ETAP Based Battery Backup System in Pharmaceutical Industries

Dr. N. Karpagam, S. Akila, J. Jeyasuruthi, T. Padmavarshini

Department of Electrical and Electronics Engineering, Velammal College of Engineering and Technology Viraganoor, Madurai.

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ABSTRACT

Emergency power supply is essential in large commercial infrastructures such as shopping malls, where critical loads including lighting, pumps, and safety systems must remain operational during grid outages. Conventional diesel generators are widely used but suffer from delayed startup, noise, emissions, and high maintenance costs. To address these issues, this work proposes the design and simulation of an Emergency Battery Deployment System for terrace-level installation in malls. The proposed system employs a Battery Energy Storage System (BESS) integrated with a Battery Management System (BMS) to ensure reliable, efficient, and safe operation. A preliminary sizing of 260 kWh has been carried out to supply approximately 130 kW of critical loads for up to two hours of autonomy. The system is modeled and analyzed using ETAP software to perform load flow, outage, and fault simulations. The results demonstrate that the battery-based system offers instantaneous response, reduced operational costs, and zero local emissions, making it a sustainable alternative to diesel generators. The project also contributes to the United Nations Sustainable Development Goals (SDGs), namely Affordable and Clean Energy (SDG 7), Industry, Innovation, and Infrastructure (SDG 9), and Sustainable Cities and Communities (SDG 11)

Keywords—Emergency power, battery energy storage system, battery management system, ETAP simulation, critical load, sustainable backup power.

INTRODUCTION

Uninterrupted power supply is critical in commercial infrastructures such as shopping malls, hospitals, and large residential complexes, where essential loads including elevators, pumps, emergency lighting, and fire safety systems must continue to operate during power outages. In most existing systems, diesel generators are deployed as the primary source of emergency backup power. Although reliable, diesel generators are associated with several limitations such as delayed startup time (10–20 seconds), noise and vibration, harmful emissions, and recurring fuel and maintenance costs [1]. These drawbacks highlight the need for a cleaner, faster, and more sustainable alternative. In recent years, Battery Energy Storage Systems (BESS) have emerged as a viable solution for providing backup power in critical infrastructures. When integrated with a Battery Management System (BMS), batteries can offer instantaneous switching, continuous monitoring of State of Charge (SOC) and State of Health (SOH), cell balancing, and protection against electrical and thermal faults [2]. Terrace - level deployment of battery systems in malls provides the advantages of safety, accessibility, and efficient space utilization .

Goal and Objective

The goal of this project is to design and simulate a battery-based emergency backup system for shopping malls, deployed at the terrace level, in order to provide uninterrupted power supply to critical loads during grid outages. The system seeks to act as a sustainable, clean, and instant-response alternative to conventional diesel generators, which arse associated with delayed startup, high maintenance, and environmental concerns. To achieve this goal, the project objectives include: conducting a critical load assessment of essential equipment such as chiller pumps, scrubber pumps, softener pumps, emergency lighting, and fire safety systems; performing battery sizing calculations to supply approximately 130 kW of load for two hours of autonomy; modeling the proposed system

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in ETAP software with components such as the grid, transformer, and Automatic Transfer Switch (ATS); integrating a Battery Management System (BMS) to ensure safe operation through SOC/SOH monitoring, cell balancing, and fault protection; and finally, executing simulation studies such as load flow, outage response, and fault analysis to validate the performance and reliability of the system. Additionally, the project aims to compare the proposed solution with conventional diesel generator backup in terms of cost, response time, and sustainability, thereby demonstrating its feasibility as a future-ready alternative .*Maintaining the Integrity of the Specifications*

LITERATURE SURVEY

Battery Energy Storage Systems (BESS) have gained considerable attention as viable solutions for enhancing the reliability and resilience of electrical networks, particularly in critical infrastructure applications. Their ability to provide instantaneous backup power, support peak load management, and integrate renewable energy sources makes them an increasingly preferred alternative to traditional diesel generators.

In [1], the authors investigated the deployment of BESS for emergency supply in distribution networks and demonstrated improvements in outage response and reliability indices such as SAIDI and SAIFI. The study highlighted that strategic placement of BESS could significantly mitigate the impact of faults and facilitate faster service restoration.

