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Development of Smart Control System for Improved Energy Management in Building

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Abstract:
The advancement of technology has led to a rapid increase in modern appliances, transitioning from time-consuming manual processes to advanced smart control systems. However, many circuits, especially power supply circuitry, utilize inductors and transformers that draw higher currents than specified by manufacturers. Oversizing or undersizing these components can lead to adverse effects such as fire outbreaks or reduced equipment lifespan, ultimately costing more to replace. In response, this research proposes a smart control system to monitor, regulate, and balance energy demand and supply, employing load shedding in critical situations based on priority scheduling. The system, designed using Arduino IDE software for monitoring and decision-making, and simulated using Proteus software with the Senate building in FUTO as a case study, aims to optimize energy consumption and conserve usage. A hardware prototype validates the proposed control system, demonstrating organized shedding during peak load periods and reducing manual intervention. The proposed system offers a payback period of 2 months if implemented in the Senate building, providing efficiency, reliability, and cost savings.

Indexed Terms: Total Connected Load Current (CABC), Section A&B Load Current (CAB), Section A Load Current (CA), Renewable Energy Source Current (CRES), Battery Voltage (VB).

I. Introduction:

Despite increasing integration of renewable energy sources, residential energy supply still heavily relies on non-renewable resources through public utility services. Efforts to minimize energy usage, including adjusting usage times and employing efficient devices, are incentivized by governments to promote energy efficiency [1]. Efficient energy consumption is vital for balancing supply and demand, leading to benefits such as increased financial capital, environmental quality, and human comfort [2].

II. Objective:

The rapid increase in energy demand due to technological advancement poses challenges, particularly in power supply circuitry, where inductors and transformers draw significant inrush currents. Additionally, the efficiency of solar panels declines over time due to exposure to UV light and adverse weather conditions. Poorly sized systems can lead to fire outbreaks or reduced battery lifespan, necessitating costly replacements. To address these issues, a smart control system is proposed to monitor and compare renewable energy source power output with electrical load, prioritizing based on need. This system aims to reduce human intervention while ensuring resilience and reliability.

The primary objective of this research is to develop a smart control system for managing specific renewable energy resources at FUTO. To accomplish this, the following secondary objectives will be pursued:

i. Develop a block diagram for the smart control system. ii. Create a system algorithm and flowchart. iii. Design a circuit diagram for the smart control system. iv. Assess load demand and available resources at the Senate Building, FUTO. v. Develop and implement a

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software program for the system's operation sequence. vi. Construct a Smart Controller. vii. Test the effectiveness of the proposed system solution in improving energy efficiency.

III. Literature Review:

Previous research has explored the development of smart controllers, providing valuable insights for advancing this research topic. This section reviews several research papers authored by seasoned professionals in this field.

In [6], a home load management system was proposed for distribution utilities to mitigate unnecessary load shedding during peak hours. The system, based on Arduino technology, was simulated and tested using Proteus software, demonstrating cost-effectiveness and ease of implementation. It allowed for automatic switching off of heavy loads during peak hours without human intervention, encouraging their use during off-peak periods. Key features included cost-effectiveness, easy implementation, SMS notification, and a short payback period of one month if load reduction during peak hours reached 50%. Such projects offer benefits to both consumers and utilities, with potential savings for both domestic and commercial users. The system's estimated cost ranged from $28 to $43, depending on the inclusion of a Global System for Mobile Communications module for message notification.

[2] introduced a modular IoT-based Home Energy Management System, empowering users to regulate the electrical consumption of their appliances remotely. This system facilitated energy management in both urban and rural areas, integrating non-smart devices into the IoT space. Deployed in various real environments, including offices and high-energy-consuming households, the system achieved significant energy savings, with improvements over existing smart-device-only

[12] presented an embedded system incorporating solar and storage energy resources into a smart home, managing power flow during peak and off-peak periods. The system facilitated two-way communication between the homeowner and utility provider, resulting in a 33% reduction in energy bills.

[13] introduced a hybridized intelligent home renewable energy management system (HIHREM) that combines solar energy and energy storage services with smart home technology. By applying demand response and time-of-consumption pricing, the system minimized electricity costs while maximizing renewable energy consumption, achieving a 48% reduction in energy consumption and utilizing 65% of total generated renewable energy.

