Automated PLC-Based Power Saving System for Classroom Electrical Loads Using Real Time Clock, Sensors, and Night-Time Cutoff Mechanism

Prasant Adhikari [1], Cheetiz Tamang [2], Hari Chettri [3], Newang Shenga [4]

[1,2,3,4] Student , Department of Electrical and Electronics Engineering, CCCT Chisopani, Sikkim

Abstract

The growing demand for electricity in educational institutions usually results in energy wastage by continuous use of electrical appliances such as lights and fans, even during idle time in classrooms. The remedy for this is through a smart and automatic system of managing power use effectively. In this paper, an effective solution by using a Siemens S7-200 Programmable Logic Controller (PLC) trainer kit with an embedded real-time clock (RTC) for scheduling is presented. The system is designed to regulate classroom electrical loads based on the institution's schedule, such that devices are utilized only when required. In order to further improve its decision-making, the system also includes a number of sensors like a Light Dependent Resistor (LDR) to track ambient light intensity, a temperature sensor to determine fan usage according to thermal condition, and an infrared (IR) sensor to determine occupancy. A contactor mechanism is also included to automatically switch off the power supply to classrooms or even blocks during nighttime hours, saving standby energy unnecessarily. The prototype was successfully designed and piloted in a real school setting, demonstrating efficacy in conserving electricity use by about 28%. The system is economical, scalable, and simple to maintain, providing an efficient and sustainable energy management solution for schools in the quest to improve efficiency and lower operational costs.

Keywords: PLC, Power Saving, Classroom Automation, Real-Time Clock (RTC), IR Sensor, Contactor, Energy Efficiency, Timetable-Based Control.

1. Introduction

In most educational institutions, electrical devices like fans and lights remain on even when classrooms are empty. This causes tremendous wastage of energy and a rise in the consumption rate of electricity. The main cause of such wastage is the lack of an efficient automation system and the practice of manual intervention in switching electrical devices on or off. In schools that have huge campuses and huge numbers of classrooms, the overall effect of this wastage of energy is enormous economically and environmentally as well.In response to this, the necessity for an intelligent, automated power management system has become increasingly evident. Such systems can optimize energy efficiency by managing electrical loads as a function of actual occupancy and environmental conditions, as well as the institutional calendar. A realistic approach is described in this paper using a Siemens S7-200 Programmable Logic

Controller (PLC) trainer kit with a Real-Time Clock (RTC) to provide schedule-based automation. PLCs have been renowned for decades as robust, programmable control devices that can be programmed to power industrial and automation applications with high reliability [4], [5], [6]. Previous studies have established feasibility and advantages of automation with the aid of PLCs. For instance, Puneeth S. et al. developed a power management system that efficiently controlled household appliances with the aid of PLCs, which minimized unnecessary power consumption by a great margin [1]. Erdal Irmak et al. also developed an interactive PLC-based home automation system, offering centralized control over lighting and HVAC systems with minimal user interface [2]. Zazilah et al. developed a PLC-based smart classroom energy-conserving system with sensors to automatically regulate lighting and air conditioning by occupancy [3]. While efficient, there was no night-time cut-off and schedule synchronization function, significant improvements achieved by our system. Besides these deployments, novel technologies in microcontroller-based smart automation and scheduling algorithms have also been explored to increase energy efficiency in domestic and institutional settings [9], [10]. These included, primarily, leveraging low-cost platforms like Arduino with environmental sensors and mobile interfaces for load control optimization. Based on these ideas, our system incorporates multiple environment sensors like a Light Dependent Resistor (LDR) for sensing ambient light intensity, a temperature sensor (DHT11) to ascertain the operating conditions for fans and a human presence infrared (IR) sensor to sense the presence of human beings in a classroom. In addition to these, to prevent wastage of power during idle periods, particularly during the night, a contactor is integrated to disconnect the power supply to classrooms and building blocks during idle hours.