A comprehensive review in [2] compared stationary and mobile battery systems, underscoring their advantages over conventional diesel-based systems, particularly in urban environments where air quality and noise are major concerns. The review emphasized the flexibility of mobile BESS units, which can be dispatched to different locations based on demand, thereby offering grid support during both planned and unplanned outages.

The coordinated operation of BESS for critical load support during natural disasters and grid failures was addressed in [3]. The study employed optimization models for load prioritization and battery dispatch, showing that well-orchestrated BESS operation can substantially reduce downtime and operational costs, especially in sectors like healthcare, retail, and emergency services.

Battery Management Systems (BMS), a crucial enabler for the safe and efficient use of BESS, were the focus of [4]. The study delved into key BMS functionalities such as State of Charge (SOC) and State of Health (SOH) estimation, thermal management, cell balancing, and protection mechanisms. These features are critical for preventing overcharging, overheating, and ensuring uniform battery performance—especially important in multi-battery configurations often used in large commercial settings.

Simulation-based approaches have also been increasingly adopted to evaluate the performance of BESS under various grid conditions. In [5], ETAP software was utilized to simulate outage scenarios in commercial infrastructures, providing insights into the load-carrying capabilities and response times of BESS. These simulations serve as vital tools for validating system designs before real-world deployment.

Problem Identification

Reliable electricity supply is a critical requirement in multistorey buildings, as it ensures the continuous operation of essential services such as elevators, fire safety systems, HVAC equipment, and medical facilities. However, present backup practices exhibit significant limitations that compromise energy resilience during unexpected power outages.

First, unexpected total power failures resulting from grid disturbances, transformer faults, or distribution panel issues can lead to blackouts, disrupting both safety and operational continuity [1]. Conventional diesel generator-based solutions are widely adopted; however, they suffer from delayed response times, high maintenance costs, and environmental impacts [2].

Second, most existing systems lack smart battery backup solutions capable of providing instantaneous power with intelligent load management. The absence of emergency load prioritization results in competition between

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critical and non-critical loads, reducing the effectiveness of backup systems during emergencies [3].

Third, the current reliance on manual intervention for activating emergency systems increases recovery time and raises safety concerns in time-sensitive environments such as hospitals, industrial plants, and high-rise apartments.

Finally, there is poor integration with modern energy infrastructures, including renewable energy systems, energy-efficient devices, and hybrid storage technologies. This limits the ability of buildings to utilize sustainable energy resources effectively [4].

Therefore, there is a critical need for a sustainable, automated, and intelligent emergency battery deployment system that ensures uninterrupted supply to critical loads, minimizes downtime, and reduces dependency on fossil-fuel-based generators.

PROPOSED METHODOLOGY

The proposed system focuses on the deployment of an emergency battery backup system for multi-storey buildings to ensure uninterrupted power supply for critical loads during unexpected failures. The methodology involves systematic stages as outlined below.

A. Load Data Collection and Floor Plan Input

The first step involves gathering detailed electrical load data from the building, including connected equipment, floor-wise distribution, and priority classification of loads. The architectural floor plan is analyzed to determine the layout of electrical distribution and the placement of critical equipment.

B. Circuit Design and Simulation in ETAP

A comprehensive circuit model of the building's electrical system is developed in ETAP software. The model includes the utility grid connection (33 kV), step-down transformer (1000 kVA), distribution panel (415 V), and single-floor loads (230 V). This digital model enables accurate simulation of power flow and fault conditions.

C. Emergency Load Prediction and Prioritization

Critical loads such as chiller pumps (70 kW), scrubber pumps (35 kW), and softener pumps (25 kW) are identified and prioritized. The methodology ensures that during a power outage, only the most essential loads, equivalent to 130 kWh, are sustained. This prevents system overloading and ensures maximum reliability.

D. Battery Integration and Sizing

A battery backup system of 260 kWh capacity with a 2-hour autonomy is designed and integrated into the system. Automated Transfer Switches (ATS) are employed to ensure seamless transition from grid power to battery power during outages. The battery is sized based on predicted emergency load demand, efficiency considerations, and safety margins.