[14] proposed a novel energy management system capable of managing power consumption according to storage, production, and demand without compromising quality of life. The system prioritized appliances based on user selections and dynamically adjusted load priorities based on available power and weather predictions, enhancing the reliability of standalone PV systems.

IV. Materials and Methods:

A. Materials: The following hardware materials were utilized in designing and implementing the smart control system for improved renewable energy management in FUTO Senate Building:

- Power inverter
- Battery
- Polycrystalline photovoltaic panel
- Charge controller
- Microcontroller (Arduino Uno)
- Current sensor
- Voltage sensor
- 5V 10A 4-channel relay module
- Liquid Crystal Display
- Transformer
- Resistors
- Diode
- Voltage regulator
- Capacitors

The following software was employed in developing the smart controller:

- Arduino C++ programming language
- HOMER Software
- Proteus 8 Professional

systems.

[7] proposed a precise home energy management system designed to control power requirements between home appliances and power supply components. Using a Real-Time

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Energy Management System with Multi-Agent System (MAS), the system optimized device power demand and improved performance by enhancing response times and synchronization during peak and low peak periods.

In their study, [1] presented a wireless Home Energy Management (HEM) system for automatic regulation of home appliances to reduce energy consumption. Featuring intelligent sockets and a central smart controller with rule-based algorithms, the system effectively reduced energy consumption and costs while maintaining user lifestyles.

[8] introduced an intelligent energy management system integrating renewable energy sources and distributed energy storage in a residential building. By switching residential loads based on operating constraints, the system reduced operating costs and carbon emissions, with additional benefits from interconnected residential greenhouses.

[9] developed a smart energy monitoring system using Arduino and Wi-Fi, offering home automation and power management through a mobile app. This system reduced manual work and enabled remote monitoring of energy consumption.

[10] outlined a smart home automation controller system allowing remote access and control of home equipment via Internet connectivity. Utilizing voice recognition and web-based applications, the system provided convenience and accessibility, particularly beneficial for elderly and disabled individuals.

[11] developed a Smart Home Energy Management System (SHEMS) utilizing Wi-Fi technology to optimize home appliance operation based on residents' activity states. Using a Hidden Markov Model algorithm, the system estimated the probability of home states, thereby reducing energy consumption effectively.

B. Methods:

The design of the smart control system for enhancing renewable energy resources in the FUTO Senate Building architecture outlines the operational model for seamless energy integration into the building. Figure 1 depicts the block diagram of the micro-grid energy demand.

Hydropower energy from the Otamiri River, a high AC voltage source, undergoes voltage reduction via a transformerless voltage division unit before being directly fed into the analog-to-digital converter for voltage measurements.