By automating power in the classroom, the system not only reduces its reliance on humans but also enhances energy efficiency, reduces operational costs, and encourages green practice. It is an economical, scalable solution well suited for schools wanting to optimize resource utilization and environmental stewardship.

2. Litrature review

Efficient management of electrical energy in institutional buildings has become a crucial area of research due to rising energy costs and growing environmental concerns. Various studies have proposed the use of Programmable Logic Controllers (PLCs) and sensor-based automation to optimize power consumption.

Puneeth S. et al. [1] proposed a power management system for domestic appliances utilizing PLCs. Their work demonstrated effective reduction in unnecessary energy use by automating appliance control. However, the application was limited to household environments and did not account for institutional schedules or large-scale control.

Similarly, Irmak et al. [2] developed a smart home system that allowed centralized control of household devices through a computer interface. Their PLC-based design supported user interaction and basic automation. While practical for home applications, this model lacked environmental sensing and was not suitable for use in academic institutions.

Zazilah et al. [3] introduced a smart classroom energy-saving system using PLCs, incorporating sensors to manage lighting and fan operation based on real-time environmental conditions. Although this work closely relates to educational settings, it did not implement a time-based power shutdown mechanism or full integration with institutional routines.

Several foundational works also contribute to the understanding and implementation of PLC-based systems. Petruzella [4], Bolton [6], and Collins [5] provide comprehensive insights into PLC operation, ladder programming, and industrial automation concepts. Tubbs [7] offers a tutorial-based approach specifically for Siemens S7 PLCs, making it highly relevant to the hardware used in this project.

Digital logic theory forms the basis for programming decisions in automation. M. Morris Mano [8] explains essential logic structures that are implemented in both PLCs and microcontrollers for decision-making processes.

In addition, more recent work has focused on smart task scheduling and low-cost automation. Mukkawar and Sawant [9] developed an energy-efficient system that prioritized task execution based on demand, reducing idle power use. Similarly, Baraka et al. [10] proposed a low-cost Arduino and Android-based system that supported automated control of home appliances using environmental feedback and scheduling logic.

The system proposed in this paper builds upon the strengths of the above studies while addressing their limitations. By using the Siemens S7-200 PLC with an inbuilt Real-Time Clock (RTC), the system enables schedule-based automation. Furthermore, the integration of Light Dependent Resistor (LDR), temperature(DHT11), and infrared (IR) sensors ensures environmental responsiveness. A contactor-based power cutoff mechanism ensures that electrical loads are disconnected during non-operational hours, making it a comprehensive and efficient solution for classroom energy management.

3. Abbreviations and Acronyms

Table 1 : Abbreviations and Acronyms

Term	**Full Form**	**Type**
PLC	Programmable Logic Controller	Abbreviation
RTC	Real-Time Clock	Abbreviation
LDR	Light Dependent Resistor	Abbreviation

IR	Infrared (Sensor)	Abbreviation
DHT11	Digital Humidity and Temperature Sensor	Abbreviation
HVAC	Heating, Ventilation, and Air Conditioning	Acronym
/O	Input/Output	Abbreviation
AC	Alternating Current	Abbreviation
DC	Direct Current	Abbreviation
IoT	Internet of Things	Acronym
CCCT	Centre for Computer and Communication Technology	Abbreviation
kWh	Kilowatt-hour	Abbreviation
LED	Light Emitting Diode	Acronym
AI	Artificial Intelligence	Acronym
SCADA	Supervisory Control and Data Acquisition	Acronym

3. METHODOLOGY

The design and deployment of the automated PLC-based power-saving system entailed a number of systematic steps to achieve efficiency, reliability, and flexibility in educational settings.

A. Component Selection and System Architecture

- The heart of the system is the Siemens S7-200 Programmable Logic Controller (PLC), selected for its built-in Real-Time Clock (RTC) and strong digital input/output features. For monitoring environmental conditions and occupancy, the following sensors were chosen:
- Light Dependent Resistor (LDR): Tracks ambient light intensity to decide whether artificial lighting is needed.
- Temperature Sensor (DHT11): Tracks room temperature to regulate fan operation according to pre-set limits.
- Infrared (IR) Sensor: Tracks human presence to make sure electrical appliances run only when the classroom is used.
- Contactor: A contactor was added to allow full shutdown of electric supply during off-hours, increasing energy saving.

