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Research TEE

Distributed Load Shedding in Energy Distribution System with IoT

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Abstract

This project is designed to develop a modern power distribution and control system which is a very thoughtful one in reducing unwanted power usage in modern times. It is a microcontroller operated system where we fix a maximum power limit for each consumer. Night time is considered to be the peak time for energy consumption, to be precise from 6 to 11 pm. Here we program the microcontroller to cut off the supply when someone uses more power than a pre-set threshold limit. If the consumer connects more load than the threshold limit, it will alert him for a certain time and then automatically cut off the supply. The system also has cloud access to the authority's server so that they can monitor each consumer and can manage the connection and disconnection of the power supply. We program the microcontroller to monitor the load, whether it is inside the set limit. Here, we use a current and voltage sensor to calculate the unit of power consumption which will be varied according to the load connected. Microcontroller calculates the unit and amount according to the input pulses from the sensors. An LCD is interfaced for the visual display of unity and amount. A buzzer is connected to the controller to alert the over usage and the load relay will cut off if the usage remains above threshold. The controller can access the server since it has Wi-Fi connectivity. Every second the reading from each consumer will be updated to the server, and real time monitoring and control via internet becomes possible.

Keywords: LCD, microcontroller, Wi-Fi connectivity, buzzer, modern power distribution, energy sources, environmental concerns, electrical base station

INTRODUCTION

High energy usage is driven by factors like population growth, industrialization, and technological advancements. This demand strains resources like electricity and fuel, which can become limited due to factors such as finite energy sources, infrastructure constraints, and environmental concerns.

To manage this, effective control over energy consumption is necessary to prevent grid overloads and shortages. This involves optimizing energy usage, balancing supply and demand, and prioritizing critical infrastructure and services.

Load shedding is a method used to manage energy demand during peak periods. It involves intentionally cutting off power to certain areas or reducing energy supply to alleviate stress on the grid and prevent widespread outages. However, it is considered a last resort when other measures like demand response programs or energy efficiency initiatives are insufficient.

Overall, addressing the challenges of high energy usage and limited resources requires a comprehensive approach involving energy efficiency, investment in

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renewable energy, infrastructure development, and effective demand management strategies. This will help societies move towards a more resilient and sustainable energy future.

RELATED STUDY

Saleh *et al*. examined the procedures and strategies used to carry out load aggregation and discussed the crucial role that load aggregation plays in power system operations and smart grid functions. The suitability of load aggregation techniques for residential loads in smart grid operations is also covered in their study [1]. Many important issues pertaining to the grid's cyber-physical system are raised, and Tang *et al*. offer a broad framework for load control both preventive and emergency. Additionally, techniques for simulating the dynamic properties of GCPS were presented, such as co-simulation platforms and a novel approach to temporal synchronisation across simulation tools. Their report can serve as a guide for future research [2]. In order to economically increase system reliability, Awad *et al.* devised a mechanism for assigning dispatchable distributed energy units in systems of distribution [3]. Using the load shedding technique, Hirodontis *et al*. evaluated the behaviour of a 33 kV distribution network with distributed generators and a range of load types and sizes. The swing equation was used to assess the disturbance's magnitude, resulting in reduced customer disruption and a more effective system operating in emergency situations [4]. In order to stabilise the frequency, Mahat *et al*. proposed a plan to shed the ideal number of loads in the island. Customers' willingness to pay, load histories, frequency information, and the rate at which frequency changes are the foundations of the load shedding method [5].

Using a multi-agent system, Rwegasira *et al*. suggested a distributed load-shedding mechanism. With various forecasting tools, the agents in residential areas work together to lower the energy consumption. When the LoRaWAN protocol is used in its architecture, fog computing provides the computational distributed framework with the lowest possible power consumption, prices, and latency [6]. Gu *et al*. proposed a scheme that guaranteed the implementation of a decentralised UFLS by overcoming the leader-follower consensus algorithm's shortcoming through the application of the two-layer closest neighbour consensus algorithm (NNCA) [7]. Paul and Padhy provided a new real-time energy management framework that integrates load shedding and conservation voltage reduction (CVR) strategies for radial active imbalance distribution networks (UDNs). The suggested technique takes into consideration offline advantageous factors in real-time optimisation platforms as time-coupled stochastic expressions, in contrast to the opportunistic real-time optimisation procedures [8]. Zheng *et al*. offered a plan for building and putting this idea into practice for managing power demand that is based on contemporary smart control terminals and remote load regulation devices [9].