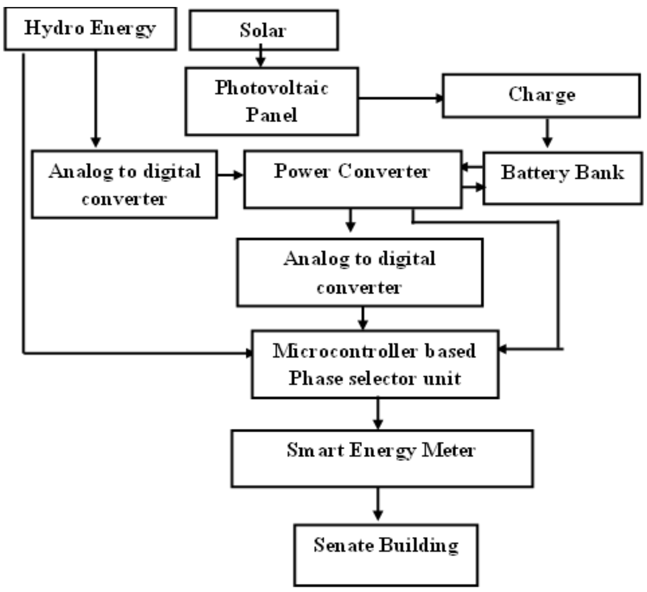

Figure 1: Micro-grid Energy Demand Optimization Block Diagram

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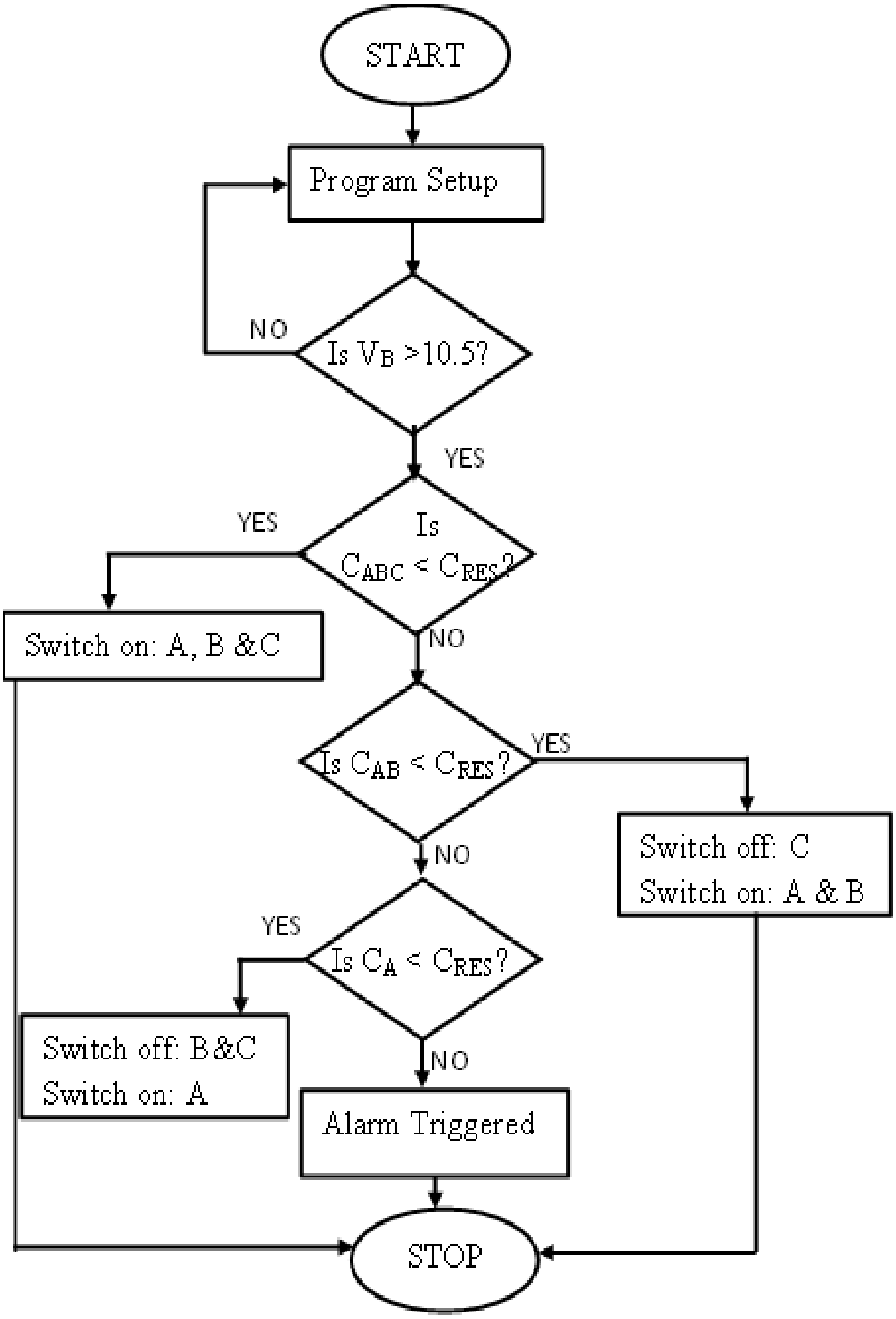

Fig. 2: Operational flowchart for the prototype system

Figure 2 illustrates the operational flowchart, commencing with the setup of the controller program. The signal flow begins with the assessment of the available power source, battery level, and current drawn by each load. If any load surpasses the predefined threshold of 25A, the system triggers the relay connected

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to that load for protection. Subsequently, it examines the disengaged port to compare the current demand of the load .