B. System Block Diagram

Fig. 1 –Block diagram of the PLC-based automated power-saving system showing integration of sensors, Arduino, relay, and contactor for classroom electrical load control

International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

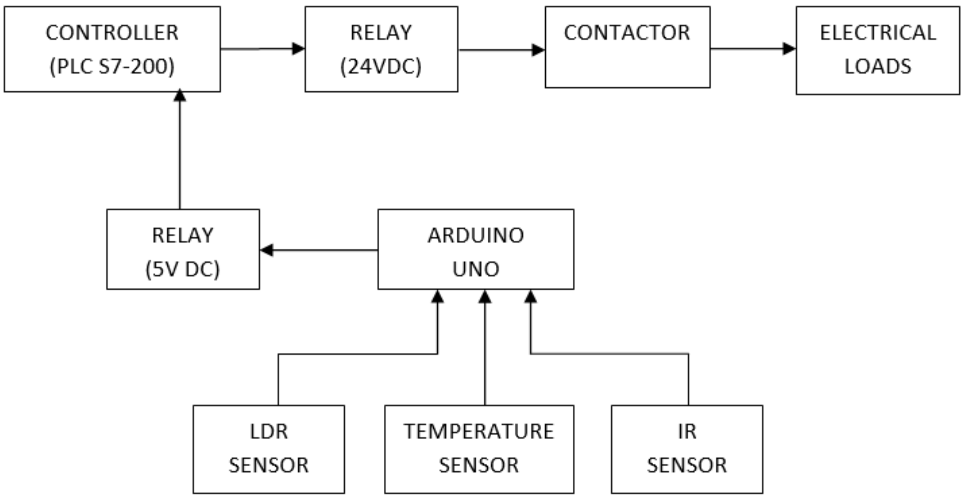


Fig. 1 shows the overall design of the proposed power-saving automated system. It comprises a PLC, Arduino, sensors, relays, and a contactor for general control and shutdown of classroom loads

The system uses a Siemens S7-200 Programmable Logic Controller (PLC) as a master controller. It is powered by a 230V AC power supply and drives a 24V DC relay that in turn drives a contactor to energize classroom electric loads (tube lights and fans). The contactor provides complete disconnection during night hours based on the PLC's Real-Time Clock (RTC).An Arduino Uno is used for the reading of the values of analog sensors and converting them into a digital signal to supply it to the PLC. An external 5V DC supply is given to the Arduino and is interfaced with the PLC through a 5V DC relay.The sensors employed are:

- LDR Sensor: Senses ambient light intensity to regulate lighting.
- DHT11 Temperature Sensor: Monitors room temperature to control fan operation if temperature exceeds a certain level.
- IR Sensor: Detects humans to ensure that loads only function when the room is occupied.

This design supports efficient and automatic handling of loads on environmental and schedule-initiated conditions, minimizing energy losses and minimizing the amount of human intervention.

