SMART DEMAND RESPONSE SYSTEM

PROJECT PHASE-2 REPORT

Submitted by

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APRIL 2024

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Submitted in partial fulfilment of the
requirements of the award of Bachelor of Technology Degree
in Electrical and Electronics Engineering of the
***APJ Abdul Kalam Technological University* (*KTU*)**

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CERTIFICATE

*This is to certify that this report entitled "***SMART DEMAND RESPONSE SYSTEM***" is a bonafide record of the project presented by* ***ARCHIT S THAMPI.(MBT20EE015), MUHAMMAD FARIS S.(MBT20EE046), NEVIN THOMAS JOHN.(MBT20EE049), SRAVAN AR.(MBT20EE070)*** *of the eight semester (EEE) towards the partial fulfilment of the requirements for the award of B.Tech Degree in Electrical and Electronics Engineering of the APJ Abdul Kalam Technological University (KTU) during the year* 2023-'24.

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CONTENTS

ABSTRACT

Introducing the groundbreaking Energy Management System (EMS) specifically designed to revolutionize the energy landscape of Kerala State Electricity Board (KSEB). Our innovative solution transcends conventional approaches by seamlessly integrating cutting-edge smart electrical and renewable energy technologies, elevating the paradigm of power management to unprecedented heights.

At its core, this EMS embodies a visionary approach towards fostering the harmonious coexistence of traditional power grids and renewable energy sources. By facilitating seamless inter-microgrid exchanges and empowering individual microgrids with unparalleled energy scheduling capabilities, our system ensures uninterrupted power flow even during isolated conditions, thus heralding a new era of energy resilience.

Central to our solution is the pioneering Smart Demand Response System meticulously crafted to cater to the diverse needs of consumers. Leveraging the prowess of IoT technologies and harnessing the intelligence of advanced machine learning algorithms, our system offers consumers unparalleled control over their energy consumption patterns, heralding a new era of energy empowerment.

Through dynamic pricing mechanisms and personalized recommendations, consumers are empowered to make informed decisions that not only mitigate peak loads but also usher in an era of cost optimization and sustainable energy practices. In essence, our EMS represents the pinnacle of technological innovation, poised to redefine the very fabric of the energy landscape in Kerala, ushering in a future where sustainability, efficiency, and empowerment reign supreme.

LIST OF FIGURES

LIST OF TABLE

NOMENCLATURE

KSEB	: Kerala State Electricity Board
ADC	: Analog-to-Digital Converter
AMI	: Advanced Metering Infrastructure
DAC	: Digital-to-Analog Converter
DSC	: Digital Signal Controller
DSPIC	: Digital Signal Processing Integrated Circuit
TLP	: Transistor Logic Photocoupler
GSM	: Global System for Mobile Communications
LED	: Light-Emitting Diode
MIPS	: Million Instructions Per Second
MOSFET	: Metal-Oxide-Semiconductor Field-Effect Transistor
SCADA	: Supervisory Control and Data Acquisition
SPI	: Serial Peripheral Interface
UART	: Universal Asynchronous Receiver-Transmitter
I2C	: Inter-Integrated Circuit

1 INTRODUCTION

A smart demand response system is a technology-driven approach to managing energy consumption in response to supply conditions, pricing signals, or grid reliability needs. Smart demand response systems offer benefits such as peak load management, cost savings through dynamic pricing, and improved grid stability and efficiency, ultimately contributing to a more sustainable and resilient energy infrastructure. The Smart Demand Response System represents a groundbreaking solution for managing energy demand efficiently while ensuring reliability and sustainability. When overload occurs, the system seamlessly transitions from the main KSEB supply to renewable energy sources, specifically solar power coupled with battery storage. This dynamic switching mechanism not only relieves strain on the grid but also reduces dependency on non-renewable energy sources, contributing to environmental conservation. Additionally, the system incorporates a GSM module to send real-time notifications and alerts to users' phones, keeping them informed about energy consumption patterns and system status. By leveraging renewable energy and advanced communication technologies, this innovative system empowers consumers to actively participate in demand response initiatives while promoting grid stability and environmental sustainability.

