DESIGN AND IMPLEMENTATION OF RESIDENTIAL BUILDING MANAGEMENT SYSTEM.

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A Final Year Design Project (FYDP) submitted to the Department of **Electrical & Electronic Engineering Department** in partial fulfillment of the requirements for the degree of
BSc. in Electrical & Electronic Engineering

Electrical & Electronic Engineering Department
Brac University
October 2025

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It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
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4. I/We have acknowledged all main sources of help.

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Ethics Statement

We hereby declare the following:

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Abstract/ Executive Summary

This project presents the design and implementation of a Residential Building Management System (BMS) aimed at improving energy efficiency, safety and comfort in modern homes. The proposed system integrates IoT-based automation using the ESP8266 NodeMCU microcontroller and various sensors to monitor temperature, humidity, motion, fire and gas leakage. It allows real-time supervision and remote operation of lighting, HVAC, safety and security systems and can be controlled through the Blynk IoT platform. Centralized BMS was optimized for cost, performance and scalability in comparison to all three design approaches Distributed, Centralized and Hybrid. Our testing confirmed reliable communication, fast response and 15-25% reduction in energy consumption. The system minimizes power waste, ensures safety and keeps cost down that supports sustainability goals. In conclusion, the system shows an effective, scalable and ethical engineering solution for smart, sustainable residential environments in Bangladesh and similar urban areas.

Keywords: Building Management System; IoT; Energy Efficiency; Automation; Sustainability; Smart Home

Table of Contents

Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

1.1.1 Problem Statement

The need for innovative solutions in Residential Building Management Systems is strengthened by the increasing demand for modern world's automation solutions, energy efficiency, safety and sustainability. Residential buildings account for most of the world's energy usage. The main reasons behind this are inefficient appliances, lack of real time monitoring and low-quality energy recovery processes. Such issues significantly raise operational costs and environmental impact. These challenges must be overcome in order to achieve sustainability goals, reduce energy costs and deliver comfort & safety.

1.1.2 Background Study

Heavy research is conducted on the benefits of combining the energy saving technology with the automated control. Research was able to show 25% reduction in energy use applying occupancy sensor controls for daylighting systems for domestic lighting. Some research was conducted in comparison of Building Energy Management Systems (BEMS) which optimise energy utilisation in HVAC lighting systems monitoring continually and automate. A further study presented a case study of a shopping mall which after retrofitting lighting systems with LED and integrating them into a centralized BMS has reduced 290 MWh annually, suggesting the potential for automated systems when it comes to limiting energy consumption.

In addition to this, technologies pertaining to Wireless Sensor Network (WSN) have been useful in energy management. Evolution of an Energy Management System (EMS) based on WSNs for real-time energy monitoring and load management has led to a reduction of peak consumption. These research studies point to automation, monitoring and energy recovery as important aspects of today's building systems.

1.1.3 Literature Gap

Although progress has been made, there are still wide gaps in research. Most research works focus on large commercial or industrial buildings, where you can have central systems and more research work has to be done on the residential parts, including the unique challenges of home, such as cost, scalability and user defined requirements.

This contribution reduces such gaps through the design of a centralized Building Management System for residential buildings through the integration of centralized control for monitoring purposes and distributed control for individual units. The system includes the use of WSN for real-time monitoring, sophisticated automation for fault detection and safety components for danger detection of fire and gas leakages. The system is targeted at a sample three-story residential building and addresses some of the limitations like cost effectiveness, manual reset functionality and emergency notification. Following the standards set by the Institute of Electrical and Electronics, such as the IEEE 1547, for distributed resources and the standard for harmonic distortion, such as the directive IEC 519, guarantees that the project will be interoperable and reliable.

1.1.4 Relevance to current and future Industry

The rationale for choosing this project is that it is aligned with future and current industry needs. As urbanization increases and energy efficiency regulations tighten, the market for cost-effective, sustainable residential building solutions will grow. Not only does the project bridge the gap between commercial BMS solutions and residential needs, but it also provides a scalable and adaptable system for energy optimization and improved sustainability in multi-unit residential complexes.

1.2 Objectives, Requirements, Specification and constraint

1.2.1. Objectives

- An automated system that detects occupancy to control appliances.
- Real-time building monitoring for fault and security detection.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements	Nonfunctional Requirement
BLYNK IoT Control (Both Phone & PC)	Owner can access the IOT control dashboard
Automatic Light Fan Turn OFF/ON	The fan and light will automatically turn ON within 5 seconds when motion is detected in the room. If no motion is detected for 15 seconds, they will automatically turn OFF.
Automatic HVAC Control.	The sensor will check the Temperature of the room and Turn on AC if Temperature>Threshold & Exhaust if Humidity>Threshold.
Manual Light & Fan Control.	Appliances can be controlled manually from IoT and sensor activation can be turned off and on from IoT.
Manual HVAC Control.	Appliances can be controlled manually from IoT and sensor activation can be turned off and on from IoT.
Automatic Fire detection and Extinguishing.	The sensor will detect the fire for 5 secs and turn on the extinguishing medium & the buzz alarm and send notification to the owner
Automatic Gas Leakage Alert and Supply cut off.	The system must send instant alerts and shut off gas within seconds of detection.
Intruder detection at night for security purposes.	Owner will be notified of any motion and can manually override
Safety notification.	Owner will be notified of any hazard detected
Room Temperature & Humidity update.	Real Time data transfer for accurate information