Bashir *et al*. focused on the unstudied issue of demand response in the setting of severely stressed power networks, which are permitted to periodically impose blackouts as a way to balance supply and demand. These utilities currently distribute their power/no-power schedules across consumer groups in a cyclic and binary manner, which results in severe capacity waste and extended periods of no power [10]. By boosting the number of participants in the load shedding programme, Faranda *et al*. introduced a novel strategy to ensure proper electrical system performance. Distributed Interruptible Load Shedding (DILS) is the name of this novel load control technique [11].

IoT-Powered Dynamic Load Shedding Scheduling

Load shedding is the deliberate turning off of power over a certain distribution region over prolonged periods of time. Dynamic load shedding maximises the electricity distribution under these circumstances. Based on a preset power consumption threshold, microcontroller units known as NodeMCU and Arduino NANO prioritise the connected loads. The microprocessor receives input from current sensors, which are used to calculate power consumption. The total power consumption of different loads is shown in a 16×2 LCD module. The microcontroller unit makes the determination of whether the power consumption is within acceptable bounds. If the NodeMCU module detects overuse, the alarm buzzer will sound for a predetermined period, alerting the user [12]. If the overuse continues, a signal is delivered to the relay telling it to cut off the power supply. The NodeMCU module incorporates a Wi-Fi module. As a result, this load system and the authority server can be connected. After that, authorities will oversee monitoring energy use. The authority may manually cut the power supply if they observe excessive use. In a similar manner, various loads can be monitored, and the power supply can be cut off when there is excessive use or when it exceeds the threshold. When power-consuming loads fall below the threshold, they can keep working normally. The layout is fully simulated using Proteus 8 Professional. The hardware circuit completed, and the model calculates the power usage and applies load shedding based on that information. The ESP8266 module is then used to transmit the acquired data to the server. HTML and PHP were used in the design of the admin and customer sides of the website. Data such as power consumption, peak hour settings, customer information, and energy bills are sent to the website [12].

China's Smart Demand Response: Obstacles and Motivators [13]

Through smart infrastructures, smart demand response (SDR) modifies end users' electricity-use in response to price signals or incentives. Peak shaving, the integration of renewables, the reduction of emissions, and the enhancement of grid resilience are all made possible in China via SDR programmes. The work of Guo *et al.* is unique from previous research in that it (a) thoroughly identifies China-specific SDR challenges and compares them with global experience; (b) finds efficient drivers to overcome new market challenges; and (c) makes policy recommendations and offers insights into China's future SDR development [13].

SYSTEM CONFIGURATION

During peak periods, the NodeMCU operates as the central control unit, monitoring the power consumption of the consumer through current sensor readings. By comparing these values to a predefined threshold, it ensures that power usage remains within acceptable limits. In the event of consumption exceeding this threshold, signalling potential excessive usage, an alarm buzzer is activated, alerting the consumer to the issue. The duration of this warning is customizable, allowing flexibility in response times. The consumer is then expected to take corrective action, such as turning off excessive loads, to bring consumption back within the threshold. If compliance is achieved promptly, normal operations resume without intervention.

However, should excessive usage persist, the system autonomously triggers load shedding through electromechanical relays, disconnecting specified loads for a predetermined duration. Once the outage duration elapses, power is automatically restored, and the system reassesses for over-usage. Throughout these processes, data is continuously transmitted via Wi-Fi to an Electrical Base Station, which forwards it to a central server for monitoring as shown in Figure 1. This enables manual checks of consumption levels and intervention in case of system failures. Moreover, the system supports the implementation of a billing system, as consumption data can be relayed to the consumer's website, facilitating billing and recharging options. Overall, this comprehensive system ensures efficient power management, consumer awareness, and accountability, bolstered by continuous monitoring and automated responses.

