International Journal of
Electrical Power System and Technology
ISSN: 2455–7293
Volume 10, Issue 2, 2024
DOI (Journal): 10.37628/IJEPST
https://journalspub.com/journal/ijepst/
Research IJEPST

Home Automation Approach Based on PLC: Ease and Sustainability

Pragati Gaikwad[1,*], Bhushan Kadam[2], Dipesh Pardeshi[3]

Abstract

Home automation is a notion that is gaining popularity as a way for people to improve their comfort, security, and energy efficiency. The use of programmable logic controllers in the context of home automation is examined in this research. Programmable logic controllers offer a dependable and adaptable foundation for automating and regulating a variety of home systems. The key elements and procedures for implementing home automation using programmable logic controllers are covered in this paper, including picking the right hardware, programming logic, integrating sensors and actuators, setting up communication protocols, and developing user interfaces. The idea behind home automation is to link all the appliances and systems to a single controller so that they can all be operated remotely and communicate with one another. The primary programmable logic controllers program is designed using a ladder diagram. This programmable logic controllers has the ability to process, sequence, time, and store instructions. Additionally, several operations are managed and controlled through the user central control unit, including main entrance control, power connection on/off, water and gas valve opening and closing, thief control system on/off, garage door control, and lighting and heat control of each room according to our predefined schedule. It emphasizes the significance of security and safety factors in home automation systems. Examined are the possible advantages and difficulties of employing programmable logic controllers for home automation, including scalability, customization, and maintenance. As a result, an interactive and comfortable automation system has been created. The article stresses the modernization and optimization of domestic living areas with programmable logic controllers-based home automation, resulting in more comfort and sustainability.

Keywords: Programmable logic controller (PLCs), ladder programming, home automation, hardware, implementation, security, challenges.

INTRODUCTION

Manufacturing control system automation was the challenge that led to the development of programmable controllers, or PLCs. Sequential control systems are used in industrial settings. Words like mode and behavior are frequently used to characterize sequential systems. These systems will go through several phases or stages of operation throughout regular operation. The behavior of the system will vary depending on its operational status [1].

The work is based on an automation system where the interface is by a programmable logic controller (PLC). Implementing a PLC application that can handle various appliances in a home like lights, smoke sensors, water level detectors, and various other appliances. Now everything is going to be automated

***Author for Correspondence**
Pragati Gaikwad
E-mail: pragatig5902@gmail.com

[1–3]Students, Department of Electronics and Electrical Engineering, Sinhgad College of Engineering, Pune, Maharashtra, India.

Received date: October 22, 2024
Accepted date: October 28, 2024
Published date: November 15, 2024

Citation: Pragati Gaikwad, Bhushan Kadam, Dipesh Pardeshi. Home Automation Approach Based on PLC: Ease and Sustainability. International Journal of Electrical Power System and Technology. 2024; 10(2): 1–14p.

using modern control techniques and vogue technology. The appliances can be connected to that network grid and accessed using a smartphone. This idea will lead to the development of smart communities [2].

Structured text, function block diagrams, ladder diagrams, sequential function charts, and instruction lists can all be programmed into PLCs. Although alternative programming languages can offer benefits like structured data structures (such as arrays and loops), ladder diagrams remain the most widely used PLC programming languages [1].

The project shows how PLCs can be used to monitor and operate lights, sensors, and other electronic equipment in houses, workplaces, and other locations. It is simple to automate and monitor inputs in real-time. The concept of computerized control and its implementation frees up valuable time and human labor that may be used for other goals. The family can enjoy a more refined and convenient environment that fits their lifestyle thanks to home automation [2].

Literature Review

The potential of home automation, sometimes referred to as smart home technology, to improve energy efficiency, raise security, and improve quality of life in residential settings has led to its considerable rise in popularity. Utilizing PLCs to control and manage a variety of household systems and devices is an essential component of contemporary home automation. This review of the literature attempts to give a broad overview of recent advances and research in PLC-based home automation.

Home Automation with PLCs: A Sturdy Approach

PLCs were first created for industrial automation, but because of their robustness, flexibility, and dependability, they are now a popular option for home automation. PLCs have been investigated by engineers and researchers for a variety of uses in the home, including but not restricted to:

1. *Lighting control:* PLCs provide accurate lighting system control, allowing users to modify brightness, establish timetables, and design lighting scenes for various activities. This leads to energy savings and enhanced ambiance [3].
2. *Energy management:* The main goal of home automation is to optimize energy usage. PLCs can regulate power-hungry appliances and HVAC systems, which lowers energy bills and their negative effects on the environment [4].
3. *Security and surveillance:* PLCs are essential to home security systems since they control cameras, alarms, and smart locks. These systems can be configured to react to crises or security breaches [5].
4. *User interfaces:* For broad acceptance, user-friendly interface development is essential. PLC-based home automation frequently incorporates user interfaces for accessibility and convenience of use, like voice control, touchscreens, and mobile apps [6].
5. *Integration with IoT:* As the Internet of Things (IoT) grows in popularity, researchers are looking into connecting PLCs with IoT devices to provide remote monitoring and control of a variety of household systems and appliances [7].

Obstacles and Potential Futures

PLC-based home automation has several drawbacks despite its benefits. Key issues that need constant attention are ensuring system dependability, managing cybersecurity risks, enhancing device interoperability, and addressing user privacy concerns. To ensure that smart homes continue to evolve, potential future advancements could include improved energy management algorithms, user interfaces, and increased integration with upcoming technology [8].

Case Reports

PLC-based home automation systems are practically demonstrated in several case studies. These practical uses demonstrate how well PLCs work to enhance security, energy efficiency, and home life.

For example, a case study by Roberts et al. (2021) shows how PLCs were used in a home context to optimize energy consumption and improve security [9].