1.2.3 Specifications

Requirement	Specification
Emergency Notification: ● Flame Detection. ● Smoke Detection. ● Alarm ● Fire Extinguish ● Gas Supply OFF	**Sensor:** HW072 Flame Sensor, Photoelectric sensor (MQ-2). **Microcontroller:** ESP8266 NodeMCU Lua V3 **Alarm:** Buzzer Module Solenoid Valve, Water sprinkler, Pump.
Automated HVAC ● Humidity Detection ● Temperature Detection	**Temperature Sensor:** Accuracy ±0.5°C (DHT11 sensors). **Humidity Sensor:** Accuracy ±3% RH (DHT11 sensor). **Automation:** Controlled by ESP8266 NodeMCU. **HVAC System:** Split AC/centralized, SEER 14+, 1.5–3 tons capacity. **Power:** 100–240V AC
Intruder Alert ● Movement Detection	**Sensors:** PIR Sensor. **Automation:** Microcontroller-based start/stop. **Alarm:** Buzzer Module.
Home Automation ● Occupancy Detection	**Detection Range:** 7m **Automation: ESP8266 NodeMCU LUA V3** Microcontroller-based control for automatic on/off. **Sensor:** PIR Sensor. **Power:** 230V AC Power supply. (For fans and lights)

1.2.4 Technical and Non-technical consideration and constraint in design process

When developing the design and development of the Residential Building Management System (BMS), the consideration of technical and non technological factors has been involved to make sure that the end solution is efficient, safe and practical to application in the real world.

1.2.4.1 Technical Considerations and Constraints

1. **System Architecture:**
   The BMS also needed an architecture that would have the capability to support several sensors and controllers and offer robust communication between the devices.
2. **Hardware Limitations:**
   Microcontrollers, relays and sensors selection was limited based on availability, cost and compatibility. Minimal latency and power loss were optimized on power ratings, response time and communications protocols (Wi-Fi, Bluetooth).
3. **Software and Control Logic:**
   Occupancy and environmental based firmware was developed on automation., Microcontrollers had memory constraints that limited their code efficiency and the requirement of real-time responsiveness imposed code-efficiency constraints.
4. **Safety and Reliability:**
   Both the circuits needed over-current protection, isolation and grounding. Calibration and Sensor fault-tolerant design was needed to prevent false alarms and provide a steady operation.
5. **Scalability:**
   The architecture had to accommodate growth to a variety of levels with the least loss of performance and this demanded modular hardware and adaptable communication protocols.

1.2.4.2 Non-Technical Considerations and Constraints

1. **Economic Constraints:**
   The project was implemented with a very limited budget which affected component selection and reduced the scope of massive implementation.
2. **Societal and Cultural Factors:**
   The system was designed to accommodate the way of life of the indigenous people and both manual and automated features offered to the system to ensure that the users feel at home and acceptable.
3. **Legal and Ethical Requirements:**
   The national codes of electrical conduct and safety were to be observed. The ethical behavior was supported in terms of proper reporting, fair cooperation and consideration of the privacy of data.

4. **Environmental Considerations:**
   The focus was on energy efficiency and the application of recyclable or low waste materials in order to minimize the environmental footprint.
5. **Time Constraints:**
   The whole project was to be done in the course of the academic semester, so efficient scheduling, resource distribution and collaboration were needed.

Balancing these technical and non-technical aspects ensured that the BMS design was both technically sound and socially responsible. The final system reflects the practical application of engineering principles under real-world limitations of cost, time, safety and sustainability.

1.2.5 Applicable compliance, standards and codes

IEEE 1588 Precision Time Protocol (PTP): This protocol ensures precise clock synchronization in network devices to present a common view of time. Time synchronization, packet-based protocol, master-slave architecture and boundary clock are some of the primary characteristics. Telecom, power systems, measurement and control systems are the applicable fields.

IEEE 21451: IEEE 21451 family of standards aims at improving interoperability and development of control and automation systems in industry by offering a common model for communication and data transfer among actuators, sensors and other equipment. Lower development cost and time, greater flexibility, improved reliability and performance are some advantages of using it.

The IEEE 21451.1: IEEE 21451.1 standard network services for intelligent transducers and actuators is aimed at providing a standard interface, enhancing interoperability among manufacturers and attaining plug-and-play capability for the easy incorporation of new devices into the current systems, with the support for various network technologies.

IEEE C62.41: IEEE C62.41 is a surge immunity test equipment standard that defines surge waveform characteristics, test process, test equipment requirements and safety procedures. It covers generation of surge waveform, testing techniques, performance requirements for generator and measuring instruments and workers' & instruments' safety for surge testing.