SCHEMATIC DIAGRAM

During peak hours, the NodeMCU serves as the guardian of power consumption, ensuring it remains within predefined limits. If usage surpasses these boundaries, an alarm prompts the user to scale back. If compliance is achieved, normal operations resume seamlessly.

However, persistent excess triggers automatic device disconnection until balance is restored. Oversight is provided by an Electrical Base Station, receiving real-time data via Wi-Fi for monitoring and intervention if required. A user-friendly website complements this setup, offering consumption tracking and streamlined bill settlement, enhancing overall efficiency as shown in Figure 2.

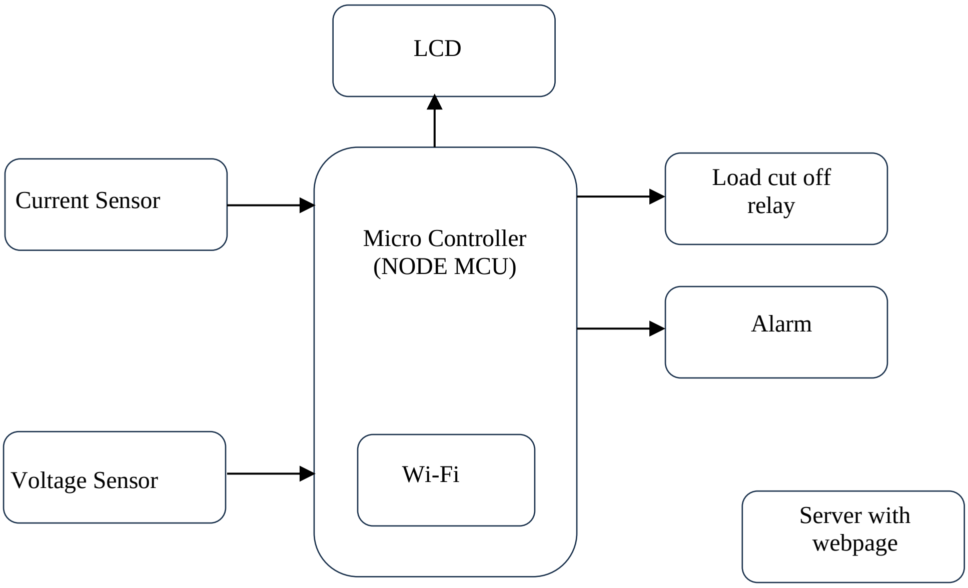

Figure 1. Block Diagram of the proposed algorithm.

SIMULATION

In the Proteus 8 Professional simulation, the NodeMCU is replaced with an Arduino UNO interfaced with a Wi-Fi module to achieve similar functionality as shown in Figure 3. During peak hours, a switch selects the peak mode, indicating "Peak" on an LCD screen. Power consumption metrics are displayed on the LCD, with brightness and contrast controlled by a variable resistor. The Arduino communicates with the Wi-Fi module via serial connection. A threshold of 10 A is set, with excess usage triggering an alarm LED and potentially leading to load shedding. Load shedding occurs if over-usage persists, with power automatically restored after a set interval. The simulation differentiates between peak and normal hours, with load shedding and alarms activated only during peak times. Virtual Terminal in Proteus displays messages regarding power cutoff and restoration. Additionally, a reading switch emulates energy meter readings, incrementing units on the LCD display. Variable resistors provide different voltage and current values for testing purposes.