E. Fault Simulation and System Analysis

Different fault scenarios are simulated in ETAP, including short-circuits and grid outages. The response of the system is analyzed in terms of voltage stability, current interruption, and fault clearance time. The role of the ATS in enabling smooth load transfer is also evaluated.

F. Deployment and Testing

The final stage involves validating the proposed methodology by conducting deployment tests within the simulation environment. Performance metrics such as response time, load sustainability, and backup duration are analyzed to verify the system's reliability under emergency conditions.

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G. Block Diagram Representation

The integration of the utility grid, transformer, distribution panel, fault detection unit, ATS, critical loads, and battery backup system.

Block Diagram

The ETAP-based emergency battery backup system is structured around a highly responsive microgrid architecture designed to ensure continuous power delivery during utility grid failures. The primary components of the system include the utility grid, Battery Energy Storage System (BESS),Relay, fault detection and protection devices, and load blocks categorized into critical and non-critical types. During normal operation, power is sourced from the utility grid, which directly supplies all connected loads within the microgrid. The system architecture is continuously monitored via voltage and frequency sensors to detect abnormalities in grid operation.

At the heart of the architecture lies the Relay, which serves as a dynamic gateway between the grid and the battery backup system. When a grid disturbance is detected, the Relay triggers an automatic transition to islanded mode, where the BESS powers critical loads. Simultaneously, ETAP's control logic governs the switching mechanism, load scheduling, and real-time decision-making. Fault detection components such as relays and sensors are embedded throughout the network to isolate faulty sections and maintain supply to unaffected areas. The control module further enhances system reliability by optimizing battery usage, load shedding strategies, and restoration protocols.

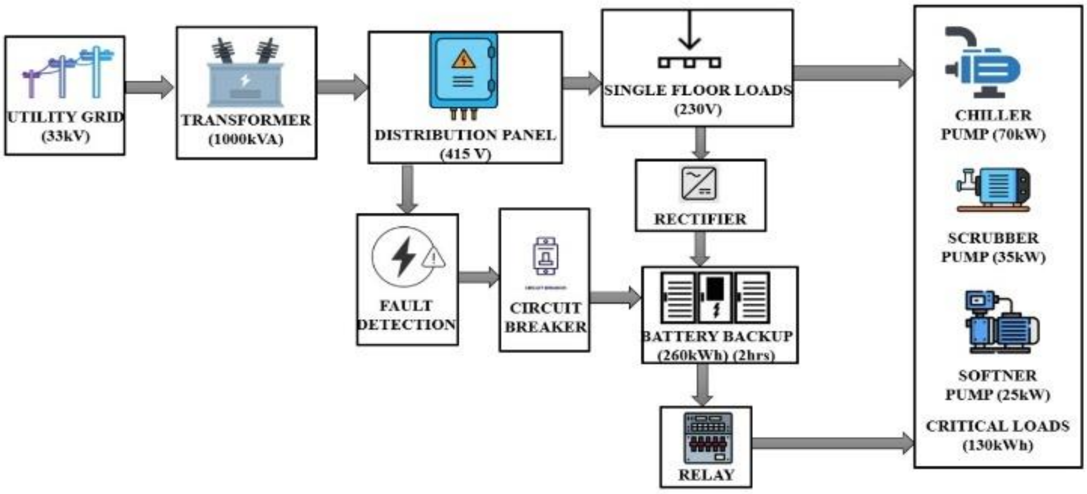

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Fig 5.1

System Design

The proposed emergency battery deployment system is designed to ensure uninterrupted power supply to critical loads in multi-storey buildings during sudden grid failures. The system architecture integrates the utility grid, transformer, distribution panel, automated transfer switch (ATS), fault detection unit, and a dedicated battery energy storage system. Under normal operating conditions, the building is powered by the utility grid at 33 kV, which is stepped down to 415 V using a 1000 kVA transformer. The distribution panel further supplies 230 V to individual floor-level loads. A fault detection unit continuously monitors the electrical network for abnormalities such as voltage dips, short circuits, or supply interruptions. In the event of a detected fault, the ATS activates, isolating the faulty grid supply and seamlessly transferring the critical load demand to the battery backup system without requiring manual intervention.