To sum up, home automation using PLCs offers a viable way to improve the efficiency and utility of living spaces. The present status of research and development in the topic has been outlined in this literature review, with a focus on applications in user interfaces, security, energy management, lighting control, and IoT integration. PLC-based home automation systems will probably continue to advance despite certain obstacles.

PLCs

A digital computer-based management system called PLC is used in manufacturing and industrial automation to manage a variety of equipment and operations. PLCs are made to carry out tasks by performing user-defined control and logic functions. Here are a few crucial PLC features.

PLC Components Include

1. *Central Processing Unit:* The PLC's CPU, which handles processing and carrying out control programs, is its brain. The input data is read and processed, and control signals are then sent to the output devices [10].
2. *Input Module:* Various sensors and input devices, including switches, sensors, and analog devices, must be interfaced with input modules. They transform the physical field signals into digital data that the PLC can process.
3. *Output Modules:* To regulate the industrial process, these modules interact with output devices, such as motors, valves, solenoids, and other actuators. They translate the PLC's digital signals into tangible actions [11–13].
4. *Memory:* PLCs have three main types of memory: system memory, which stores temporary data and system settings, data memory, which stores variables and values, and program memory, which stores the control program [14].
5. *Programming Software:* Engineers and technicians can construct control logic for PLCs using a variety of programming languages, including ladder logic, structured text, function block diagrams, etc., by using specialized software [15].
6. *Human–Machine Interface (HMI):* It is a component of a PLC system that gives operators a graphical interface through which to view and communicate with the control system. It has reporting and warning features, manual control capabilities, and process data display [16].
7. *Communication Modules:* To facilitate data exchange and network interaction with other PLCs, SCADA systems, or even enterprise-level systems, certain PLCs are equipped with optional communication modules. The block diagram of PLCs is shown in Figure 1.

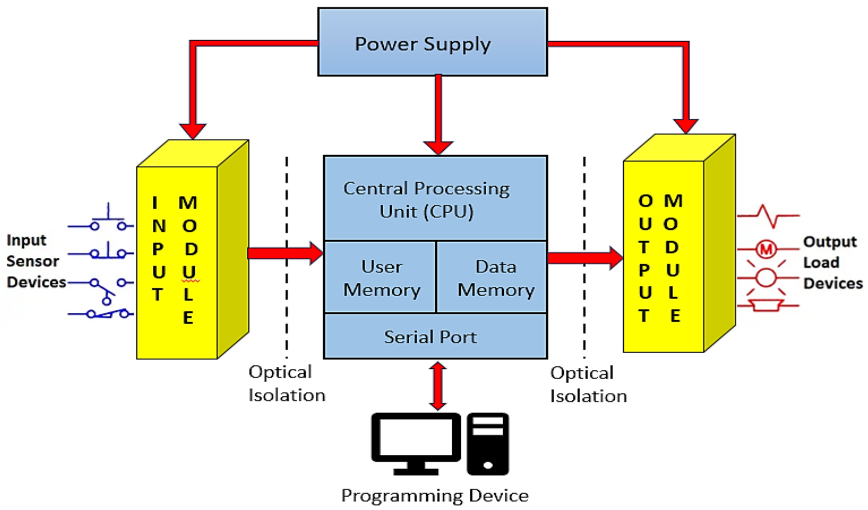

Figure 1. Block diagram of PLCs.

Programming Languages for PLCs

The following languages are commonly used to program PLCs:

1. *Ladder Logic:* It is a common option for PLC programming because it is simple to understand and resembles electrical relay schematics.
2. *Structured Text:* It is more adaptable for complicated jobs since it makes use of structured programming notions that are comparable to high-level programming languages.
3. *Function Block Diagram (FBD):* This language depicts control logic as a series of interconnected blocks that can be used in systems with several simultaneous processes.
4. *Sequential Function Chart (SFC):* SFCs are like flowcharts and are utilized for intricate, sequential control activities [17–20].

Applications for PLCs

PLCs are utilized in a variety of fields and settings, such as production procedures, automation, systems for handling materials, chemical synthesis, wastewater management, water treatment, generation and distribution of power, constructing automation, manufacturing of automobiles, food and drink preparation, HVAC (Air Conditioning, Heating, and Ventilation) management.

PLCs are the backbone of contemporary industrial automation and control systems because they provide dependable, real-time control and the adaptability to change with the needs of the system [21].

Ladder Diagram

An industrial automation and control system uses a graphical programming language called a ladder diagram, sometimes referred to as a ladder logic or ladder chart. Designing and illustrating control circuits for electrical and electronic systems is its main use. Ladder diagrams are frequently used in manufacturing, process control, and other industrial applications. Ladder diagrams are made up of horizontal rungs that hold numerous control and input/output devices and two vertical lines that indicate the power source (typically, one line for positive voltage and the other for ground).

The rungs, which feature a variety of symbols and parts like the following, show the logical control flow of a system.

1. *Contacts:* These can be limiting switches, push buttons, or other input devices. They are shown as open or closed switches. In a ladder diagram, contacts stand in for the requirements that must be fulfilled for the circuit to continue.
2. *Coils:* Relay coils or output components like motors, solenoids, or valves are frequently used to represent coils. They display the actuator or output that is under control in accordance with the contacts' defined logical requirements.
3. *Branches:* In a diagram, branches, also known as lines, link different elements and establish the left-to-right logical flow.
4. *Power Rails:* The diagram's vertical power rails on the sides serve as benchmarks for voltage and electrical continuity.

The connections between contacts and coils in a ladder diagram show the logic of the design. For instance, the following diagram illustrates a basic circuit that activates a motor upon the depressing of a push button:

```
--[Start]--[ ]----( )
             |      |
| Motor |
|       |
---------------
```


In This Schematic

- The "Start" push-button switch (shown as [Start]) is normally open and shuts when pressed.
- When the push button is pressed, the motor will be powered up, completing the logical circuit. The () symbol is the coil of a motor relay.