C. Control Flow of PLC-Based Power Management System

Fig. 2 –Control Flow Chart of the PLC-Based Power Management System

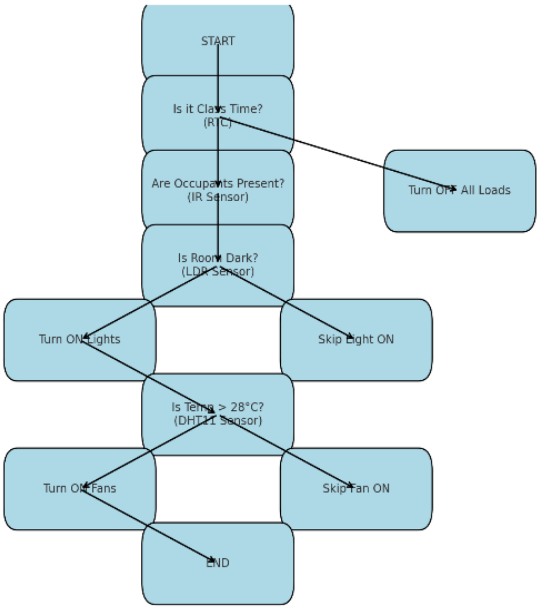


Fig 2 illustrating the control logic of the PLC-based power management system. The system checks the class timetable, room occupancy, ambient light, and temperature to make intelligent switching decisions. The logic of system operation is demonstrated in Fig. 2. The PLC checks if the time is class hours by using its internal RTC. If it is not class hours, the system turns off all the loads and enters idle mode.

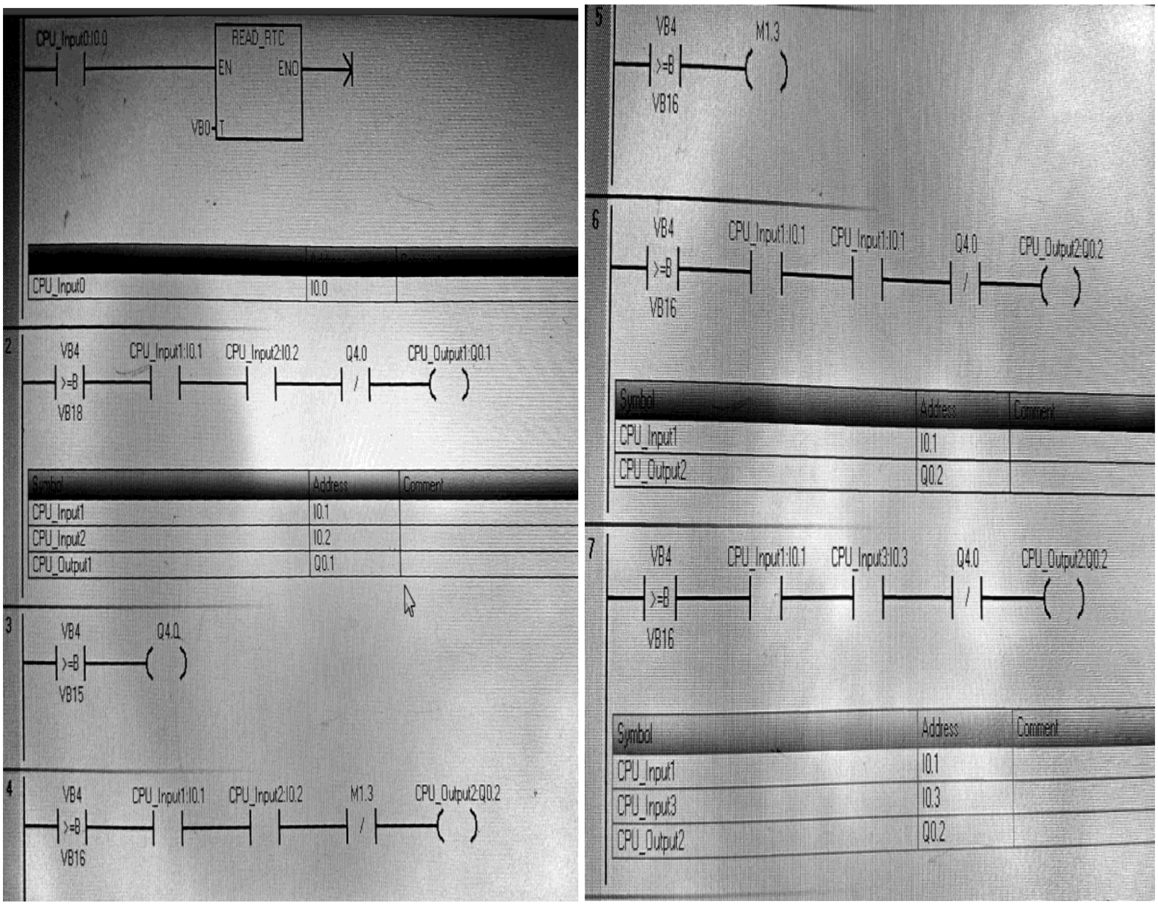
- If the time falls on a scheduled lecture time, the PLC then inspects for occupancy using an IR sensor. In the absence of students or staff, the system again switches off all appliances to prevent unnecessary power consumption.
- When the room is occupied, as well as in a reserved time slot, the PLC monitors environmental conditions to determine load status. Ambient light levels are monitored by an LDR sensor — lights are ON only when the room is dark. When the room is sufficiently lit up by natural light, the lights are OFF.
- Likewise, the system relies on a DHT11 temperature sensor to regulate fan operation. Fans are turned on if and only if the room temperature is higher than a predetermined value (e.g., 28°C). Otherwise, the system bypasses fan operation.
- This flow ensures efficient handling of classroom electrical loads, eliminating energy wastage through real-time decision-making and scheduling synchronization.