The battery system is designed with a capacity of 260 kWh, providing up to two hours of backup power. It is sized to sustain a critical load demand of approximately 130 kWh, which includes essential equipment such as the chiller pump rated at 70 kW, the scrubber pump rated at 35 kW, and the softener pump rated at 25 kW. This

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prioritization of essential equipment ensures that the system maintains building safety and functionality during outages, while non-critical loads are disconnected to optimize available energy storage. The overall design emphasizes reliability, quick fault response, and efficient load prioritization.

The functional structure of the system is illustrated in the block diagram shown in Fig. 1. Power from the utility grid is supplied to the building through the transformer and distribution panel under normal conditions. The fault detection unit monitors the grid and, in case of failure, signals the ATS to switch the supply from the grid to the battery system. The stored energy in the battery is then deployed exclusively to critical loads, ensuring continuous operation until the grid supply is restored.

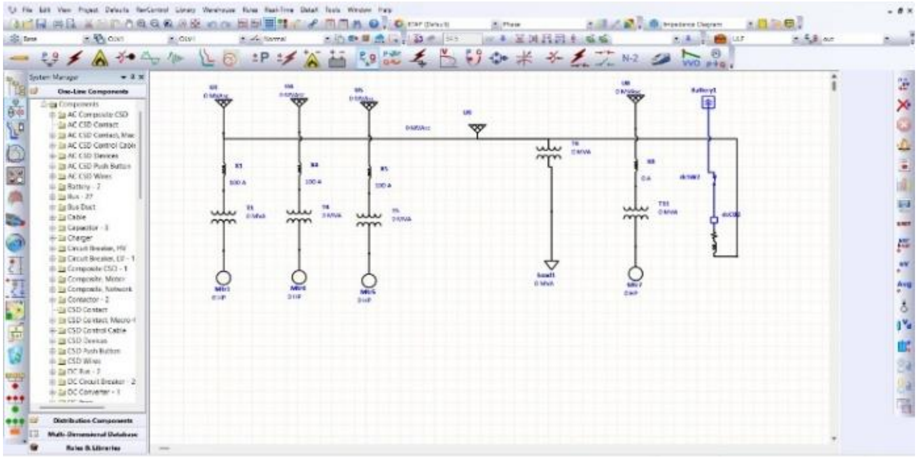

Fig 6.1

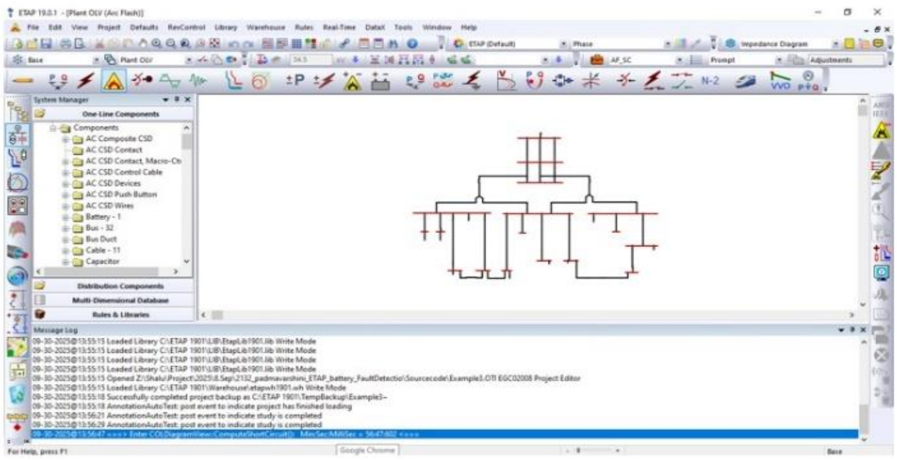

Fig 6.2

SIMULATION AND RESULT

Emergency battery deployment system was modeled and simulated using ETAP software to analyze its performance under different operating and fault conditions. The simulation model consisted of the utility grid connection at 33 kV, a 1000 kVA step-down transformer, the 415 V distribution panel, and floor-level loads operating at 230 V. The battery storage system with a rated capacity of 260 kWh and an autonomy of two hours was integrated into the system through an automated transfer switch (ATS). Critical loads including the chiller pump (70 kW), scrubber pump (35 kW), and softener pump (25 kW) were incorporated to validate prioritized load support during outages.