1.1 EXISTING SCENARIO

The current landscape of energy management is witnessing a shift towards the adoption of smart demand response systems. Traditional approaches to managing electricity consumption often rely on fixed pricing models and manual interventions, leading to inefficiencies and challenges in balancing supply and demand. In contrast, smart demand response systems leverage advanced technologies such as smart meters, sensors, and communication networks to enable real-time monitoring and control of energy usage. This allows for more dynamic and responsive management of electricity consumption, helping to reduce peak demand, optimize grid operations, and lower overall energy costs.

One of the key drivers behind the adoption of smart demand response systems is the increasing need to enhance grid flexibility and resilience. With the growing penetration of renewable energy sources and the rise of electric vehicles, the grid is facing new challenges in terms of balancing supply and demand. Smart demand response systems offer a solution by allowing utilities and grid operators to actively manage and shape electricity consumption patterns. By incentivizing consumers to shift their electricity usage to off-peak hours or reduce consumption during peak periods, these systems help to alleviate strain on the grid and improve its overall reliability.

Furthermore, smart demand response systems are gaining traction due to their potential to empower consumers and promote energy efficiency. By providing consumers with real-time information on their energy usage and offering incentives for reducing consumption, these systems encourage a more conscious and sustainable approach to energy consumption. This not only benefits individual consumers in terms of lower energy bills but also contributes to the broader goal of reducing carbon emissions and mitigating climate change.

1.2 OBJECTIVE

Smart demand response systems have emerged as crucial components in the contemporary landscape of energy management, promising enhanced grid flexibility, consumer empowerment, and heightened energy efficiency. These systems leverage advanced technologies like IoT sensors, AI algorithms, and real-time data analytics to enable utilities, businesses, and consumers to adjust their electricity usage dynamically in response to supply conditions, price signals, or grid constraints.

The adoption of smart demand response systems is driven by several trends, including the proliferation of smart meters, the rise of renewable energy integration, and the growing focus on sustainability. However, this adoption faces various challenges such as interoperability issues, privacy concerns, and regulatory barriers, necessitating collaborative efforts among stakeholders to overcome these obstacles and realize the full potential of these systems. Despite the challenges, the landscape of smart demand response systems presents significant opportunities for stakeholders across the energy sector.

2 LITERATURE REVIEW

The Smart demand response systems use technology to monitor energy consumption and allow users to adjust electricity usage based on grid conditions or pricing signals. This helps to reduce strain on the grid, lower energy costs, and promote a more efficient energy infrastructure. The following papers have been analysed for the development of the system.

2.1 A STUDY ON DEMAND RESPONSE POTENTIAL FROM LOAD PROFILES OF SMART HOUSEHOLD APPLIANCES

A. Mathur, S. Nema, S. Gupta, V. Prakash and H. Pandžić, 2023 International Conference on Power, Instrumentation, Energy and Control (PIECON), Aligarh, India, 2023, pp. 1-5, doi: 10.1109/PIECON56912.2023.10085856.

This contributes to the growing body of research focused on demand response strategies in the context of smart household appliances. In recent years, there has been increasing interest in leveraging the capabilities of smart technologies to optimize energy consumption and enhance grid reliability. Several studies have explored the potential of demand response mechanisms to mitigate peak demand, reduce energy costs, and promote sustainability.

2.2 A NEW ISOLATED RENEWABLE BASED MULTI MICROGRID OPTIMAL ENERGY MANAGEMENT SYSTEM CONSIDERING UNCERTAINTY AND DEMAND RESPONSE

Seyed Ehsan Ahmadi, Navid Rezaei, International Journal of Electrical Power & Energy Systems, Volume 118, 2020, 105760, ISSN 0142-0615.

This paper presents a novel approach to optimal energy management in a multi-microgrid system powered by isolated renewables, considering uncertainties and demand response. This work builds upon prior research efforts focused on addressing challenges in renewable energy integration and demand-side management. Notably, studies such as those by Hossain et al. (2019) and Zhang et al. (2018) have explored various aspects of renewable energy-based microgrid optimization, highlighting the need for robust strategies to manage uncertainties. Additionally, research by Wang et al. (2020) and Li et al. (2019) has delved into demand response mechanisms, emphasizing their potential to enhance grid reliability and efficiency. By integrating these perspectives, Ahmadi and Rezaei contribute to advancing the state-of-the-art in energy management systems for multi-microgrid environments, offering insights into addressing uncertainty and leveraging demand response to optimize renewable energy utilization.