IEEE C37.90: IEEE C37.90 is an electric power apparatus relay and relay system standard. It outlines the performance requirements, test methods, environmental characteristics and interchangeability between relays of various manufacturers. The standard covers overcurrent, differential and distance classes of relays.

IEEE 1547: IEEE 1547 is an interconnection standard for distributed resources (DERs) with electric power systems. It lays down technical requirements, grid support functions and safety

& interoperability requirements for DERs for safe operation and reliable operation.It also deals with testing, commissioning and maintenance.

IEEE 519: IEEE 519 is a standard that provides guidelines on limiting harmonic distortion in electrical power systems, including setting harmonic limits, proposing means of mitigation and outlining monitoring & measurement guidelines.

IEEE C37.2: IEEE C37.2 covers power switchgear construction, design, testing and application, i.e., circuit breakers, switchgear assemblies and test procedures, in accordance with IEC specifications for protection and performance testing.

IEEE 1451.1: IEEE 1451.1 defines the interface of smart sensors and actuators, which ensures interoperability and reduces system integration issues. It defines a common network interface, facilitates wired and wireless communications protocols and extends device integration.

1.3 Systematic Overview/summary of the proposed project

Building Management System (BMS) for Residential Building is designed to deploy an integrated solution of monitoring, control and optimization of essential electrical and safety systems for a multi-storey residential building. The system is designed to enhance energy efficiency, safety and user comfort through automation and intelligent decision-making.

This BMS consists of networked microcontrollers, actuators and sensors, which communicate with a central network topology. The switching of lighting, fans and appliances is controlled based on occupancy and environmental conditions and real-time monitoring of temperature, gas leaks and smoke for safety reasons. This sensor data is then processed by a central controller and sent to a local dashboard or a mobile application, controlling it by the user and monitoring the system.

The system would also be autopilot with very few human input, both manual and automatic modes. With software, embedded automation algorithms and logic are applied to allow fast response relation and fault detection. Power optimization, anomaly detection and maintenance prediction can be applied to data obtained by two or more sensors.

In an economic consideration, the system is to be developed on a set budget taking a more cost-effective and scalable consideration. It can either be incorporated on a floor by floor basis or the entire building depending on the resources at hand. The architecture is easily extensible in the future as it does not require the entire setup to be redesigned.

To summarize, the proposed BMS is a holistic platform that incorporates the factors of energy management, safety automation and sustainability in one platform. It shows the application of engineering concepts in reality to create a smart, safe and ecological house to address the requirements of modern life in the city of Bangladesh.

1.4 Conclusion

The project Residential Building Building Management System (BMS) is an excellent example of a contemporary engineering modality in enhancing the energy efficiency, safety and convenience features within residential complexes. The system shows that using intelligent control, the conventional buildings could be made smart and sustainable by incorporating automation, real-time monitoring and the harvesting of renewable energy.

Through the judicious compromise between technical, economic and environmental factors, the suggested design is practical, cost-effective and dependable. Not only will it eliminate the present problems of energy wastage and safety hazards, but it will also be in harmony with the long-term objective of sustainable urban life in Bangladesh.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

The design part of the project “Residential Building Management System” can be done in three effective design approaches according to its implementation. All these design approaches fulfills our objective of designing a building management system. But there must be differences in implementation complications. This chapter is analyzing all these implementation complications keeping many reasons in account and choosing the best design approach among them which fulfills our all the objective of making a cost efficient, adaptable, sustainable and automate appliances energy management to reduce energy waste The assessment criteria included Management complexity, Installation cost, Scalability, Failure Risk, Energy Efficiency, Maintenance, System complexity in a dependable and viable option for real-world usage.

2.2 Identify multiple design approach

2.2.1 Design Approach 01:

Distributed Building Management System:

It has multiple Control panels. The objective of this design is to develop a floor-level observation, control and management system for multi-story residential or commercial buildings. The proposed system includes establishing a dedicated control room on each floor, which allows centralized monitoring and management of all flats on that specific floor.