During normal operating conditions, the system delivered uninterrupted power from the utility grid, and the battery remained in standby mode. Fault scenarios such as three-phase short circuits, single-line-to-ground faults, and sudden grid outages were simulated to evaluate the system's reliability. The results demonstrated that the fault detection unit successfully identified disturbances and triggered the ATS to switch from grid supply to battery backup within a negligible transition time, thereby maintaining continuous operation of the critical loads.

The performance analysis revealed that the 260 kWh battery system sustained the prioritized critical load demand of 130 kWh for the expected two-hour duration without significant voltage deviations. Load prioritization ensured that essential systems remained operational while non-critical loads were shed automatically, preventing overload and optimizing energy utilization. The ETAP fault analysis further confirmed stable voltage and current profiles across the system, even under severe outage conditions.

These results validate that the proposed system provides an efficient and reliable backup solution for emergency situations in multi-storey buildings. The integration of automated switching and properly sized battery storage enhances resilience, reduces dependence on diesel generators, and ensures uninterrupted operation of essential building services during power failures.

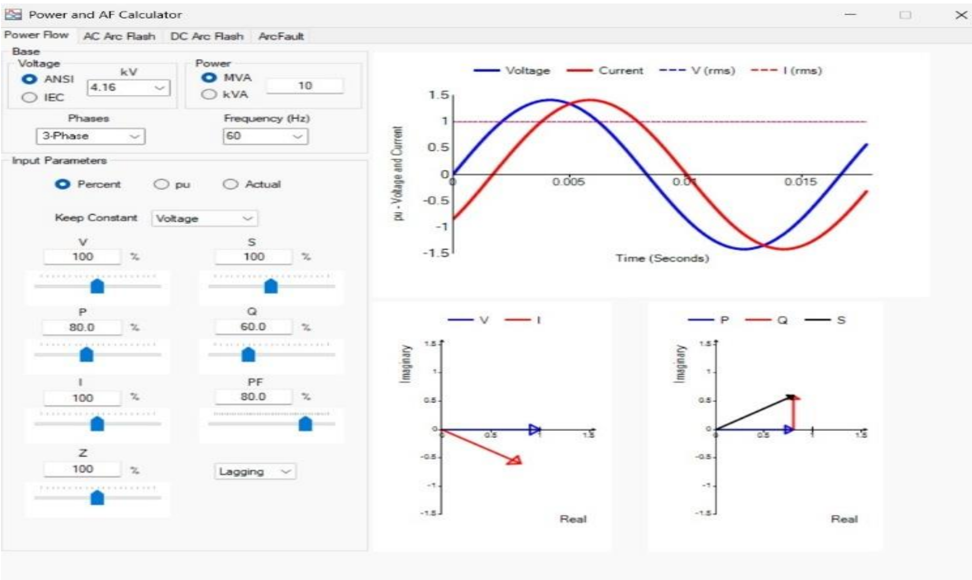

Fig 7.1

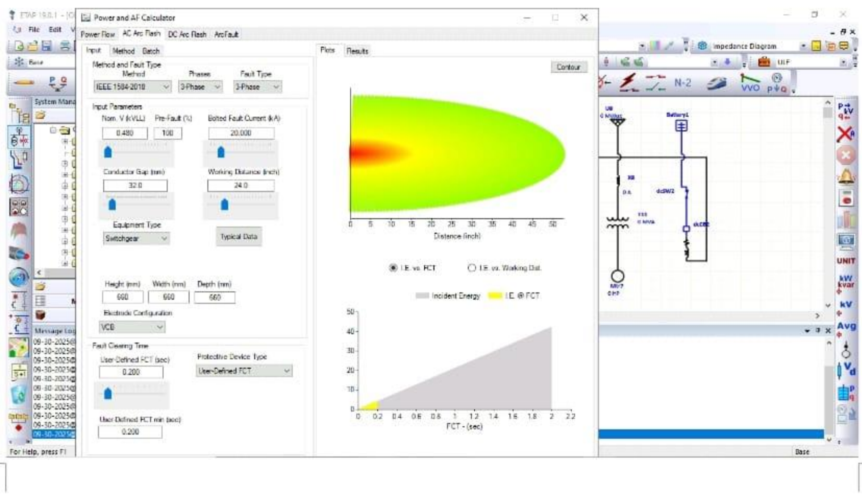

Fig 7.2

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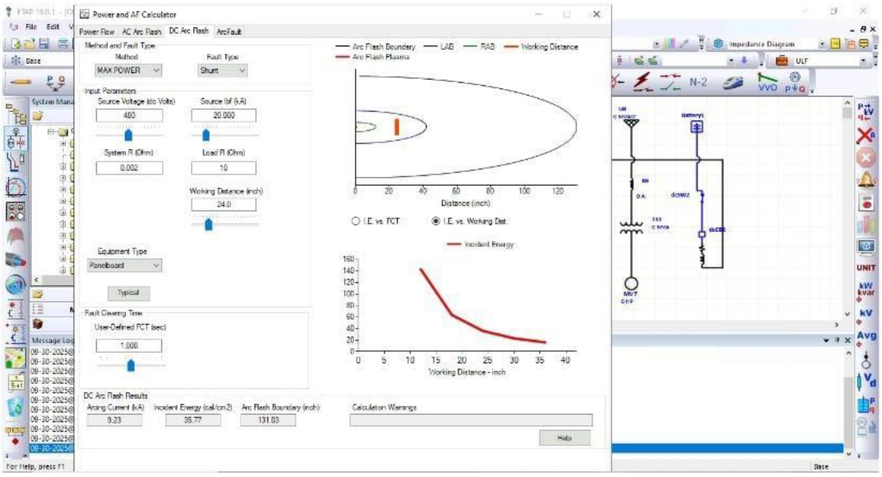