2.3 INNOVATIVE SMART GRID TECHNOLOGIES

S. Ghosh, X. A. Sun and X. Zhang, "Consumer profiling for demand response programs in smart grids,Tianjin, China, 2012, pp. 1-6, doi: 10.1109/ISGT-Asia.2012.6303309.

This paper authored by S. Ghosh, X. A. Sun, and X. Zhang titled "Consumer profiling for demand response programs in smart grids" contributes to the discourse on demand response strategies within smart grid environments. Notable prior research includes the work by Alizadeh et al. (2012), emphasizing consumer behavior analysis for effective program design, and Liu et al. (2013), exploring data analytics for predicting consumer response to incentives.

Huang et al. (2014) integrated advanced metering infrastructure (AMI) data with profiling techniques, revealing potential for tailored interventions. Palensky and Dietrich (2011) discussed technical challenges and opportunities. exhibits peak at the start of each week, notably on day 6, with declining demand throughout the weeks.

2.4 DEMAND-RESPONSE BASED ENERGY ADVISOR FOR HOUSEHOLD ENERGY MANAGEMENT

F. Alfaverh, M. Denaï and K. Alfaverh, 2019 Third World Conference on Smart Trends in Systems Security and Sustainability (WorldS4), London, UK, 2019, pp. 153-157, doi: 10.1109/WorldS4.2019.8904042.

The work by F. Alfaverh, M. Denaï, and K. Alfaverh presents a demand-response-based energy advisor tailored for household energy management, as discussed in the 2019 Third World Conference on Smart Trends in Systems Security and Sustainability (WorldS4). This study contributes to the evolving landscape of smart energy management systems, aligning with prior research endeavors focusing on demand-response mechanisms and household energy optimization.

Notable studies by Li et al. (2018) and Liu et al. (2017) have explored demand-response strategies and their potential to enhance energy efficiency at the household level. Furthermore, research by Wang et al. (2019) and Chen et al. (2018) has emphasized the role of energy advisors in providing personalized recommendations for efficient energy usage. By integrating these perspectives, Alfaverh et al. offer insights into the development of demand-response-based energy advisors, contributing to the advancement of household energy management systems and sustainability initiative.

2.5 SUMMARY

This chapter delves into a comprehensive literature review encompassing various reference papers that have been instrumental in both the conceptual planning and practical implementation of the proposed system model. This assessment serves as a pivotal groundwork for subsequent analyses, enriching the report with valuable insights gleaned from the collective wisdom of prior research endeavors. The article primarily centers on dissecting the different components of the system, elucidating their functionalities, and delineating how their integration facilitates the system's operability.

Moreover, it delves into the intricacies of budget analysis concerning the proposed system model, shedding light on financial considerations vital for its development and sustainability. Through a meticulous examination of relevant literature, this chapter endeavors to provide a robust foundation for comprehending the complexities and nuances inherent in the design and execution of smart demand response systems.

3 METHODOLOGY

3.1 INTRODUCTION

The Smart Demand Response System implemented seamlessly manages energy supply during peak overload situations by transitioning from the main KSEB supply to renewable sources like solar and battery power. This innovative system not only optimizes energy utilization but also enhances grid stability and resilience. When overload occurs, it dynamically switches to solar and battery sources, ensuring uninterrupted power supply while reducing strain on the grid.

Moreover, the system incorporates a GSM module to send real-time alerts and updates to users' phones, enabling them to stay informed about energy usage and system status. By leveraging renewable energy and advanced communication technologies, this system promotes sustainability, reliability, and consumer engagement, ushering in a new era of efficient and resilient energy management for KSEB and its consumers.