D. Sensor Signal Processing

Since the Siemens S7-200 PLC only accepts digital inputs, an Arduino microcontroller was used to handle the analog sensors (LDR, temperature sensor, and IR sensor). The Arduino interprets the analog signals, converts them to digital outputs according to calibrated thresholds, and feeds these signals to the PLC for making decisions.

E. PLC Programming and Logic Development

Fig -3 Ladder logic diagram used in the Siemens S7-200 PLC for time and sensor-based load control.



The ladder logic diagram in Fig. 3 shows the fundamental decision-making process employed in the Siemens S7-200 PLC with STEP 7 MicroWIN. The program consists of blocks of logic that address time-based control, sensor-based status, and load actuation.

The initial steps deal with schedule synchronization with the internal Real-Time Clock (RTC) to check against specified class hours. As soon as the time requirement is fulfilled, the logic moves to the next step.

The second part of the program reads digital inputs from the Arduino, which are the outputs of the IR, temperature, and LDR sensors. These signals are used:

Lights turn on only when the ambient light is less than a certain level (low LDR level).

Fans are switched ON only when the room temperature is higher than the set limit.

Loads are inhibited when there is no presence detected by the IR sensor.

The last process of the program employs a relay output to turn on or off the power to the electrical loads of the classroom by energizing a contactor. Complete power shutdown is also implemented during off-peak times, especially at nighttime.

In general, the ladder logic is designed to reduce human involvement and be energy saving by using time- and environment-based automation

F. Installation and Integration

The installation of system elements was done within a classroom, where sensors were placed in strategically chosen locations for precise monitoring of environmental factors and presence. PLC and Arduino were contained within a control panel that was interfaced with the classroom's electrical circuits to control light and fan operations.

G. Testing and Validation

The system was tested in a phase over several weeks to test it for its functioning in different conditions. Simulations for different usage patterns, varying conditions of ambient lighting, and fluctuating temperatures were carried out as part of tests. Monitoring the response of the system to validate correspondence to programmed logic and energy conservation targets.

4. Result and Observation

The proposed PLC-based automated power-saving system was implemented and tested in a real classroom environment over several weeks. The setup consisted of 5 tube lights (25 W each) and 4 ceiling fans (70 W each), giving a total connected load of 405 W. The system was designed to operate only during scheduled lecture times and respond dynamically to environmental conditions and occupancy.

A. System Performance and Observations

- Timetable Accuracy: The Siemens S7-200 PLC, using its inbuilt RTC, successfully turned classroom loads ON and OFF in alignment with the class schedule (9:30 AM – 12:15 PM and 1:15 PM – 4:00 PM), and remained OFF during lunch and after 4:00 PM.
- LDR Sensor Response: The system effectively utilized LDR input to keep lights OFF when sufficient daylight was available.
- Temperature-Based Fan Control: A DHT11 sensor was used to monitor ambient room temperature. Fans were activated only when the temperature exceeded 28°C, preventing unnecessary fan use in cooler conditions.
- Occupancy Detection: The IR sensor ensured that fans and lights operated only when students or staff were present, enhancing energy conservation.
- Night-Time Power Shutdown: A contactor controlled by the PLC cut off the classroom power supply strictly from 4:00 PM to 9:00 AM, eliminating overnight standby power usage.
- Energy Savings: During the observation period, the system achieved an estimated 28% reduction in electricity consumption.