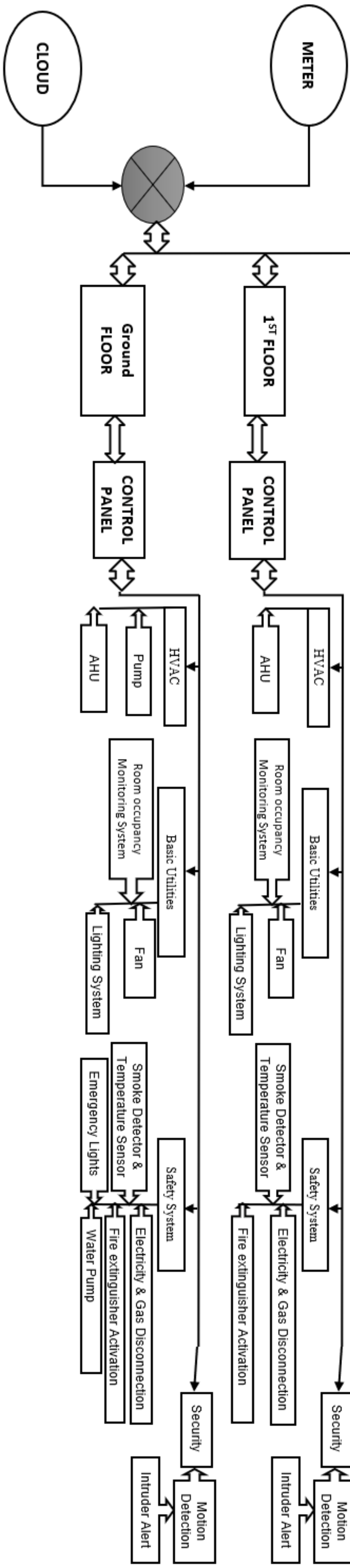


Figure 2.2.1: Distributed Building Management System.

2.2.2 Design Approach 02:

Centralized Building Management System

A Centralized Building Management System is implemented in such a way all monitoring and control functions are managed from a single centralized control or monitoring panel. This system provides a universal platform for overseeing the entire building's operations.

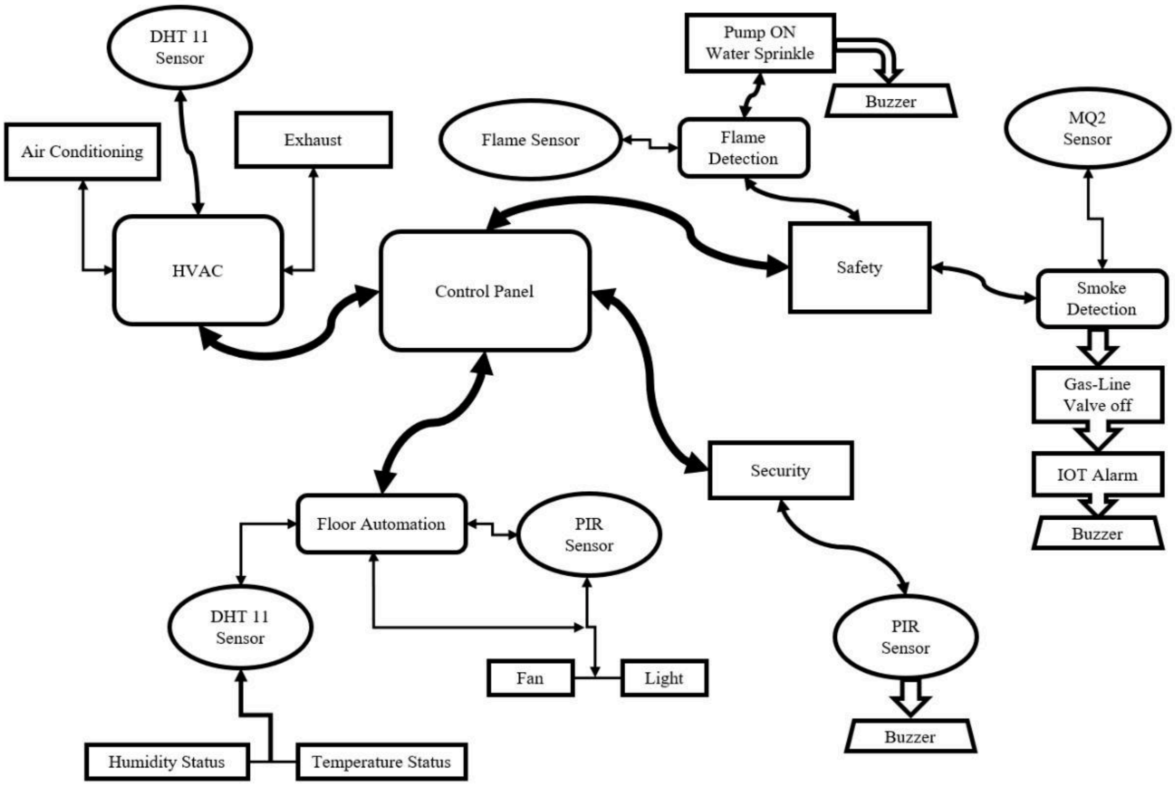


Figure 2.2.2: Centralized Building Management System.

2.2.3 Design Approach 03:

Hybrid Building Management System:

This BMS is a combination of both Centralized and Distributed control architectures. This approach offers a balanced solution by integrating floor-level control rooms with a centralized control system, enabling comprehensive and flexible building management.