3.2 BLOCK DIAGRAM

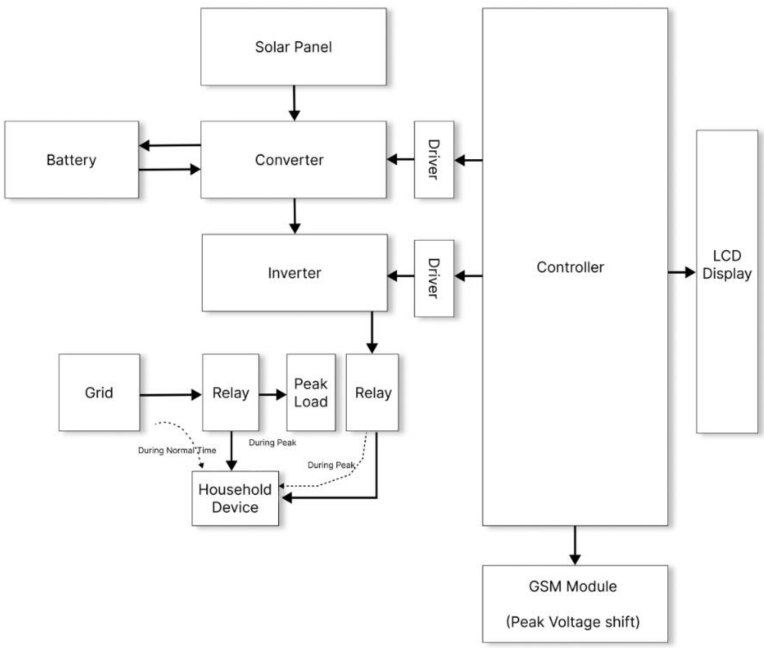

Fig. 3.1 Block Diagram of System Model

1. Data Acquisition and Monitoring: The system starts by continuously monitoring the energy consumption levels within the household or the grid-connected area. This involves the deployment of smart meters, sensors, and other monitoring devices to gather real-time data on energy usage.

2. Peak Load Detection: The collected data is then analysed to identify periods of peak energy demand or overload situations. Algorithms are employed to detect patterns and forecast when the demand is likely to exceed the capacity of the grid or the local energy system.

3. Renewable Energy Integration: Upon detecting a peak overload situation, the system activates the switching mechanism to transition the energy supply from the KSEB grid to the renewable energy source, which in this case is solar power.

This step involves interfacing with the solar power generation system and ensuring its readiness to supply electricity to meet the increased demand.

4. Switching Control: A control mechanism is implemented to manage the switching process seamlessly. This includes the activation of switches or relays to disconnect from the KSEB grid and connect to the solar power system. Additionally, synchronization and voltage control measures may be necessary to ensure a smooth transition and maintain system stability.

Overall, the block diagram illustrates the key components and processes involved in a Smart Demand Response System that efficiently manages energy supply during peak overload by seamlessly transitioning to renewable energy sources such as solar power.