HARDWARE SETUP

The admin page serves as a central hub for the administrator or utility area manager to oversee and manage users' electricity usage within the region. Here, the administrator can view a comprehensive list of users and their corresponding electricity consumption data. This data allows the administrator to monitor usage patterns and make informed decisions regarding peak time adjustments based on seasonal variations in electricity consumption and production. Additionally, the administrator has the authority to update the user list as needed, adding new users or removing expired ones. This flexibility empowers the administrator to fine-tune peak hours to optimize energy management effectively. A user-friendly dashboard presents key information such as username, consumer ID, account balance, energy usage, and alert status as shown in the prototype of Figure 4. By entering their user ID and password, users can view their current electricity usage in real-time, ensuring transparency and enabling proactive management of their energy consumption.

Users also have the option to remotely control loads, with button functionality contingent on network accessibility. High-speed network connectivity ensures swift response times, whereas slower networks may result in minor delays in relay actions. To recharge their accounts, users can choose from four preset monetary options. Prepaid recharging is available to avoid disconnection due to low balance warnings. A system of periodic deductions from the total pool, proportional to energy consumption, ensures continuous service. In this system, a fixed amount of Rs. 12 per unit of energy consumed is deducted, facilitating straightforward billing and payment processes for users.

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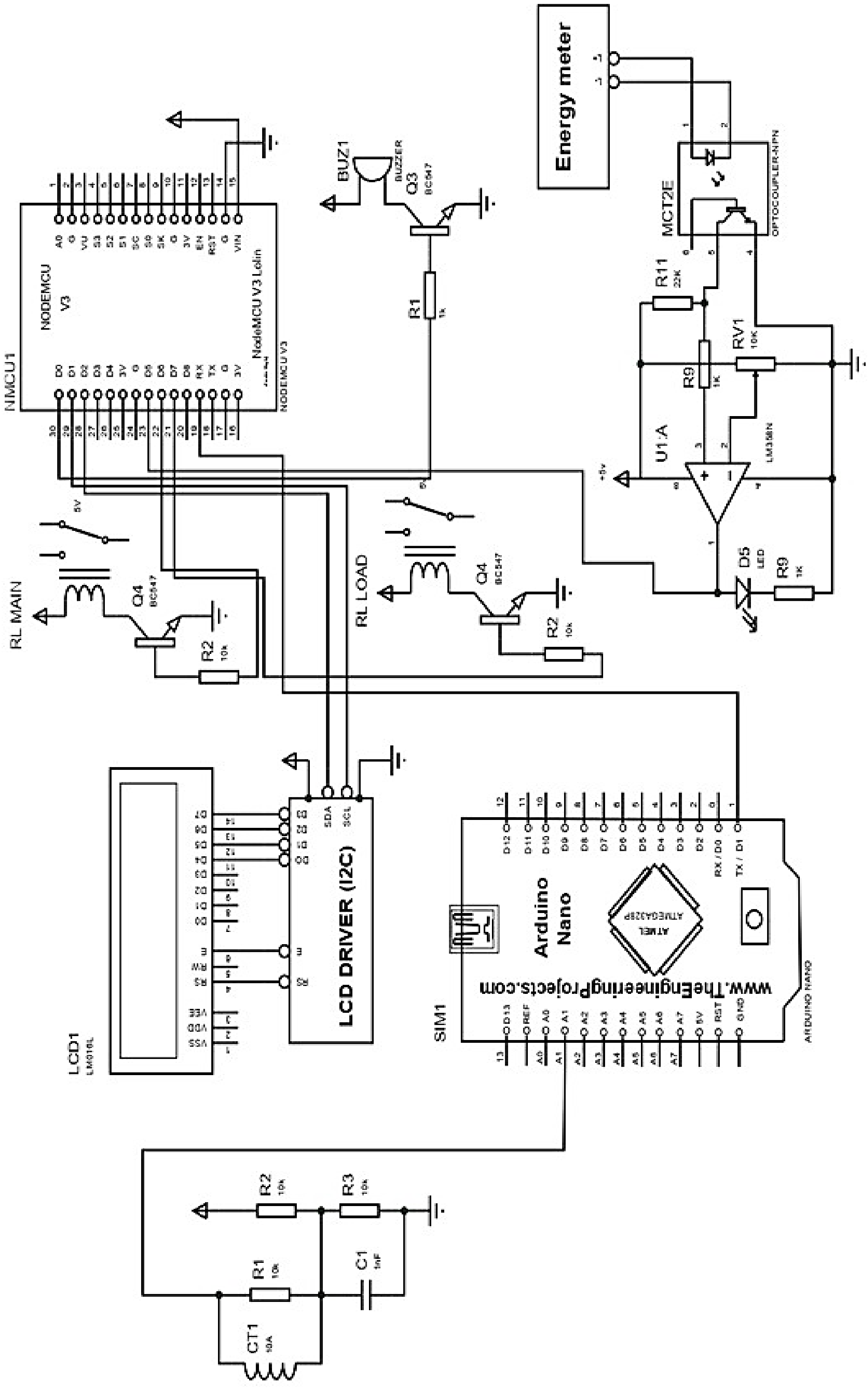