Like traditional electrical schematics, ladder diagrams are meant to be easy to read and comprehend for engineers and technicians. They make troubleshooting and circuit change easier in industrial environments by giving a visual depiction of the control logic.

An essential tool in industrial automation, ladder diagrams are frequently employed for a variety of tasks, from basic motor control to intricate production procedures.

Home Automation

Using PLCs to complete a home automation system entail integrating a variety of devices and making sure they work together well to provide control and automation for your house. These are the essential components and steps to consider.

Key Elements

1. *Selection of PLC:* Select the PLC that best meets your needs for home automation. The PLC should have sufficient inputs and outputs for your features and devices in addition to the required communication tools.
2. *Tools and Indicators:* Determine the sensors you require and the devices you wish to manage. Lighting, HVAC systems, door locks, security cameras, motion detectors, temperature sensors, and so on may be examples of this.
3. *Transmission Protocols:* Depending on the equipment you intend to utilize, make sure your devices and PLC support compatible communication protocols, such as Modbus, BACnet, or Ethernet/IP.
4. *Software for Programming:* Get the PLC's necessary programming software. Most PLCs feature programming environments that are unique to them, such as function block diagrams, ladder logic, and structured text.

Hardware

To operate and monitor numerous appliances and systems in your house, setting up a home automation system using a PLC necessitates a selection of appropriate hardware components. The following are some necessary hardware parts for a PLC-based home automation system:

1. *PLC:* Select a PLC based on the demands you have for home automation. Choose a PLC that can manage the quantity of input and output points needed for your automation jobs as they vary in size and functionality. Siemens, Allen-Bradley (Rockwell Automation), Schneider Electric, and numerous more companies are common producers of PLCs [21].

Input Devices

- *Digital Input Modules:* These can be used as input devices in conjunction with push buttons, motion detectors, door/window sensors, and other digital sensors.
- *Analog Input Modules:* Use to communicate with sensors, such as potentiometers, temperature sensors, and light sensors, that produce continuous analog signals.

Output Devices

- *Digital Output Modules:* These are types of output device that can be used to operate locks, lights, fans, and other digital devices.
- *Analog Output Modules:* Useful for controlling devices that need changeable control, such as dimmable lights or motor speed controllers.

- *Communication Modules:* Think about using Ethernet/IP, Modbus, or Wi-Fi modules to connect to your home network to control your home automation system remotely or combine it with other systems.

Sensors and Actuators

- *Motion Detectors:* For security and lighting automation.
- *Temperature Sensors:* Useful for HVAC control.
- *Light Sensors:* Control lighting based on ambient light levels.
- *Motor Control Relays:* For controlling fans, blinds, or other motorized devices.
- *Valves and Solenoids:* For home irrigation and plumbing control.
- *Security Cameras:* Integrate cameras for video surveillance.
- *Door Locks:* For access control and security.
- *Smoke and CO_2 Detectors:* Enhance safety and automation.

2. *HMI:* To monitor and manage your home automation system, utilize a smartphone app, touchscreens, or a dedicated HMI panel.
3. *Power source:* Make sure your automation system's PLC and other devices are powered by a suitable power source.
4. *Encloser:* Installing your PLC and other components in an appropriate enclosure will shield them from physical harm, moisture, and dust.
5. *Wiring and Cables:* To connect all your gadgets to the PLC and power supply, you'll need wiring, connectors, and cables.
6. *Electrical Accessories:* Terminal blocks, fuses, surge protectors, and other electrical parts that guarantee dependable and secure operation are examples of electrical accessories.
7. *Hardware for mounting:* Enclosures, brackets, and mounts that hold your sensors and gadgets firmly in place.
8. *Security and Access Control Devices:* If you wish to restrict entry to your house, consider RFID card readers, keypads, or biometric scanners.
9. *Networking Hardware:* You could need routers, switches, and wireless access points if your home automation system needs to be connected to the internet.
10. It is important to adhere to electrical safety regulations and seek advice from a qualified electrician or automation specialist when needed to guarantee that your home automation system is appropriately planned, set up, and secure for operation.

System Design

The hardware and software implementations are divided into two parts in system design. The following is a block diagram of the system.

The streamlined block diagram for PLC-based advance home automation is shown in Figure 1. The SMPS in this block diagram receives an AC supply, which is utilized to convert 230V AC to 24V DC, which is then sent to the PLC. The block diagram of the system design is shown in Figure 2. For this project, we are utilizing an apparatus that senses events or changes in quantities and generates an output in line with such changes as a PLC (DVP 10-SX). It offers functions, such as controlling doors, tank water levels, and home appliances, among others. With the purpose of monitoring and managing the mechanical and lighting systems, the control system is a sophisticated network of electrical devices.

The PLC is a specially made machine control computer that can read digital and analog inputs from different sensors, run a logic program that may be customized by the user, and write the digital and analog output values to different output elements. Temperature sensors are employed in this project because we are measuring the room's temperature. We activate the fan and adjust its speed in response to changes in the room temperature using this temperature signal, which is then sent to the converter. We obtain a 0–10V signal from the converter, which translates the temperature sensor's signal in accordance with changes in resistance, and then we supply the PLC with the converter's output. PLC monitors the Solid-State Relay (SSR), which produces an output of 0–230V AC after receiving 0–10V from a converter. The fan is then supplied with the SSR's output. A single mobile phone's dial tone is recognized by the DTMF decoder circuit, which then outputs decoded data that is in bits. As a result, the PLC will regulate the circuit's relay, which in turn regulates the door latch. It converts the DTMF input to digital output by decoding the input using the IC MT8870, a touch-tone decoder IC. This IC determines the frequencies of the limited tones and confirms that they match the standard DTMF frequency using a digital counting technique. It allows the dialer and the mobile phone exchange to communicate in one direction alone. Limit switches track and display the flow of water. Limit switch initiates communication with the limit switch motor's readings, the PLC controls on and off.