Fig 7.3

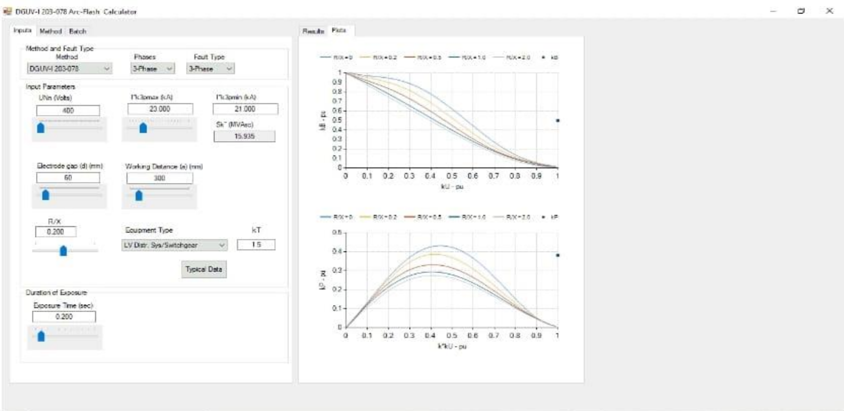

Fig 7.4

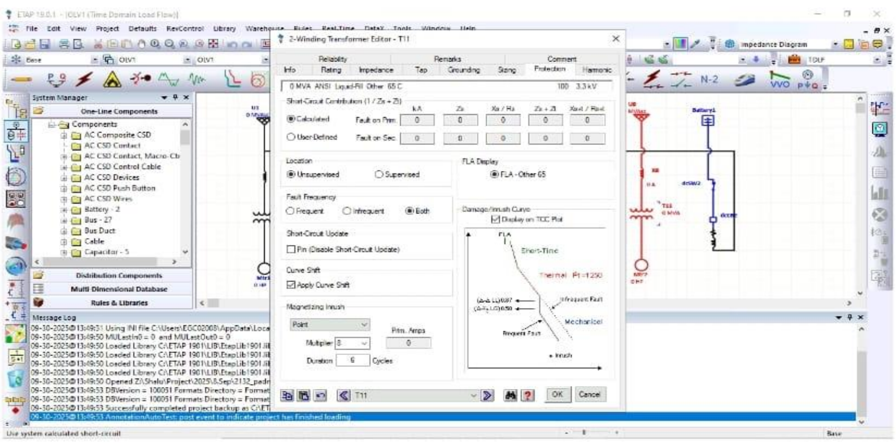

Fig 7.5

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DISCUSSION

The simulation results demonstrate that the proposed emergency battery deployment system can effectively ensure uninterrupted power supply to critical loads in multi-storey buildings during unexpected outages. The ETAP simulations confirmed that the automatic transfer switch provided seamless transition between the grid and battery supply, thereby eliminating manual intervention and reducing downtime. The observed transition time was negligible, which is crucial for sensitive loads such as pumps and control equipment.

The battery storage system, sized at 260 kWh, was able to sustain critical loads totaling 130 kWh for the expected two-hour backup period. This validates the design methodology adopted for load prioritization and energy sizing. In comparison to conventional diesel generator-based backup systems, the proposed design offers significant advantages in terms of reduced emissions, lower operating noise, and faster response to disturbances. Furthermore, the stability of the load voltage profile during simulated faults indicates that the system is capable of maintaining power quality within acceptable limits throughout the backup period.

Another important aspect highlighted by the simulation is the effectiveness of load prioritization. By restricting supply to only essential systems such as the chiller, scrubber, and softener pumps, the available battery capacity was utilized optimally without risk of overloading. This strategy enhances system resilience, particularly in large buildings where power demand during faults can be unpredictable.

The results align with findings reported in recent literature on hybrid microgrids and building-integrated battery systems [1], [2], thereby reinforcing the viability of battery energy storage as a reliable emergency power solution. However, practical deployment may require additional considerations such as battery management systems (BMS), thermal management, and cost optimization, which were not explicitly modeled in this study. Future work will focus on incorporating these aspects to extend system lifetime and enhance operational efficiency.