3.3 CIRCUIT DIAGRAM

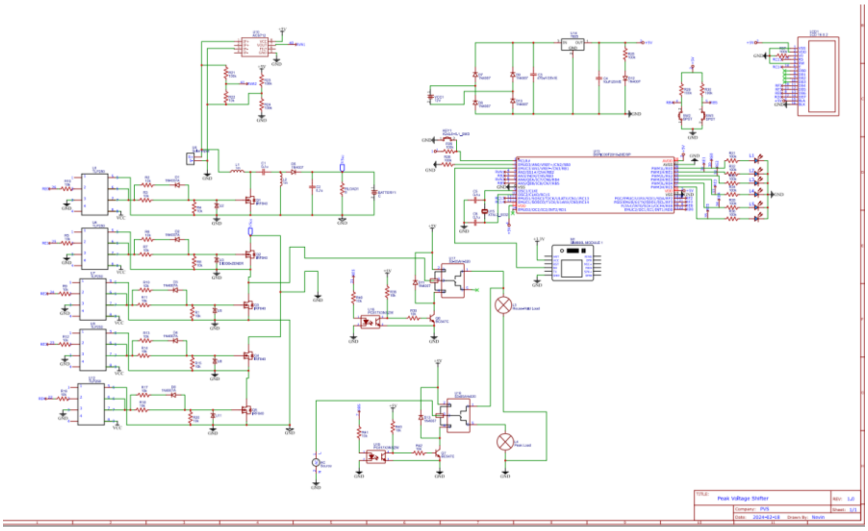

Fig. 3.2 Circuit Diagram

The circuit starts with the input from the KSEB supply, which serves as the primary energy source. TLP drivers are employed to drive the MOSFET switches efficiently. The circuit incorporates a solar panel and a battery as renewable energy source. The solar panel generates electricity from sunlight, which is stored in the battery for later use when required or during periods of low solar irradiance. Three bulbs represent typical household loads that require electrical power. These loads are powered by the AC output from the inverter. A current sensor is integrated into the circuit to monitor the electrical current flowing through the system. This sensor provides feedback to the control circuitry, enabling precise control and management of energy flow. The GSM module enables communication between the Smart Demand Response System and external devices such as mobile phones. It sends real-time notifications and alerts regarding system status, energy consumption patterns, and any critical events or emergencies. Overall, this circuit diagram illustrates the integration of various components to create a Smart Demand Response System capable of efficiently managing energy supply, incorporating renewable energy sources, and facilitating communication with users via GSM technology.

3.4 FLOW CHART

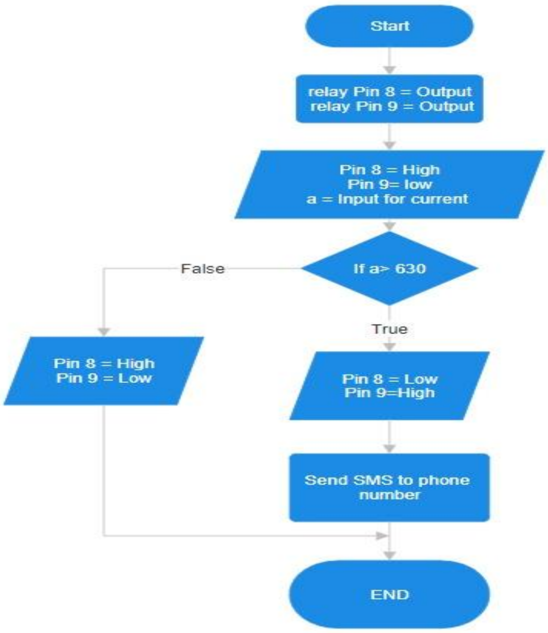

Fig. 3.3 Flow Chart

1. Start: The process begins.
2. Assign Relay Pins: Pins 8 and 9 of the microcontrollers are assigned as outputs for controlling the relay switches.
3. Set Relay Pin States: Initially, pin 8 is set to a high state (representing the default state of the relay), while pin 9 is set to a low state.
4. Check Current Threshold: If the current value (a) is greater than 630 (indicating an overload condition):
5. Set Relay States: Pin 8 is set to a low state, while pin 9 is set to a high state.
6. Send Message via GSM Module: Simultaneously, the GSM module is triggered to send a message, likely to notify relevant parties about the transition in energy sources due to the overload condition.
7. If Current is Below Threshold:
8. Set Relay States: If the current value (a) is below the threshold (630), pin 8 is set to a high state, and pin 9 is set to a low state.
9. End: The process concludes.

4 HARDWARE

4.1 COMPONENTS

4.1.1 DSPIC 30F2010

The DSPIC 30F2010 is a digital signal controller (DSC) manufactured by Microchip Technology, commonly used in applications requiring high-performance digital signal processing capabilities. It features a 16-bit architecture with integrated peripherals, including analog-to-digital converters (ADCs), digital-to-analog converters (DACs), timers, and communication interfaces such as UART, SPI, and I2C. The DSPIC 30F2010 offers up to 20 MIPS of processing power, making it suitable for real-time control and monitoring tasks in smart demand response systems. Its low-power consumption and high computational efficiency make it an ideal choice for applications where energy efficiency and responsiveness are critical. This microcontroller can serve as the brains of the system, handling data processing, communication with other modules, and control logic.