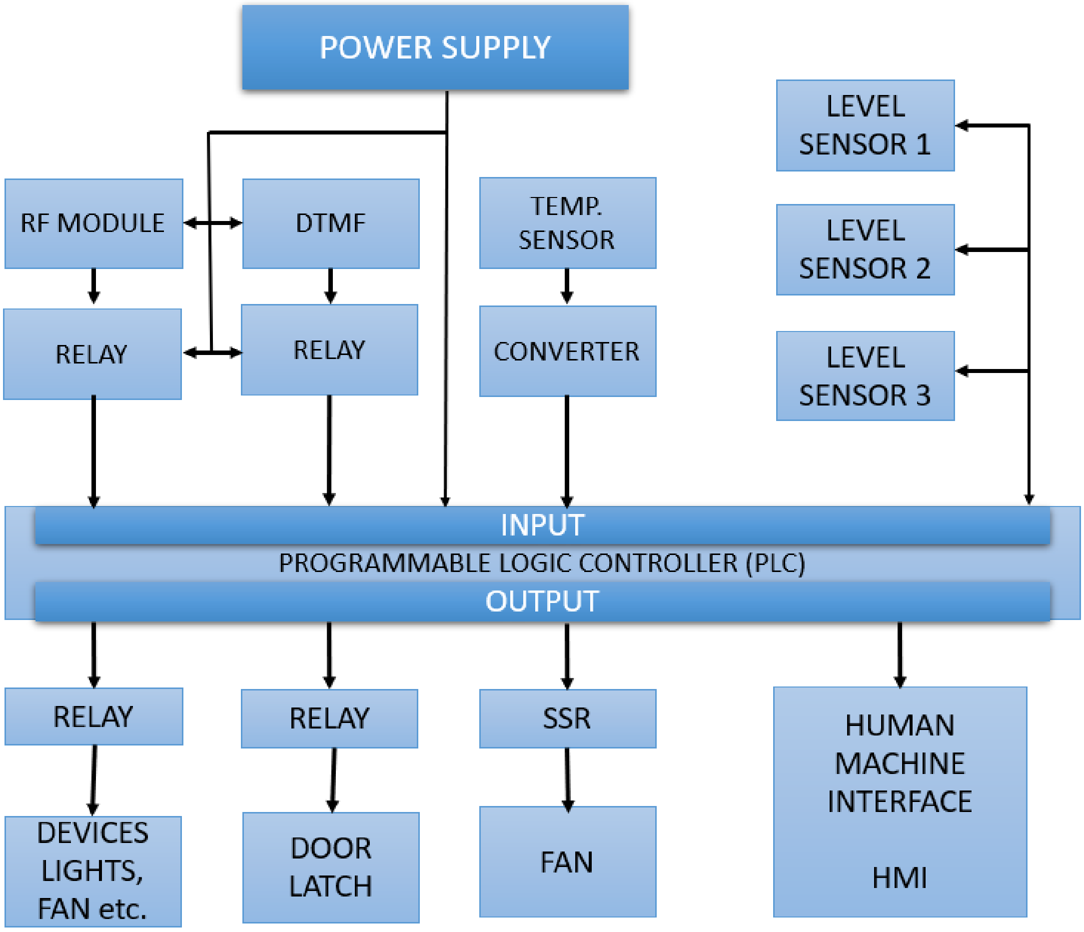

Figure 2. Block diagram of system design.

Implementation

Automatic level control for overhead water tanks.

Problem Synopsis

The water pump should turn on when the overhead tank's water level drops to its lowest point and continues to run until the tank's water level rises to its highest point. The water pump should shut off when the overhead tank reaches its maximum level.

The discharge line of this water pump is attached to the overhead tank, and the inlet line is connected to a well. The water pump should never be permitted to start in both manual and auto mode when the well water level is low. The level control block diagram for overhead water tanks is shown in Figure 3.

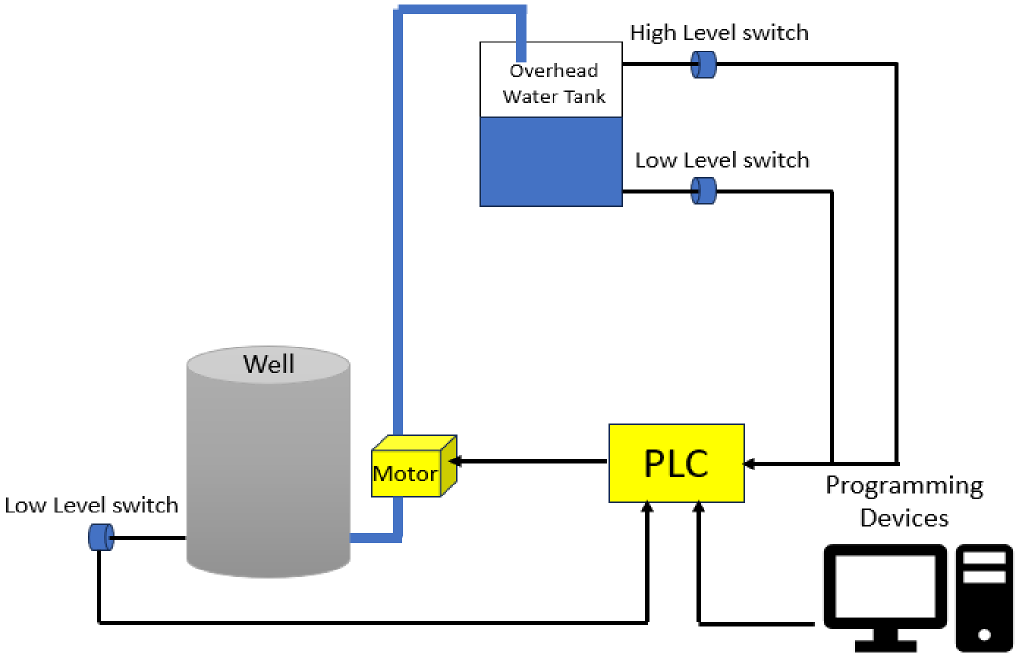

Figure 3. Level control block diagram for overhead water tanks.

