis of historical data, weather patterns, and consumer behaviours. Armed with this predictive insight, proactive resource allocation, maintenance schedules, and refined distribution strategies can be implemented to minimize downtime and maximize energy conservation, underscoring the pivotal role of predictive analytics in fostering resilient and efficient power distribution systems.

5. Smart Grid Automation and Self-Healing:

Automating the smart grid and integrating self-healing mechanisms are integral components for mitigating the impact of power outages and enhancing the efficiency of electricity distribution. By leveraging advanced automation technologies, the smart grid can rapidly detect and isolate faults, reroute power flows, and restore supply to unaffected areas in real-time. This seamless integration of automation facilitates swift responses to outage events, minimizing downtime and expediting the restoration process. Furthermore,

smart grid automation optimizes resource utilization, ensuring maximal efficiency in power distribution operations while bolstering system resilience against disruptions.

6. Results and Discussion

Incorporating smart panels into the decentralized electricity control system represents a pivotal technological advancement in the field. This transformative technology not only enhances operational efficiency and minimizes wastage but also enables dynamic adaptation of power distribution to meet evolving demands through intelligent allocation while furnishing real-time control.

The web-enabled platform presents dynamic monitoring and control functionalities for the comprehensive smart panel and switching module system. Furthermore, it furnishes users with manual control alternatives via the web interface, augmenting its operational versatility.

The various goals acquired with the help of smart panel are:-

- Ensures uninterrupted power supply to critical loads during periods of peak demand or outages, thereby safeguarding vital operations.
- Enhances the reliability and resilience of the power grid by prioritizing critical loads, reducing the risk of widespread disruptions.
- Mitigates the adverse impact of power outages on essential infrastructure, minimizing downtime and potential economic losses.

7. Conclusion

Our proposed smart panel model is designed for the monitoring and allocation of precedence-grounded power source selection, also referred to as a customized power force. This model facilitates the creation of power circuits with integrated accessories capable of implementing load shedding based on priority levels. While the system primarily operates on a predefined algorithm, it offers flexibility for manual intervention when necessary, such as switching off loads or activating dormant loads, with the assistance of specialized software. By automating load shedding processes, this model not only alleviates the physical strain on operators but also contributes to the improvement of overall electrical energy management systems. It is suitable for installation in various settings including services, educational institutions, organizations, factories, and residential properties, particularly those reliant on backup energy sources during fluctuations in mains power supply or generator operation. A comparative analysis between conventional power distribution systems and our proposed model highlights several key distinctions. Unlike conventional systems, our model provides a comprehensive mechanism for managing power distribution based on load priority levels. Additionally, it incorporates

automatic and prioritized load shedding features, ensuring continuous power supply to critical loads for extended durations—a functionality lacking in traditional systems.

Furthermore, our model offers remote load switching capabilities through a software-based mobile interface, a feature absent in conventional systems. This remote operation capability enhances operational flexibility and facilitates efficient load management, particularly in scenarios where physical access to the electrical system may be limited or impractical.

In summary, our proposed smart panel model represents a significant advancement in power distribution technology, offering enhanced functionality, flexibility, and efficiency compared to conventional systems. Its implementation promises to revolutionize power management practices across diverse applications, ultimately leading to improved reliability and performance in electrical energy operation systems.

8. Declaration

Funding of interests

No funding was received to assist with the preparation of this manuscript.

Conflicts of interests

The authors have no compelling interests to declare that are relevant to the content of this article.

Data Availability Statement

This study did not generate or use any datasets, and therefore, no data availability statement is applicable

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