Figure 2. Circuit Diagram of the proposed system.

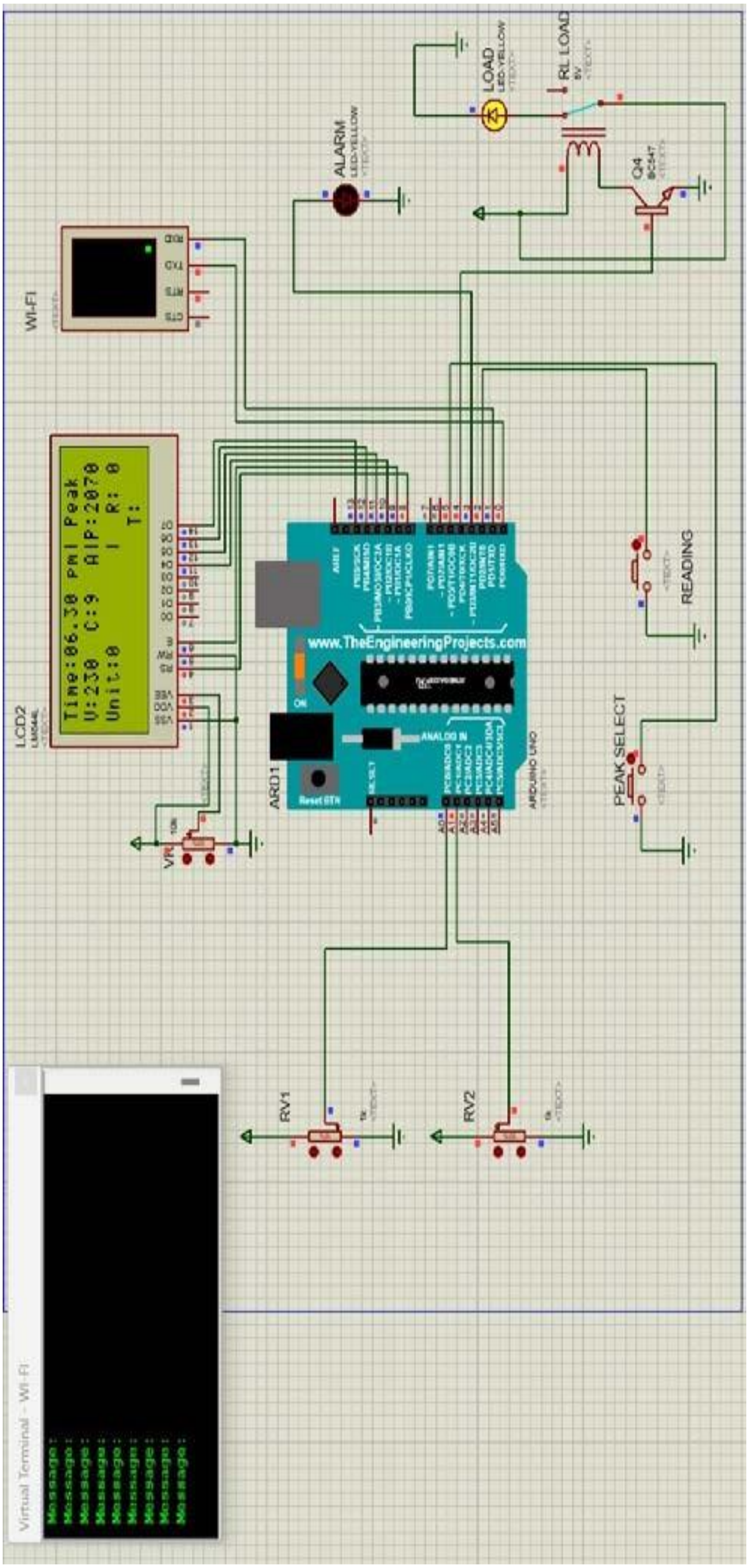

Figure 3. Simulation Diagram of the proposed algorithm.

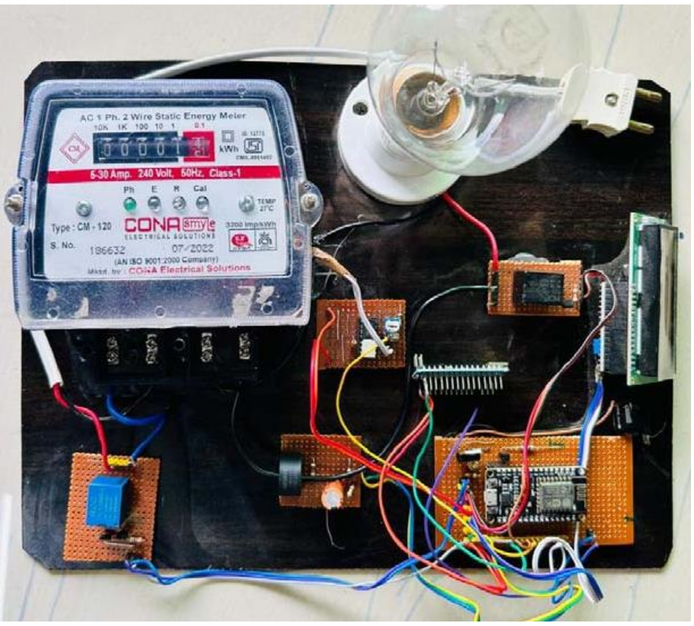