Fixing the Issue

1. Two level switches are positioned at the top and bottom of the overhead tank, respectively, to detect the high and low levels. The switches provide a digital output when the corresponding levels are detected.
2. A level switch at the bottom of the well, which also outputs in digital terms, is used to detect the well's low level.
3. The PLC's output to the motor that is connected to the water pump must be turned on and off when these inputs are received to maintain the water level in the overhead tank as specified in the control description.
4. To initiate the process when the mode is manual, Master Start/Stop has also been included.

Inputs and Outputs

1. Overhead tank high-level switch – input (OTHLSW).
2. Overhead tank low-level switch – input (OTLLSW).
3. Well low-level switch – input (WHLSW).
4. Auto/manual switch – input (A/MSW).
5. Start switch – input (STRT).
6. Stop switch – input (STOP).
7. Motor coil – output (MTR COIL).

Ladder Diagram
Overview of ladder is shown in Figure 4.

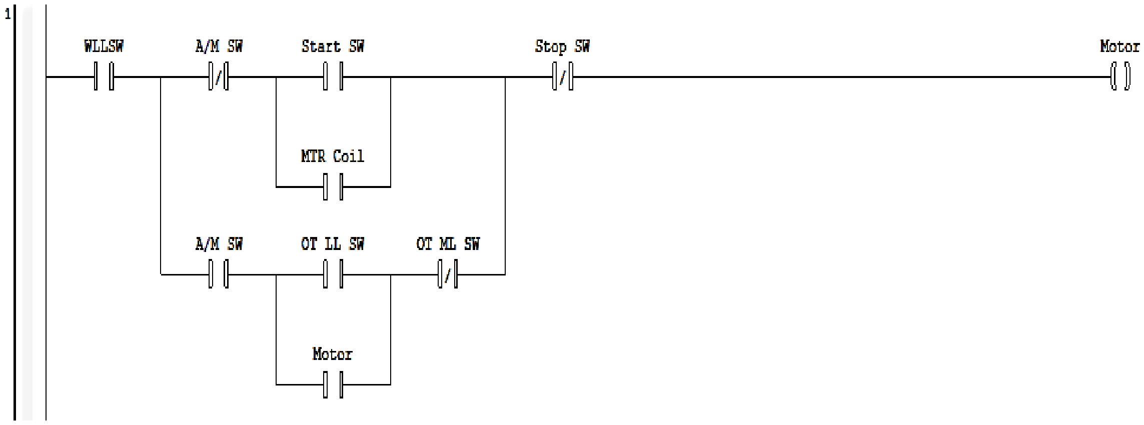

Figure 4. Ladder overview.

Access Control System for Doors

The primary mechanism of automatic door opening and shutting involves using sensors to detect an object near the door and providing the PLC with this information so that the door can be opened or closed.

The primary benefit of an automated door opener and closer is that it does not need human oversight to function. The block schematic of the door access control system is shown in Figure 5.

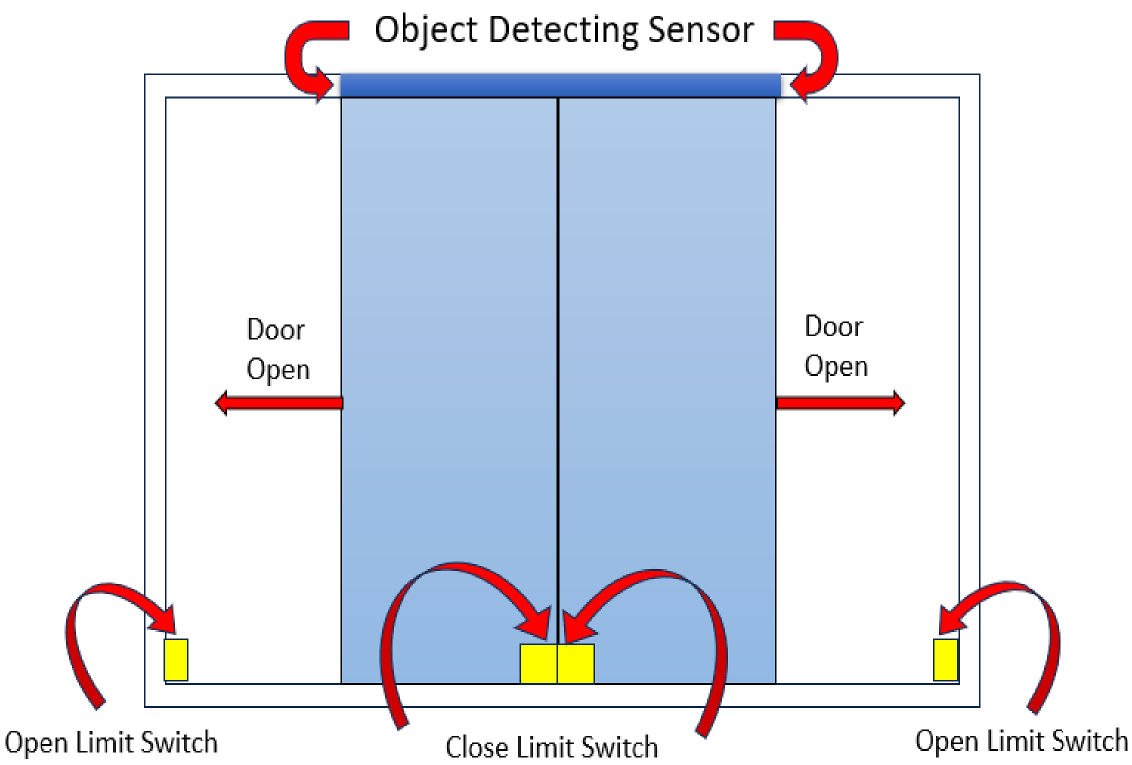

Figure 5. Block schematic of the door access control system.