B. Energy Consumption Analysis

The following comparison illustrates the impact of the automation system:

Table 2 : Energy Consumption Analysis

Condition	Daily Usage (kWh)	Monthly Usage (kWh)	Energy Saved (%)

Without Automation	2.835	62.37	–
With Automation (Scheduled + Sensor Based)	2.025	44.55	~28%

C. Idle Time Energy Saved

The system also prevented idle-time energy consumption during:

a. LunchBreak(1hr):

405 W×1 hr = 0.405 kWh/day

b. Night Shutdown (17 hrs):

405 W×17 hrs = 6.885kWh/day

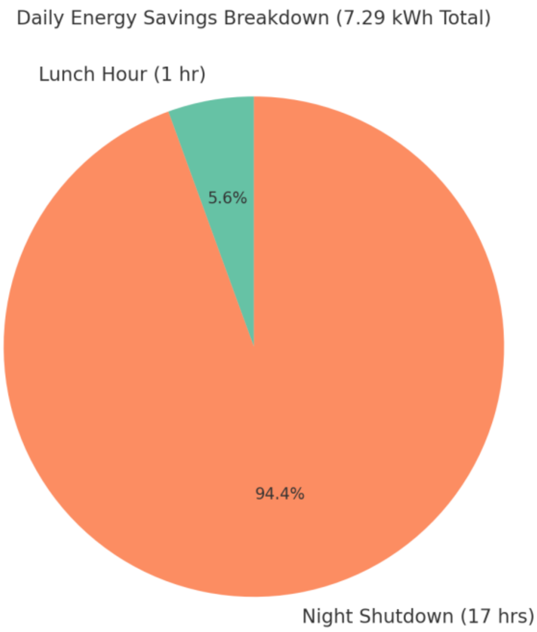
c. Total Daily Energy Saved:

0.405+6.

885 = 7.29kWh/day

D. Visual Representation

Fig. 5 – Daily Energy Savings Breakdown



As seen in Fig. 5, the majority of the daily energy savings comes from the nighttime shutdown (approximately 94%), while the lunch break contributes to the remaining 6%. This demonstrates how even short idle periods can lead to significant cumulative savings when managed automatically.

Advantages and limitations

A. Advantages

- Time-Based Automation: Using the onboard Real-Time Clock (RTC) capability of the Siemens S7-200 PLC enables precise scheduling of electric loads according to the institutional schedule. This eliminates the requirement for human intervention and allows for consistent operation.
- Sensor-Based Load Optimization: LDR, IR, and DHT11 sensors enable lights and fans to switch on only when needed, depending on the environment like light intensity, temperature,and occupancy. It reduces wasteful power consumption during unoccupied or brighter times.
- Night-Time:Power Switch-Off: An integrated contactor allows for complete shutdown of electrical loads at the end of the working day. This helps minimize power drain from appliances running overnight or standby system loads.
- Scalability: Due to the modularity in the system, it can easily be duplicated in numerous classrooms or even an entire building without having to make drastic changes in the manner of logic or hardware setup.
- Low Maintenance and Reliability: PLC-based control systems are highly dependable, immune to environmental interference, and have a long life span during operation, thus being ideal for long-term institutional applications with low maintenance.
- Long-Term Cost Saving: Even though the initial cost of installation is greater, the substantial reduction in electricity consumption leads to long-term cost savings, and hence the system is economically viable for educational institutations.
- Future-Proof: The system is designed to be future-proofed so that it can integrate with IoT modules, energy monitoring dashboards, or wireless control features in the future without having to re-implement the base infrastructure.