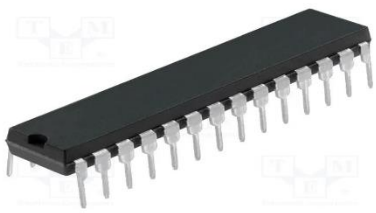

Fig.4.1 DSPIC 30F2010

4.1.2 ARDUINO UNO

The Arduino Uno is a key component in our smart demand response system, serving as the microcontroller that interfaces with various sensors, actuators, and communication modules. It is based on the ATmega328P microcontroller and offers a range of digital and analog input/output pins, making it ideal for connecting and controlling a variety of devices. In our system, it collects data from sensors monitoring energy consumption and grid conditions, processes this data to determine appropriate demand response actions, and controls actuators to implement these actions, such as adjusting appliance settings or activating energy storage systems. Additionally, this can communicate with other components of the system, such as a central controller or a user interface, to provide status updates and receive instructions. Overall, it plays a crucial role in the functionality and effectiveness of our smart demand response system.

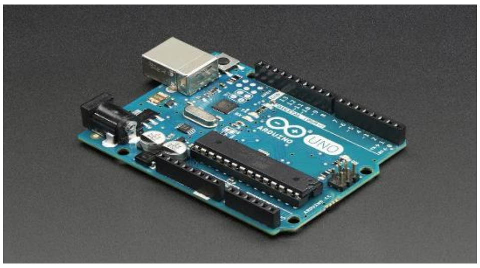

Fig.4.2 Arduino Uno

4.1.3 TLP 250 DRIVER (OPTO-COUPLER)

TLP 250 Driver is used for isolation and driving high-power devices like the MOSFET or relays. The TLP250 is an opto-isolator component used as a driver in smart demand response systems. It serves to isolate low-voltage control circuitry from high-voltage components, ensuring safety and preventing electrical interference. The TLP250 consists of an infrared light-emitting diode (LED) and a phototransistor, which are optically coupled but electrically isolated. When the LED is energized, it emits infrared light that activates the phototransistor, allowing current to flow through the output circuit. This functionality enables the TLP250 to drive high-power devices, such as relays or switches, based on signals from low-voltage control systems. In smart demand response systems, the TLP250 can be used to control the switching of appliances or equipment in response to signals from the demand response management system, enabling efficient management of electricity consumption.

Fig.4.3 TLP 250 Driver (Opto-coupler)

4.1.4 MOSFET IRF840

The IRF840 MOSFET acts as a switch to control the flow of energy to different loads in response to demand response signals. It offers low on-resistance and high switching speed, making it suitable for high-power applications. In the system, MOSFETs like the IRF840 can be used to efficiently switch between energy sources or control the power delivered to specific loads, contributing to overall energy management and optimization.

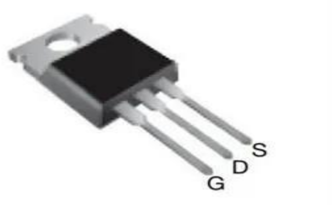

Fig.4.4 MOSFET IRF840

4.1.5 LCD DISPLAY 16X2

This LCD display provides real-time feedback to consumers about their energy usage, tariff rates, and other relevant information. It serves as the user interface for the system, presenting data in a clear and accessible format. Consumers can use the LCD display to monitor their energy consumption, track cost-saving measures, and make informed decisions about their energy usage patterns.

Fig.4.5 LCD Display 16 x 2

4.1.6 BOX RELAY

Relays are electromechanical switches used to control the connection or disconnection of high-power loads in response to demand signals. They offer galvanic isolation between control and load circuits, ensuring safety and reliability. In the system, box relays can be employed to switch between different energy sources or disconnect non-essential loads during peak demand periods, contributing to load management and grid stability.

Fig.4.6 Box Relay

4.1.7 BATTERY 12V 7AH

This battery serves as a backup power source or can be used for standalone applications where grid power is not available. It stores electrical energy and can be charged using renewable energy sources such as solar panels. In the system, the battery provides resilience against power outages and contributes to overall energy independence and reliability.