Figure 4. Hardware Setup of the proposed prototype.

Figure 5. Admin Side Website page.

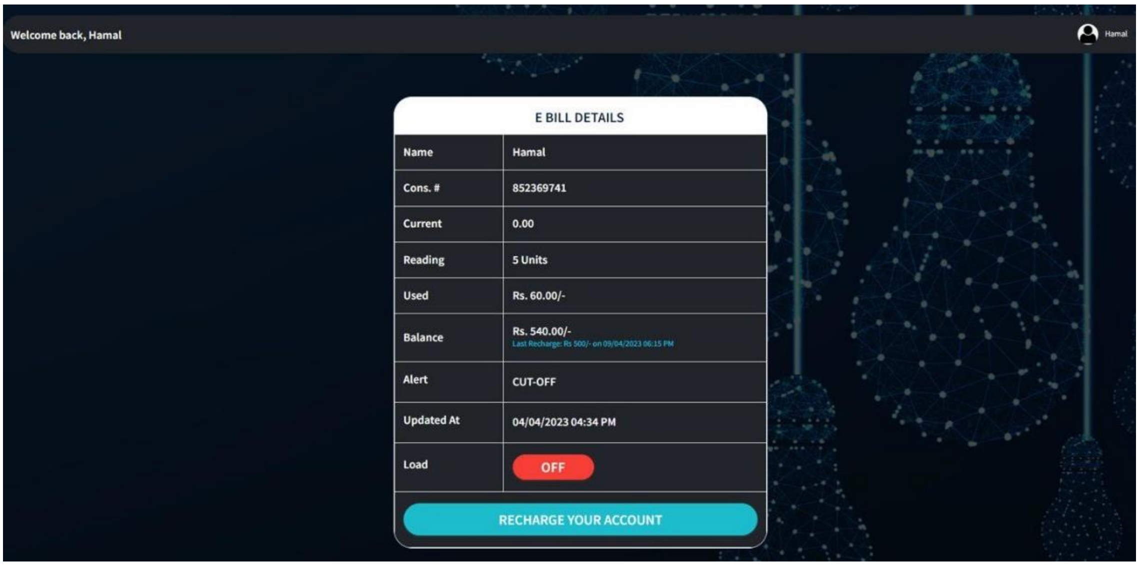

Figure 6. User Side Website page.