B. Limitations

- Initial Setup Cost: While the system is inexpensive in the long run, the initial setup cost of PLCs, sensors, relays, and installation for the first time might be too expensive for small or disadvantaged organizations.
- Rigid Structure of Logic: The existing framework involves reprogramming manually in case of a modification in the institutional schedule. It does not have adaptive scheduling or dynamic logic adaptation.
- Sensor Dependence: The system's accuracy and reliability heavily depend on sensors' correct installation and calibration. Incorrect installation can lead to spurious signals or incorrect load management.
- Use of External Microcontroller (Arduino): As the S7-200 PLC lacks analog input capability, an additional Arduino is utilized to convert analog sensor output to digital. This adds hardware complexity and can contribute some to debugging.

- Lacking Remote Monitoring: It does not have a user interface and wireless communication to remotely monitor and control it in real-time. It may be an area with the future potential for improvement through IoT integration

2. Conclusion

The deployment of an automated PLC-based energy-saving system in Educational institutions addresses the grave issue of energy wastage through standby electrical appliances. By utilizing timetable logic along with real-time environmental and occupancy sensing, the system turns on lights and fans only when needed, based on actual class usage patterns.

Use of the Siemens S7-200 PLC, in combination with an Arduino microcontroller for sensor data processing, is a cost-effective and expandable solution that can be easily applied in varied institutional settings.

Addition of a night-time shutdown feature adds to energy savings by avoiding unnecessary power usage during off-peak hours.

Testing and validation have shown a significant reduction in energy consumption by about 28% that indicates the effectiveness of the system in promoting energy efficiency. Also, the automation reduces the use of manual intervention by a great extent, eliminating human error and ensuring uniform operation.

Future developments may involve the utilization of wireless communication for remote monitoring and control and the application of machine learning algorithms for forecasting occupancy patterns and further optimizing energy consumption. Such developments would open the way for smarter, more sustainable learning environments.

3. Future scope

- Wireless Control: Introduce wireless communication modules for easier system installation and scalability.
- Predictive Automation: Implement machine learning algorithms to predict occupancy patterns and optimize energy use further.
- Extended Device Control: Expand the system to manage additional devices such as air conditioners, projectors, and smart boards.
- Remote Monitoring: Develop a user-friendly mobile application or web dashboard for system status monitoring and remote control.

References

1. S. Puneeth, C. S. Shivaraj, and C. Ravi Prasad, “Power Management System for Appliances using PLC,” International Journal of Engineering Research & Technology (IJERT), vol. 3, no. 8, pp. 1–4, Aug. 2014
2. D.Irmak, E. Kabalcı, and A. Köse, “Design and Implementation of a Computer Interacted Smart Home System Based on PLC,” in Proc. 4th Int. Conf. on Application of Information and Communication Technologies (AICT), Tashkent, Uzbekistan, 2010, pp. 1–5.

3. Z. B. May and Y. A. A. B. M. Yaseen, “Smart Energy Saving Classroom System Using Programmable Logic Controller,” Adv. Mater. Res., vol. 660, pp. 158–162, 2013.
4. Frank D Petruzella , Programmable Logic Controllers , 1989
5. Kevin Collins, PLC Programming for Industrial Automation, 2006
6. W. Bolton, Programmable Logic Controllers, 1996
7. Stephen P. Tubbs, Programmable Logic Controller (PLC) Tutorial, Siemens Simatic S7-1200, July 2007
8. M. Morris Mano, Digital Logic And Computer Design, September,1979
9. Madhuri R. Mukkawar; S. D. Sawant (2015), “Energy EfficientAutomation System with Smart Task Scheduling" in Computing Communication Control and Automation (ICCUBEA), 16 July 2015.
10. Kim Baraka; Marc Ghobril; Sami Malek; Rouwaidakanj; Ayman Kayssi, “Low cost Arduino/Android-Based Energy-Efficient Home Automation System with Smart Task Scheduling” in Computational Intelligence, Communication Systems and Networks (CICSyN), 01 August 2013.