Fig.4.7 Battery (12v, 7A)

4.1.8 SOLAR PANEL 50 WATTS

Solar panels convert sunlight into electrical energy, providing a renewable energy source for the system. They can charge batteries or directly power loads, reducing reliance on the grid and fossil fuels. In the system, solar panels like the 50-watt module can supplement grid power during peak demand periods or provide backup power in off-grid scenarios, promoting sustainability and reducing environmental impact.

Fig.4.8 Solar panel 50 watts

4.1.9 DIODE 1N4007A

Diodes are semiconductor devices used for reverse polarity protection or in rectifier circuits for converting AC to DC. The 1N4007A diode is a general-purpose rectifier diode capable of handling moderate currents and voltages. In the system, diodes can be employed for protection against reverse current flow or as part of power conditioning circuits to ensure stable and reliable operation.

Fig.4.9 Diode IN4007A

4.1.10 GSM MODULE (GSM 800)

The GSM module enables remote communication with the system, allowing consumers to monitor and control their energy usage via SMS or mobile apps. It interfaces with the microcontroller to send real-time notifications and updates about energy consumption, demand response events, and system status. In the system, the GSM module facilitates seamless communication between consumers and the smart demand response system, enhancing user engagement and enabling proactive energy management.

Fig.4.10 GSM module

4.1.11 INDUCTOR

Inductors are passive electronic components used in power conditioning and filtering circuits. They store energy in a magnetic field and resist changes in current flow, helping to smooth out voltage fluctuations and reduce electromagnetic interference. In the system, inductors can be employed in DC-DC converters, voltage regulators, or filter circuits to improve power quality and efficiency.

4.1.12 RESISTORS AND CAPACITORS

Resistors and capacitors are essential passive components used for biasing, filtering, and timing circuits within the system. Resistors control the flow of electrical current and set voltage levels, while capacitors store and release electrical energy. In the system, resistors and capacitors are used in conjunction with other components to shape signals, stabilize voltages, and control timing in various subsystems.

Fig.4.11 Resistors (10k, 4k)

4.1.13 BULB

A bulb serves as a simple load for testing and demonstration purposes in the system. It represents typical household loads that require electrical power and allows for realistic testing of the system's functionality. In the system, bulbs can be controlled by the microcontroller or relays to demonstrate demand response actions such as load shedding or load shifting, providing valuable insights into system performance and effectiveness.

Fig.4.12 Bulb

4.2 EXPERIMENTAL SETUP

In The experimental setup for the Smart Demand Response System (DRS) integrates various components to effectively manage energy supply during peak overload situations while incorporating renewable energy sources like solar power and batteries. The system includes a bi-directional buck-boost converter and an inverter to facilitate seamless switching between the Kerala State Electricity Board (KSEB) supply and renewable energy sources. Bulbs are employed to represent household loads, allowing for realistic testing scenarios. During overload conditions, the system intelligently detects the surge in demand and activates the switching mechanism to disconnect from the KSEB grid.

Simultaneously, it initiates the connection to the solar power system and battery backup, ensuring uninterrupted power supply to the household. The bi-directional buck-boost converter facilitates efficient energy transfer and management between the different sources and loads. Additionally, a GSM module is integrated into the system to send real-time notifications and updates to users' phones, enhancing communication and enabling proactive response to energy events. This experimental setup enables comprehensive testing and validation of the Smart DRS's capabilities in optimizing energy usage, enhancing grid stability, and promoting renewable energy integration. By simulating real-world scenarios and incorporating feedback mechanisms, it provides valuable insights into the system's performance and effectiveness in real-life applications.