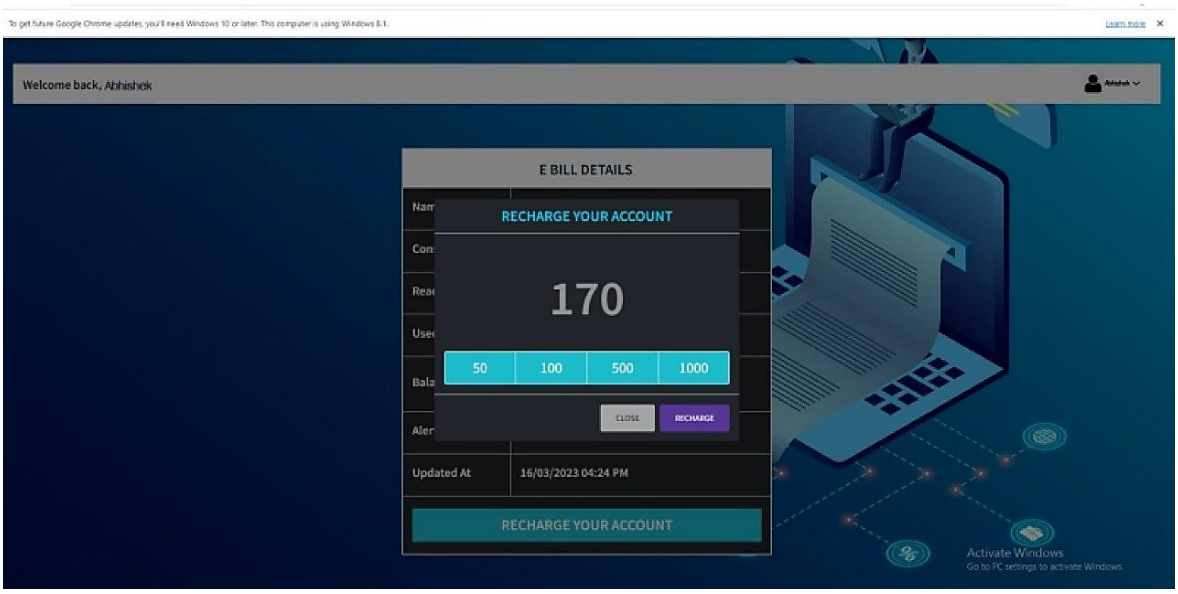

Figure 7. Recharging Page.

WEBSITE

On the home or user page of the electricity utility account, customers have access to critical information related to their energy consumption and payment details as shown in Figure 5. The consumer website provides users with tools to monitor and manage their electricity usage efficiently. Real-time data obtained from servers ensures accuracy and reliability, minimizing errors in consumption reporting. A prominent feature of the dashboard is the alert status column, which directly correlates with the load shedding procedure. If excess usage triggers a warning, followed by load shedding, the status reflects "CUT OFF", providing users with immediate feedback on their energy consumption behaviour. The user side website page is shown in Figure 6. Recharging Page of the website shown in Figure 7.

CONCLUSION

A dynamic load shedding management system ensures uninterrupted power supply to consumers by allowing them to prioritize tasks within operational limits, preventing complete power outages. This user-friendly approach aligns with the notion of electricity as a basic right. The system integrates simulation, hardware implementation, and web interfaces for both administrators and users. Users can monitor power consumption, manage energy bills through prepaid recharging, and optimize energy usage, thereby reducing costs.

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