Sustainability Impact

Emergency battery deployment system contributes significantly to sustainable energy management in modern buildings. By integrating a battery energy storage system (BESS) instead of conventional diesel generator sets, the design eliminates greenhouse gas emissions, reduces noise pollution, and minimizes dependence on fossil fuels. This transition aligns with global efforts toward decarbonization and supports the integration of clean energy solutions in urban infrastructure.

The prioritization of critical loads ensures that energy is utilized responsibly during outages, thereby reducing unnecessary consumption and preventing wastage. This directly supports the principles of responsible energy use and efficiency. Moreover, the ability to provide reliable power during emergencies enhances the resilience of buildings, which is an essential component of sustainable cities and communities.

In the broader context, the system supports multiple United Nations Sustainable Development Goals (SDGs), including Affordable and Clean Energy (SDG 7) by ensuring reliable access to clean backup power, Industry, Innovation, and Infrastructure (SDG 9) by advancing energy management technologies, Sustainable Cities and Communities (SDG 11) through improved urban energy resilience, and Responsible Consumption and Production (SDG 12) by promoting efficient utilization of stored energy.

Thus, the project not only addresses immediate technical challenges in emergency power management but also contributes to long-term sustainability by reducing environmental impact, enhancing building safety, and supporting global clean energy transitions.

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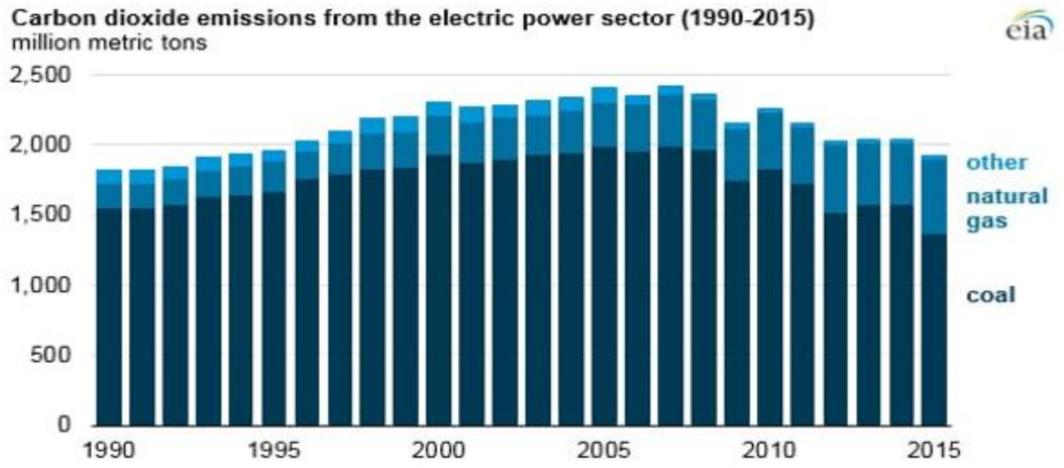