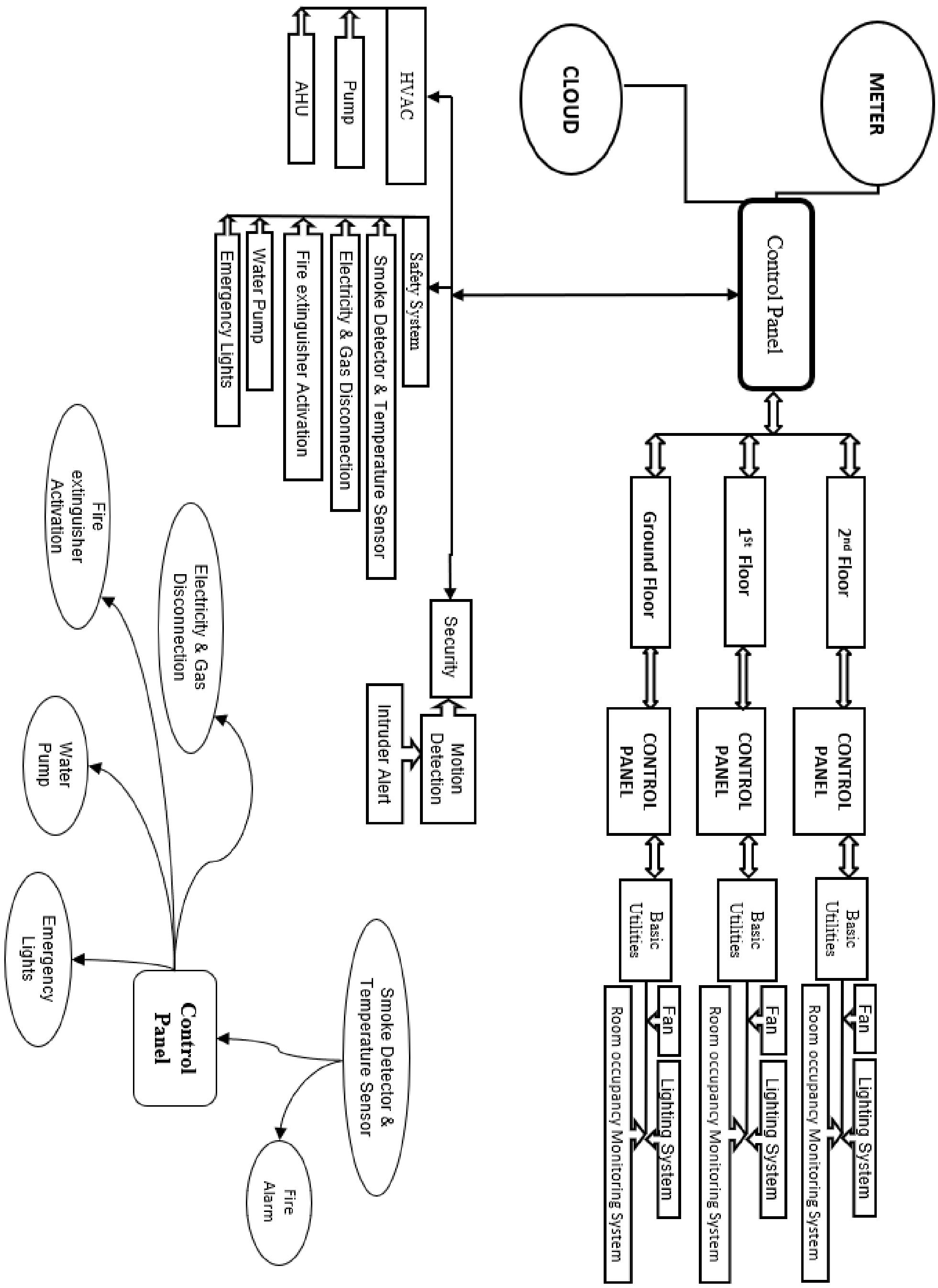


Figure 2.2.3: Hybrid Building Management System

2.3 Describe multiple design approach

2.3.1 Description of Distributed Building Management System:

Each of the floors has its own control panel, Every control panel does a specific job. Each floor independently manages the HVAC, AHU, Floor automation, Security system and Safety systems of that floor. Fire detection, gas leakage and their safety actions are controlled floor based. Cloud or Meter only provides data but is separately controlled. As the control panel is floor based, it gives a flexibility to keep all other floors operative if any of the floor of the building is faulty. It is easy to fix the faults.

In every floor there will be a control panel and microcontrollers of the control panel will actually complete the tasks and control only that floor. NodeMCU (ESP8266 which has an integrated WiFi module in built) is used as a microcontroller of this control panel in every floor. PIR sensor will work for Home Automation or Appliances controlling purpose, HVAC and AHU will be controlled depending on the readings of DHT11, Water pump will be controlled on the need of the water supply, Fire detection through flame sensor and Gas leakage through MQ2 sensors reading and fire extinguishing and gas shut off valves will be shut as safety methods, PIR will also work as intruder detection. All of the systems will be controlled through each floor's control panel or monitoring panel only for its installed floor.

In this approach, the management systems become highly scalable and reliable as we can add as many floors and zones as we want and they are not dependent on each other.