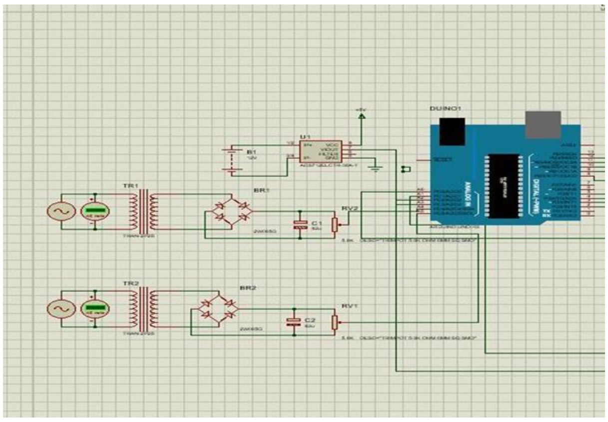

Figure 3 illustrates the Circuit Diagram of the Smart Control System designed for the Senate Building at FUTO.

COMPONENTS SPECIFICATION

a. Arduino Microcontroller (Arduino Nano): The properties of the Arduino's microcontroller are detailed in Table 1.

Table 1. Properties of the Arduino Nano Microcontroller

Properties	**Values**
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	22 (6 of which are PWM)
Flash Memory	32kB
Clock Speed	16MHz
Power Consumption	19mA

b. Four-channel Relay Module: The relay module serves as a link between the high-voltage home circuit and the low-voltage from the Arduino.

c. 10A PWM Charge Controller

d. 12V, 7.5Ah Lead Acid Battery

e. 20W polycrystalline PV panel

Table 2. Properties of Polycrystalline PV panel

Properties	**Values**
Peak Power	20W
Open Circuit Voltage	21.4V
Short Circuit Current	1.32A
Power Allowance Range	5%
Max Power Voltage	16.94V
Max System Current	1.18A

f. 500W power inverter with 12V input DC voltage and 220VAC output voltage

g. LCD 20x4 pixels, 5V input power

h. Fixed resistor [120Ω]

i. Smoothing Capacitor 82µF/12V

j. Rectifier diode 1N4007 (1A, 2W)

k. Transformer

VI. LOAD DEMAND ASSESSMENT

Estimation of hourly electrical energy demand (energy demand profile) of a given facility is paramount in the optimal energy management of renewable energy system, since the renewable energy sources are normally transient in supply.

Quantitative research method was used for this study. A survey through the university senate building was carried out and checklists were developed to generate information on the electrical load profile. The information collected from the survey was tabulated to the total loads of the building. The facility studied is the Senate building of the Federal University of Technology Owerri (FUTO).

The estimated daily load profile of the facility is shown in Figure 4. From the load profile, it can be seen that the maximum demand occurs during daytime from 10 am to 4 pm for the offices, which corresponds to the working hours in the University. During this period, a significant portion of the facility's energy consumption is attributed to various office-related activities, including lighting, air conditioning, and operation of electronic equipment.

It's noteworthy that 34% of the total offices/rooms across the area of survey were surveyed and visited, providing valuable insights into the energy consumption patterns within the facility. A typical senate load classification is given in Table 3, outlining the distribution of power demand across different

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sections of the building. Additionally, Table 4 provides detailed information on the AC power ratings of various appliances commonly found in the facility, along with their respective classifications serves as a foundational basis for the development and implementation of the smart controller system. By understanding the specific energy requirements and usage power consumption levels.

This comprehensive analysis of the facility's energy consumption patterns and load

patterns of different sections within the facility, the smart controller can effectively optimize energy utilization and enhance overall energy efficiency.

VI. LOAD PROFILE FOR SENATE BUILDING

Table 3: Total Load Profile Specifications for Senate Building

Equipment	Qty	Power (W)	Total Power (kW)	Hours/day	Day (9am-5pm) kWh	Night (6pm-6am) kWh
Air Conditioner	131	1120	146.7	8 Hrs	1173.80	-
Standing Fan	8	42	0.336	8 Hrs	2.7	-
Ceiling Fans	133	80	10.6	8 Hrs	85.1	-
Other Lighting points	46	60	2.8	8 Hrs	22.1	-
Security Lights I	12	18	0.22	-	-	2.6
Security Lights II	24	50	1.2	-	-	14.4
Computers	268	300	80.4	8 Hrs	643.2	-
Printers/Photocopier/Scanners	22	570	12.5	4 Hrs	50.2	-
Printers/Photocopier/Scanners	89	1000	89.0	4 Hrs	356.0	-
Printers/Photocopier/Scanners	66	1450	95.7	2 Hrs	382.8	-
Total peak load	-	-	449.2 kW	-	2793.6 kWh/day	17 kWh/day
Senate building daily load	-	-	-	-	2804.6 kWh/day	-
Senate building yearly load	-	-	-	-	729.2 MWh/year	-