Fig 9.1

Future Scope

While the emergency battery deployment system demonstrates reliable performance in simulation, several avenues exist for future enhancement and practical deployment. One key area is the integration of advanced battery management systems (BMS) to monitor state-of-charge, state-of-health, and thermal conditions, which would extend battery lifespan and improve safety. Additionally, hybrid energy storage systems that combine batteries with supercapacitors or fuel cells may be explored to improve response times and provide longer backup durations.

The incorporation of renewable energy sources, such as rooftop solar photovoltaics, can further reduce dependency on the utility grid and enhance sustainability by enabling partial charging of the battery system during normal operation. Intelligent load forecasting and predictive algorithms using artificial intelligence and machine learning may also be developed to dynamically prioritize loads and optimize battery utilization based on real-time conditions.

At the building level, future work may focus on scaling the system to accommodate larger infrastructures, such as hospitals, data centers, and commercial complexes, where uninterrupted power supply is critical. Integration with smart grid infrastructure and demand response programs would also allow the system to contribute to grid stability during peak demand, thereby increasing its value beyond emergency backup.

In summary, the proposed system provides a strong foundation for reliable emergency power management, and with the incorporation of advanced monitoring, renewable integration, and smart control strategies, it can evolve into a comprehensive energy resilience solution for sustainable urban infrastructure.

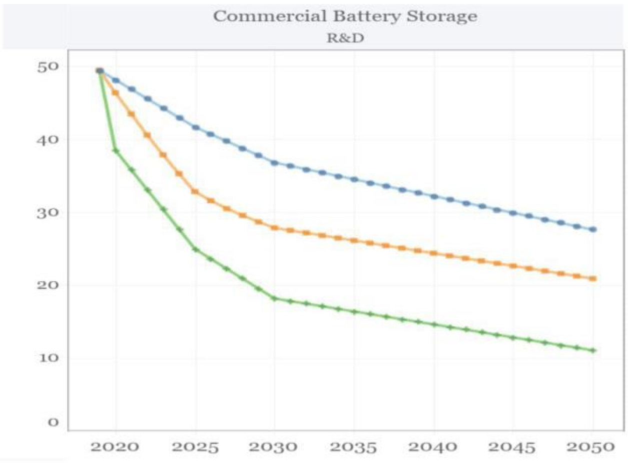

Fig 10.1

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CONCLUSION

This work presents the design and simulation of an emergency battery deployment system for multi-storey buildings to ensure uninterrupted supply of critical loads during unexpected power outages. The methodology involved systematic load data collection, circuit modeling in ETAP, fault simulation, and battery sizing for prioritized load support. The simulation results confirmed that the proposed system provides seamless transition between the utility grid and battery storage through an automated transfer switch, thereby eliminating manual intervention and minimizing downtime.

The designed 260 kWh battery system successfully sustained 130 kWh of critical loads for a backup period of two hours while maintaining stable voltage conditions. The strategy of prioritizing essential loads such as pumps ensured optimal utilization of stored energy and prevented system overloading. Compared to conventional diesel generator systems, the proposed approach offers advantages in terms of reduced emissions, improved response time, and enhanced sustainability.

Overall, the proposed system demonstrates a reliable, efficient, and environmentally friendly solution for emergency power management in modern buildings. The outcomes not only address the immediate technical challenge of uninterrupted critical load supply but also contribute to broader sustainability goals by promoting clean energy integration and responsible energy use.

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