2.3.2 Description of Centralized Building Management System:

The whole building has only one motherboard or control panel. The whole system is controlled from this central panel. Every task and actions are monitored and decisions taken from this one panel. All the microcontrollers (ESP8266/NodeMCU) are installed here. Every floor of the building is controlled from that one place. It controls the Home Automation, HVAC, Safety and Security from the control panel. All the relays and wirings of the whole building are connected in this one panel. All the DHT11 Sensors of every flat take readings of the temperature and humidity and the central control panel has one dedicated microcontroller that receives this data and controls the Exhausts, Fans & Air conditioner automatically. All the PIR sensors of Every floor sense signal to its dedicated microcontroller in the main control panel and according to the motion detection these microcontrollers control the Fans, Lights of the rooms and turn on/off them. Flame sensors and MQ2 sensors of each flats and floors senses fire and gas leakages and sends signal to the main panel's dedicated microcontroller and this microcontroller sends signal to the dedicated relays to take safety measures to extinguish the fire or defend any occurrences or accidents (Shut the solenoid valve of gas main supply, activate sprinklers if needed).

2.3.3 Description of Hybrid Building Management System:

In this Building management system a local control panel exists, but there are also floor control panels. In this system, both centralized and distributed control panels are integrated.

In this system, there is a centralized control panel. Here, updates of floor automation systems, sensors readings are sent to the microcontroller. Through IoT (Blynk) statuses are monitored. Though, same work is also done by the Floor Control Panels as well. Sensors (PIR) send the same readings to those micro controllers also. But in this case, Floor's control panels do the automation part. Central control gives manual access only through IoT. In case of Safety, Floor microcontroller plays the role and central control works as back up controller if the floor controller fails to control the safety system. Sensors (Flame sensor, MQ2) are connected with both Floors control panels of their specific floor and Central control panel. Same data or readings of the sensors are sent to both the central and distributed control panel. From IoT control access can be shifted to the microcontrollers (ESP8266). So, in emergency cases if the floor controller is damaged the same signal will be sent to the central control and central controller can take the safety measures if fire detected or gas leakage detected. The building's HVAC system is mainly controlled by the Floor control Panel. As it is easy for a microcontroller to work in a lower processing load than a central control panel controller, as the central controller has to control the HVAC of the whole building according to the readings of the DHT11 sensors. Distributed microcontrollers will mainly do automated actions and centralized will have both manual and automatic action. It is also controlled by IoT. Security actions will be controlled by distributed control panels. But in IoT it will show the intruder alert that security officers can monitor the whole building through IoT as well as the residences of the building. The central control panel will also have an intruder alert but it is around the building area. PIR sensors will sense motion then send signals of the intruders and an alarm will notify the guards and they can check on CCTV.

2.4 Analysis of multiple design approach

Approach	Distributed BMS	Centralized BMS (Optimal Solution)	Hybrid BMS
Management Complexity	Simplifies management at a local level, as each system is controlled independently.	Reduces management effort by centralizing control in one place.	Offers localized control for quick decision-making while enabling centralized oversight
Installation Cost	Higher cost due to multiple control panels, sensors and localized wiring.	Lower installation cost as fewer control panels and localized equipment are required.	Moderate cost, as it balances the need for localized and centralized components.
Scalability	Easy to scale by adding independent systems for new areas or floors.	Limited scalability; adding new areas can increase system complexity	Highly scalable, as it allows for additional localized control panels
Failure Risk	Minimal impact on other systems if a single localized panel fails; highly resilient to faults in other areas.	Susceptible to single-point failures; if the central panel fails, the entire system may become non-operational.	Reduces single-point failures by combining localized autonomy and centralized backup.
Energy Efficiency	May lead to inefficiencies if individual panels are not synchronized with a unified energy management strategy.	More energy-efficient as central control ensures unified energy management across the building.	Maximizes energy efficiency by combining localized control for precision with centralized energy optimization strategies.
Maintenance	Requires separate maintenance schedules for each localized system, increasing operational complexity.	Easier maintenance with a single centralized system but downtime could affect the entire building.	Balances maintenance needs; localized systems allow for maintenance without affecting the entire building, while centralized monitoring assists in fault detection and reporting.
System Complexity	More complex to design and integrate due to multiple control points and isolated operations.	Less complex to design as all systems are unified under a central control panel.	Moderate complexity; requires integration of both centralized and distributed components for optimal operation.
Recommended Use Cases	Suitable for large buildings with independently operated zones or systems, such as malls or industrial complexes.	Ideal for smaller buildings or facilities with simple operational needs where single-point control is sufficient.	Best suited for residential complexes or medium-sized buildings requiring both floor-wise control and centralized monitoring for optimal operation and user convenience.

2.5 Conclusion

After analyzing all three design approaches, the Centralized Building Management System proved to be the most practical and efficient solution for residential use. While the Distributed and Hybrid systems offer flexibility and fault tolerance, they increase cost and complexity.