Logic Synopsis

1. *RUNG0000:* Latching rung to use the master start and stop PB to control the system.
2. *RUNG0001:* The object-detecting sensor will activate the door motor until the open limit switch is turned on when it detects people within a certain range.
3. *RUNG0002:* A timer is utilized to set a 10-second delay before turning on the closing door motor when no one is within range.
4. *RUNG0004:* Closing motor activated until the closed limit switch was activated.

Inputs and Outputs: Name vs input/output is shown in Table 1.

Table 1. Name vs input/output.

Address	Name	Input/Output
I:0/0	Start	Input
I:0/1	Stop	Input
B3:0	Start latch	Binary
I:0/2	Object detecting sensor	Input
I:0/3	Open limit switch	Input
I:0/4	Close limit switch	Input
O:0/0	Opening door motor	Output
O:0/1	Closing door motor	Output

Ladder Diagram: The ladder diagram for doors is shown in Figure 6.

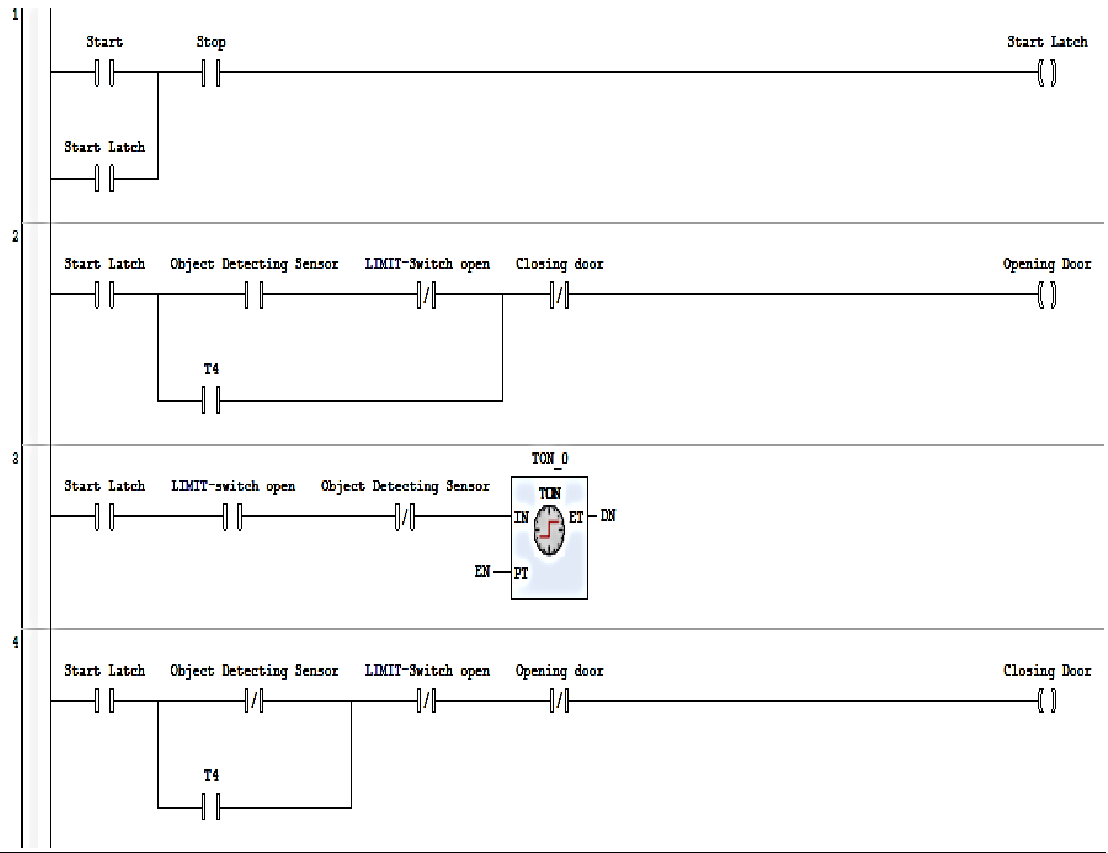

Figure 6. Ladder diagram for doors.

Light On/Off Control

PLCs are frequently used in both residential and industrial automation to automate the control of lightbulbs. This is an illustration of how to set up a simple automation system that uses a PLC to control lights. It is important to note that PLC models and software can differ, therefore for precise information, consult the documentation provided by your PLC. The block schematic of light on/off control is shown in Figure 7.

Required Elements

a) *PLC:* To manage the bulbs, you will need a PLC that can handle the voltage and current needed. This PLC should include digital input and output modules.
b) *Light Bulbs:* The ones you wish to programmatically change.
c) *Relays:* Relays may be necessary to properly control your lamps if the PLC output voltage is insufficient to supply the necessary voltage.
d) *Electricity Source:* Make sure that the PLC and the lights have a steady source of electricity.
e) *Wiring:* Attach the output module of the PLC to the lights and, if necessary, the relay. Utilize the appropriate voltage levels and adhere to wiring requirements.