Figure 4: Estimated Average Daily Load Profile for Senate Building

Table 4: Load Data for the Renewable Power Supply for the Entire Building in terms of Priority

Priority Level	Unit	Quantity	Total Power (kW)	Duration Of Usage (Hr)	Energy Consumption (KWH)
Priority One	(VC floor)				
	Air Condition	28	31.36	8	250.88
	Energy Lamp	237	14.22	8	113.76
	Computer unit	105	30.9	4	123.6
	Printer/Photocopier	27	27.0	4	108.0
	Photocopier	2	2.9	2	5.8
	Total		106.4		602.04
Priority Two	(Registry floor)				
	Air Condition	55	61.6	8	492.8

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	Energy Lamp	148	8.88	8	71.04
	Computer unit	82	24.6	4	98.4
	Printer/Photocopier	26	26.0	4	104
	Photocopier	2	2.9	2	5.8
	Total		123.98		772.04
Priority three	(Bursary)				
	Air Condition	48	53.76	8	430.1
	Energy Lamp	167	10.02	8	80.16
	Computer unit	81	24.3	4	97.2
	Printer/Photocopier	34	34	4	136.0
	Photocopier	2	2.9	2	5.8
	Sub-total		124.98		749.26
Basic total			355.36		2123 MWH

Note: Reserve/emergency overload is 25% of basic total load
25×355.36=88.8425×355.36=88.84
88.84100=3.410088.84=3.4
Therefore, the Senate building total energy demand is 355.36+88.84=444.2355.36+88.84=444.2 kW.

VII. HARDWARE IMPLEMENTATION

A prototype of the energy management system is built using a project-based scenario with one ACS 712 current sensor to determine the connected renewable energy sources [solar and hydro]. For testing, implementation, and evaluation, the prototype current values were factored to the scale 1:888 to perform a safe, practical demonstration.

Three lamps of 10W, 15W, and 5W were connected to portray the different load sections (A, B & C) scenarios for the experiment. During off-peak times, the three lamps can be turned ON and OFF anytime, but during peak hours, only a specified amount of the load can be used depending on priority. In this case, a total limit of 0.5A was set to check the proposed design's implementation, if the load exceeds this limit the buzzer is triggered.

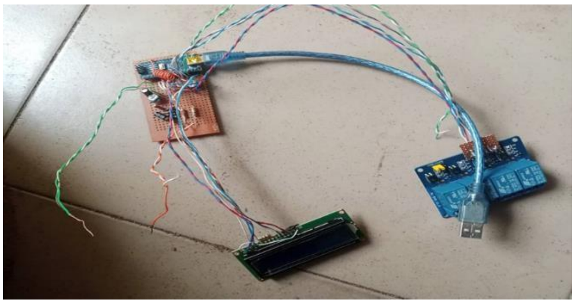

Figure 5: Implementation Stage of a Smart Controller for Renewable Energy Management in FUTO

The input terminal of the relay module were connected to the digital pin of the micro-controller which are triggered individually in accordance to the program coded driving the system. Similarly, the current sensing unit is connected to the analog pin 1 of the controller. This helps to measure the current drawn by the connected loads in each section of the FUTO senate building. The control, being the heart of the system, displays the action that are taken place in the LCD for easy visualization.

VIII. UNIT TEST FOR CURRENT SENSING CIRCUITRY

The current drawn by the load were tested with the aid of multimeter and Arduino serial monitor. Table 3.6 shows the current values based on the current demand of the entire sections (Section A, B & C).

Table 5: Current value based on the current demand

Section A	Section B	Section C	Action	Current
OFF	OFF	OFF	Buzzer ON	IL > 0.5

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ON	IL > 0.5	OFF	Section A ON	0.3 ≤ IL ≤ 0.5
ON	OFF	OFF	Section A ON	0.15 < IL < 0.3
ON	ON	OFF	Section A & B ON	0.05 ≤ IL ≤ 0.15
ON	ON	ON	All Sections ON	IL < 0.05
OFF	OFF	OFF	No Power Source	IL < 0.05

IX. RESULTS AND DISCUSSION

SIMULATION RESULTS AND DISCUSSION FOR THE SMART CONTROLLER ARCHITECTURE

The simulation result shows the LCD screen during different scenarios.