The Centralized BMS reduces installation cost, simplifies control and ensures unified energy management from a single panel. Though it carries a risk of single-point failure, this can be minimized with proper safeguards. Overall, it best meets the project goals of cost efficiency, simplicity, sustainability and effective automation, making it the chosen and implemented design.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

Different types of modern engineering and IT tools have been used to simulate the design approaches and make a visualization of them. The hardware tools are used for taking the readings of the different cases and sending & receiving signals to the IoT and taking actions, powering the microcontrollers and relays and sensors. Meanwhile, the software tools are used for coding, implementation, functioning automation, control and monitor systems and appliances.

3.2 Select appropriate engineering and IT tools

3.2.1 Hardware Tools:

- PIR Sensor
- MQ2 Sensor (Gas Detection Sensor)
- DHT11 (Humidity & Temperature Sensor)
- HW072 (Flame Sensor)
- ESP8266 (NodeMCU)
- Relay
- Adapter

3.2.2 Software Tools:

- Proteus 8 Professional
- Arduino IDE
- BLYNK IoT
- C programming language

3.3 Use of modern engineering and IT tools

3.3.1 Proteus 8 Professional

To design a microcontroller based project and simulate it Proteus is very much suitable. It shows realtime simulation results which is very much important in our project especially the firmware and hardware integration phase of our building management system. In proteus we can test run codes for sensors and microcontrollers. As it shows the real time results, we can check if the codes have any errors or bugs. If any errors and bugs are found we can fix the codes. We can also design the complete circuit through this we can figure out which components we need to design the Building Management System. By running the simulation we can also check and confirm that our circuit is properly working or not. So, through this we can get a clear concept of our circuit and fix if any issues are found. Also, Proteus is free. Matlab's Simulink is not fully free. We need a license to use it. Also some special features like embedded system-level integration circuit simulation are not supported by it. Also to design PCB we need to use another software tool like Altium. We also know about Pspice, which is another circuit designing tool. It is not designed for microcontroller programming and software development as well as integrated farmware and hardware development.

3.3.2 Arduino IDE

It is so flexible for Microcontroller programming and uploading codes in microcontroller boards. In this software C programming language is used to write codes for any type of microcontroller. In this Software every type of microcontroller and microcontroller board is available. It is also free and needs no licensing. CodeVision AVR is very complex and not user- friendly. Most importantly the libraries for Blynk IoT and Sensors are available in this software. We don't need to source them from the internet. We can source them from the software. So, multiple software dependency is not needed here.

3.3.3 BLYNK IoT

Blynk IoT is a free IoT platform with a good amount of signal limit for sensors. It is easy to design and can be modified the way we want to. It is easy to connect with microcontroller and avoid control clashes because it provides auth code and template ID for individual Dashboard. So Identification of segments (HVAC, Floor, Security, Safety) becomes easy. We can send e-mail notifications or direct calls or sms to our devices if needed. Which is actually helpful during any accident or safety incident and also in giving access to another user. The unlimited data limit service needs to be bought, which is about 12000taka. But, if anyone uses free data transmission and receives from microcontroller to Blynk and if the limit reaches to its max he can at least use manual control and send signals to the microcontroller. CADIO is also an IoT, but we didn't use it because CADIO generates code for the controller through AI by itself. It doesn't give any opportunity to the user to modify the code. It gives many graphical switches or accesses but it can be complex to the Senior Citizens as an user.

3.4 Conclusion

After going through multiple research papers verified by IEEE, ResearchGate etc we chose all the modern IT tools for our project. This chapter shows the importance of our modern IT tools and finding the easy accessible softwares for our project through our project timeline.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

In any engineering project choosing the right design is rarely so easy. Every project has to pass through multiple design approaches. Every design approach has its own benefits and drawbacks. In this case optimization is important and needed. Trial and error or intuition can create complications and delay project timeline and put its success in risk. But a structured approach by filtering multiple approaches can make the project smooth and proactive with many benefits. In this section, we are going to optimize among three different design approaches for Residential Building Management Systems. By evaluating this model based on circuit complexity & performance we are going to find out the most proactive and easy to implement with proper functioning design approach. From this we can be sure about which design approach is the most optimal with the objectives of our project.