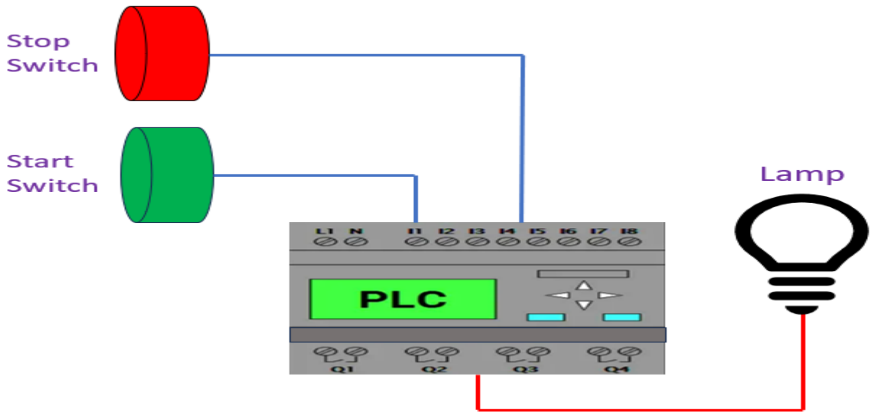

Figure 7. Block schematic of light on/off control.

Function

- The connections ([]) connected to the “Start” button close when the button is pressed, igniting the coils ([ ]).
- Consequently, the coil-connected internal relay contacts () close, enabling electricity to flow to Light 1, Light 2, and Light 3. This illuminates the three lamps.
- The lamps turn off and the coils become de-energized when the “Start” button is removed or pressed again.

Ladder Diagram

The ladder Diagram for lamps is shown in Figure 8.

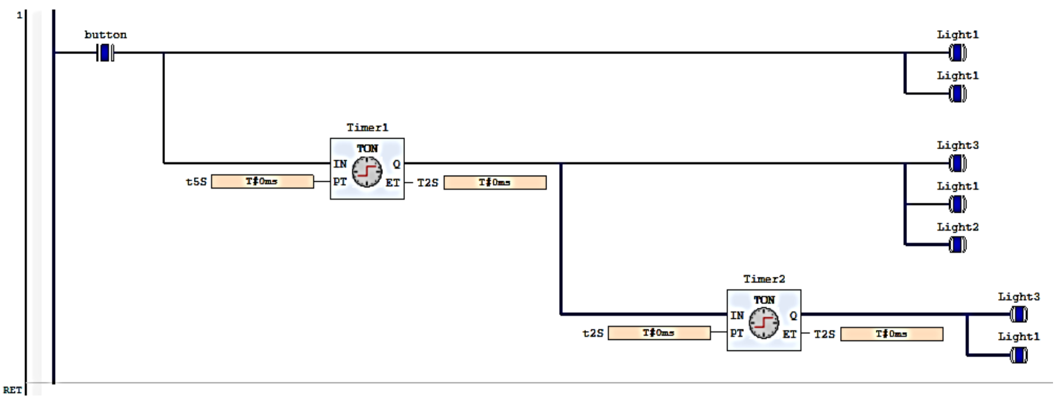

Figure 8. Ladder diagram for lamps.

Security and Challenges

Utilizing PLCs for home automation has several advantages, including ease and energy savings, but there are also security concerns and issues that must be resolved to guarantee a dependable and safe system. The following security issues and difficulties arise when employing PLCs for home automation.

Security Concerns

- *Unauthorized Access:* One major security risk is unauthorized access to the PLC or home automation system. An attacker can take control of equipment, undermine security measures, and even do harm if they manage to get access.
- *Data Privacy:* User behavior and preferences are only two examples of the types of information that home automation systems frequently gather and send about the home. Maintaining the confidentiality of this information is essential to preventing breaches and improper use.
- *Network Vulnerabilities:* PLCs are generally linked to the internet or the home network. Cyberattacks could target the automation system due to network security flaws.
- *Vulnerabilities in IoT gadgets:* The IoT, which is known to have security flaws, includes a lot of home automation gadgets. Attackers may be able to take advantage of these gadgets if they are linked to the PLC.
- *Data Tampering and Eavesdropping:* Attackers can intercept data communications that go between the PLC and devices, which may result in data tampering or eavesdropping. Both power and privacy could be jeopardized by this.
- *Attacks:* Denial of Service (DoS) can target PLC-based home automation systems by overloading the system with traffic, which causes the system to become unusable.

Challenges

- *Interoperability*: Due to differing communication protocols, integrating several home automation devices from different manufacturers might be difficult. It is crucial to guarantee compatibility and interoperability.
- *Complexity*: As more devices are added, home automation systems may grow increasingly complicated. It can be difficult to maintain and manage this complexity, particularly for non-technical people.
- *Reliability*: PLCs are recognized for their dependability, but as systems get more sophisticated, there is a greater chance of malfunctions or breakdowns. It is difficult to make sure the system runs consistently.
- *Energy Efficiency*: Although home automation can improve energy efficiency, setting it up to save as much energy as possible without compromising comfort can be difficult.
- *User Acceptance*: It might be difficult to persuade homeowners to install and utilize home automation systems. Because of perceived complexity or security concerns, users could be apprehensive.

Mitigating Security Concerns

- *Secure Network Configuration:* To safeguard the home automation system, put in place strong network security measures, such as firewalls, secure access control, and network segmentation.
- *Encryption:* To avoid eavesdropping, encrypt data transfers between the PLC and devices. Make use of SSL/TLS-based secure communication methods.
- *Frequent Upgrades:* Apply the most recent security patches and upgrades to the PLC’s firmware and all devices connected to it.
- *Access Control:* Use strong passwords and distinctive usernames to provide robust access controls. When it is feasible, enable two-factor authentication.

- *Data Protection Guidelines:* Verify that data privacy procedures and policies abide by all applicable laws. Retain and collect only the amount of data required to keep the system operating.
- *Frequent Security Audits:* To find system vulnerabilities, do penetration tests and security audits.
- *User Education:* Inform users of the value of privacy and security and offer advice on appropriate procedures.

To build a dependable and secure home automation system with PLCs, it is crucial to strike a balance between the advantages and convenience of home automation and the requirement for security and problem-solving. It necessitates a comprehensive strategy that considers both user- and technical-related factors.