CONCLUSION AND RECOMMENDATION

A Smart Controller for energy management system for the Senate Building was developed. This system monitors and balances the energy source and electrical load by load shedding the less prioritized sections of the building, as proposed in this research. The Smart Controller System was effectively built, giving the building the ability to control the electrical consumption of their appliances. The Arduino-based smart controller for energy management system was simulated and tested using Arduino IDE and Proteus software. The design provides a virtual display that helps to visualize which section of the system is ON/OFF. The Senate building in FUTO was divided into three sections (Section A, B, and C) and selected for the prototype experiment. The result showed that the smart controller and the connected section of the building interact effectively for optimum energy utilization. The proposed system can be a cost-effective energy management system. The hardware prototype can be applied easily to heavy buildings due to its easy-to-use design. The Smart Controller can easily switch off the heavy sections of a building without human intervention.

The cost-effectiveness and easy application are key features of the proposed Smart Controller Energy management system. This project is essential for both individual households and the electric power utility sector, as both can benefit from this research work.

Hence, it is highly recommended to both individual households and electric power utilities sector to control the use of hefty electrical load during peak and off-peak hours as well as a substantial amount of cutback in finance for both household and industrial consumers is achieved by using this. This prototype design is solely implemented with only solar PV panel as hydropower system is not functioning at the time of this thesis.

Further research needs to be conducted to improve the system's designs by adding the wireless monitoring of renewable energy sources using android phone and sensitization of individuals on the need for energy management.

REFERENCES

[1] H. Shareef, E. Al-hassan, and R. Sirjani, "Wireless Home Energy Management System with Smart Rule-Based applied sciences Wireless Home Energy Management System with Smart Rule-Based Controller," no. June, 2020, doi: 10.3390/app10134533.

[2] E. A. Affum, K. A. Agyekum, C. A. Gyampomah, K. Ntiamoah-sarpong, and J. D. Gadze, "Smart Home Energy Management System based on the Internet of Things (IoT)," vol. 12, no. 2, 2021.

[3] Z. Maheshwari, "AN APPROACH TO MODELING AND OPTIMIZATION OF INTEGRATED RENEWABLE ENERGY SYSTEMS (IRES)," 2013.

[4] ClientEarth, "Fossil fuel and Climate Change: the fact." 2020, [Online]. Available: www.clientearth.org.

[5] H. Ritchie and M. Roser, Energy Mix. 2018.

[6] M. Bilal, B. Saad, and M. S. Saleem, "Design of home load management system for load rationing in Pakistan," no. September 2020, pp. 1–17, 2021, doi: 10.1002/eng2.12312.

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[7] Y. A. L. Sultan, B. S. Sami, and B. A. Zafar, "Smart Home Energy Management System A Multi-agent Approach for Scheduling and Controlling Household Appliances," vol. 12, no. 3, pp. 237–244, 2021.
[8] A. Ajao, "Intelligent Home Energy Management Systems for Distributed Renewable Generators, Dispatchable Residential Loads and Distributed Energy Storage Devices," 2017.
[9] N. Sulthana, "Smart Energy Meter and Monitoring System using IoT," vol. 8, no. 14, pp. 50–53, 2020.
[10] S. K. Vishwakarma, P. Upadhyaya, B. Kumari, and A. K. Mishra, "Smart Energy Efficient Home Automation System Using IoT," 2019 4th Int. Conf. Internet Things Smart Innov. Usages, no. February, pp. 1–4, 2020, doi: 10.1109/IoT-SIU.2019.8777607.
[11] B. Mubdir, A. Al-hindawi, and N. Hadi, "Design of Smart Home Energy Management System for Saving Energy," vol. 12, no. 33, pp. 521–536, 2016, doi: 10.19044/esj.2016.v12n33p521.
[12] A. El-hag, M. Bahadiri, M. Harbaji, and Y. A. El, "Energy Procedia Smart Home Renewable Energy Management System," Energy Procedia, vol. 12, pp. 120–126, 2011, doi: 10.1016/j.egypro.2011.10.017.
[13] Y. Ma and B. Li, "Hybridized Intelligent Home Renewable Energy Management System for Smart Grids," pp. 1–14, 2020.
[14] A. Solihin, "Design of a Smart Energy Management System for Photovoltaic Stand-Alone Building Design of a Smart Energy Management System for Photovoltaic Stand-Alone Building," 2020, doi: 10.1088/1757-899X/881/1/012158.