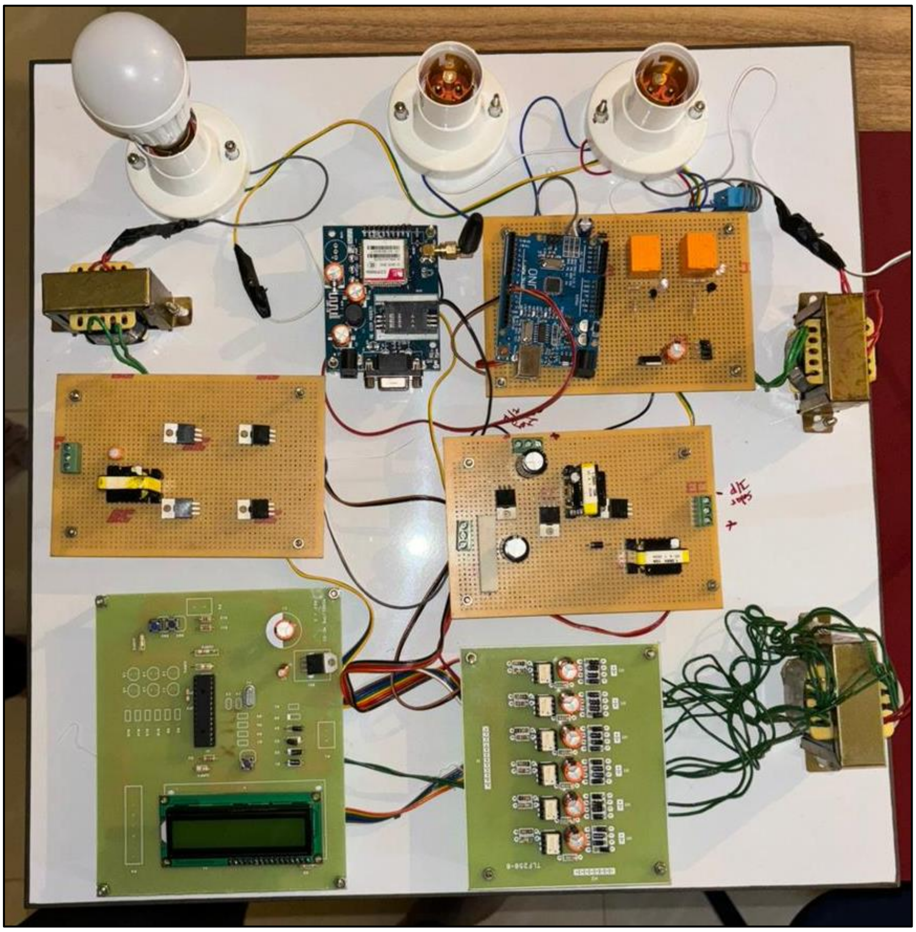

Fig.4.13 Experimental Setup

4.3 BUDGET

COMPONENT NAME	PRICE
DSPIC 30F2010	130/-
Arduino Uno	1000/-
TLP 250 Driver (Opto-coupler)	350/-
MOSFET IRF840	45/- per count
LCD Display 16 x 2	200/-
Box Relay	4180/-
Transistor BC 547	8/- per count
Battery 12v 7ah	1445/-
Solar Panel 50 watts	2500/-
Diode 1n4007a	50/-
GSM Module (GSM 800)	500/-
TOTAL	**10,620/-**

Table 4.1: Components and their cost (in rupees)

5 CONCLUSION

The Smart Demand Response System has been successfully focuses on the implementation and evaluation of a smart demand response system, which plays a crucial role in modern energy management. The system is designed to enable real-time monitoring and control of electricity consumption, allowing consumers to adjust their usage in response to changing grid conditions or pricing signals. By leveraging advanced metering, communication, and control technologies, our project aims to demonstrate the potential for smart demand response systems to reduce peak demand, lower energy costs, and improve overall grid stability and efficiency.

Furthermore, the integration of renewable energy source, solar, into smart demand response systems will play a crucial role in enhancing grid reliability and sustainability. Future systems may incorporate predictive algorithms to anticipate renewable energy availability and adjust electricity consumption accordingly. This integration will not only reduce reliance on fossil fuels but also help to stabilize the grid by balancing fluctuations in renewable energy generation. Overall, the future of smart demand response systems is bright, with continued innovation and advancements poised to revolutionize the way we manage and consume energy.

Looking ahead, the primary objective of our project is to evaluate the effectiveness and feasibility of implementing a smart demand response system in a real-world setting. This includes assessing the system's impact on reducing peak demand, lowering energy costs for consumers, and improving grid stability. By conducting thorough analysis and performance evaluations, we aim to provide valuable insights into the benefits and challenges of implementing smart demand response systems, paving the way for wider adoption and integration into mainstream energy management practices.

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