CONCLUSIONS

PLC-based home automation presents a viable way to improve residential living. The flexibility of PLCs in managing energy, lighting, security, and other aspects has been emphasized in this analysis. Nonetheless, it is imperative to tackle issues related to security and privacy, in addition to the intricacy of system integration. Home automation using PLCs has the potential to provide homeowners with increased convenience, energy efficiency, and security with ongoing developments and user education.

REFERENCES

1. Wang G. A New Approach for PLC Ladder Diagram Design. In: 2021 IEEE International Conference on Electro Information Technology (EIT). 2021. pp. 021–026. IEEE.
2. Nangtin P, Nangtin J, Vanichprapa S. Building automation system for energy saving using the simple PLC and VDO analytic. In: 2018 International Workshop on Advanced Image Technology (IWAIT). 2018. pp. 1–4. IEEE.
3. Hallak G, Bumiller G. PLC for home and industry automation. Power line communications: principles, standards and applications from multimedia to smart grid. IEEE Xplore. 2016:449–72.
4. Aher NA, Mulik CS, Porwal D, Pardeshi DB, William P. Hybrid Model to Address Software Controlled Arduino Robocar Using Advanced Computing Technique. 2023 3rd International Conference on Pervasive Computing and Social Networking (ICPCSN), Salem, India. 2023. pp. 1651–5. doi: 10.1109/ICPCSN58827.2023.00276.
5. Khairullah SS, Sharkawy AN. Design and implementation of a reliable and secure controller for smart home applications based on PLC. J Robot Contr (JRC). 2022;3(5):614–21.
6. Nikam TS, Pawar SA, Porwal D, Pardeshi DB, William P. Implementation of Bluetooth Based Cargobot Using Controlled Arduino Robocar. 2023 3rd International Conference on Pervasive Computing and Social Networking (ICPCSN), Salem, India. 2023. pp. 1548–53. doi: 10.1109/ICPCSN58827.2023.00258.
7. Chavan PK, Autade SB, Pardeshi DB, William P. Environmental impact of extra high voltage systems in switch yard transmission lines. 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. pp. 1714–18. doi: 10.1109/ICIRCA57980.2023.10220635.
8. Burhade P, Khumkar G, Pardeshi DB, William P. Assessment based on performance of harmonics and asymmetry in extra high voltage systems. 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. pp. 01–03. doi: 10.1109/ICIRCA57980.2023.10220933.
9. Chataut R, Phoummalayvane A, Akl R. Unleashing the power of IoT: a comprehensive review of IoT applications and future prospects in healthcare, agriculture, smart homes, smart cities, and industry 4.0. Sensors. 2023;23(16):7194.
10. Dinesh PM, Govindaraj KK, Manivannan N, Paramasivam ME, William P, Alagarsamy M. Deep Learning-Based Prediction of Knee Innovative Practices," 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India. 2024. pp. 1–6. doi:

10.1109/ICIPTM59628.2024.10563465.
11. William P, Singh R, Al-Samalek A, Hussain A, Badhoutiya A, Rao AK. Dynamic Energy-Aware Cloudlet-Based Mobile Cloud Computing Model for Green Computing. 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India. 2024. pp. 1–6. doi: 10.1109/ICIPTM59628.2024.10563792.
12. S. RS, S. Narayanan CS, R. G, P. S, Alagarsamy M, William P. Fuel Quantity and Quality Detection in Automobiles Using IoT. 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India. 2024. pp. 1–6. doi: 10.1109/ICIPTM59628.2024.10563735.
13. Dinesh PM, Alagarsamy M, A. K. A, K. Rameshkumar, Pavithra G, William P. Gesture Controlled Vehicle for Armed Service. 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India. 2024. pp. 1–6, doi: 10.1109/ICIPTM59628.2024.10563743.
14. Folgado FJ, Calderón D, González I, Calderón AJ. Review of industry 4.0 from the perspective of automation and supervision systems: definitions, architectures and recent trends. Electronics. 2024;13(4):782.
15. Warule S, Barde VR, Barshile MK, Kambhire SV, Bibave RR, Pardeshi DB. Electric Reaping and Fertilizing Machine. 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India. 2023. pp. 1685–91. doi: 10.1109/ICIRCA57980.2023.10220941.
16. Khan MS, Ahmed T, Aziz I, Alam FB, Bhuiya MS, Alam MJ, et al. PLC based energy-efficient home automation system with smart task scheduling. In: 2019 IEEE Sustainable Power and Energy Conference (iSPEC). 2019. pp. 35–8. IEEE.
17. Bibave R, Thokal P, Hajare R, Deulkar A, William P, Chandan AT. A Comparative Analysis of Single Phase to Three Phase Power Converter for Input Current THD Reduction. 2022 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India. 2022. pp. 325–30. doi: 10.1109/ICEARS53579.2022.9752161.
18. Bibave R, Kulkarni V. A Novel Maximum Power Point Tracking Method for Wind Energy Conversion System: A Review. 2018 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC), Chennai, India. 2018. pp. 430–3. doi: 10.1109/ICCPEIC.2018.8525198.
19. Bibave R, Kulkarni V. Maximum Power Extraction from Wind Energy System by Using Perturbation and Observation Method. 2018 International Conference on Smart Electric Drives and Power System (ICSEDPS), Nagpur, India. 2018. pp. 105–10. doi: 10.1109/ICSEDPS.2018.8536033.
20. OV GS, Karthikeyan A, Karthikeyan K, Sanjeevikumar P, Thomas SK, Babu A. Critical review of SCADA and PLC in smart buildings and energy sector. Energy Rep. 2024; 12:1518–30.
21. Soni L, Kaur A. PLC Home Automation: The Future of Smart Living. In: 2023 2nd International Conference on Edge Computing and Applications (ICECAA). 2023. pp. 1227–31. IEEE.