4.2 Optimization of multiple design approach

4.2.1 Design Approach 01 (Distributed Building Management System)

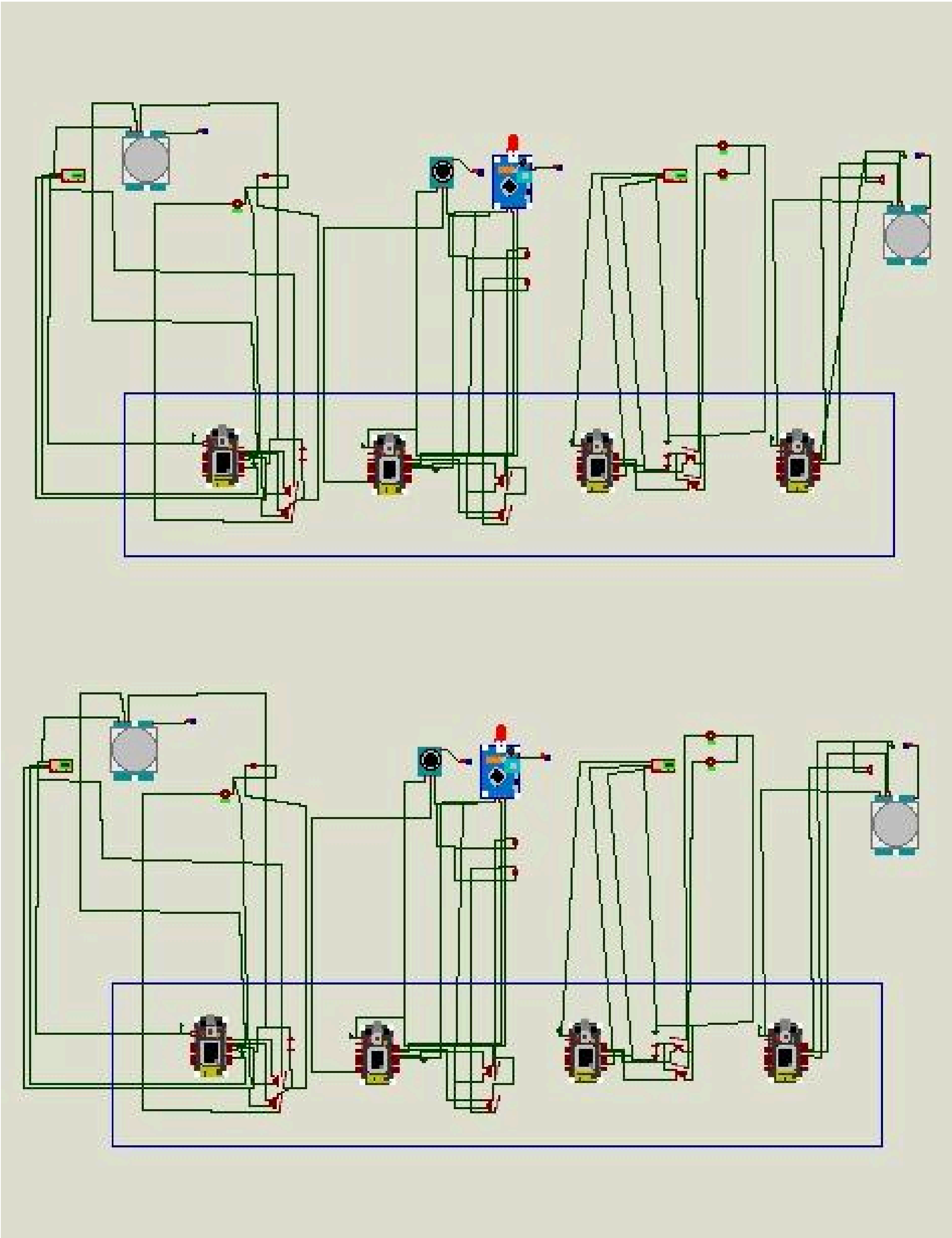


Figure: Distributed Building Management System Circuit.

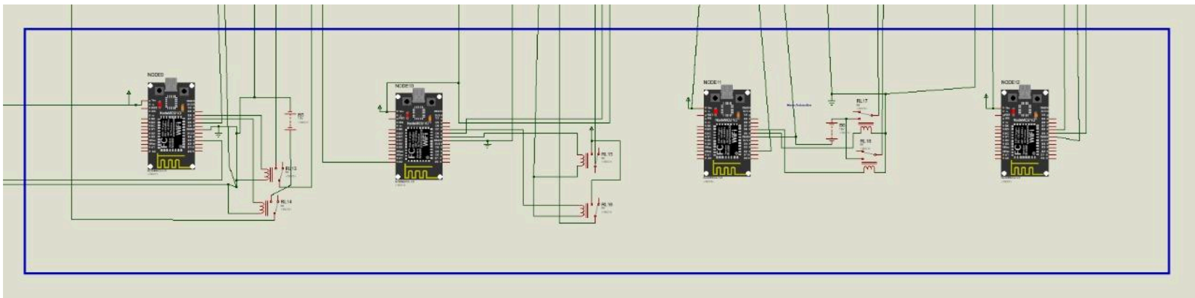


Figure: Distributed Building Management System Control Panel. (Each Floor)

The Distributed Building Management System (BMS) solution divides the building into various zones or floors and each section is controlled by a local control panel of its own. Every panel possesses specific microcontrollers, sensors and actuators that allow it to work independently of the others. This enables every floor or zone to control and monitor its own lighting, temperature, air conditioning and safety systems automatically without needing a central unit.

One of the strongest aspects of this design is modularity and fault tolerance. When a single control panel or subsystem fails, the rest of the building continues to operate. Not only does this make the system more reliable, but it also makes it easier to troubleshoot since faults can be isolated from the rest of the building.

Each node in the distributed platform is functional and consists of some smart control tasks to be executed. The PIR (Passive Infrared) motion sensors are used to detect human motion to turn on lights or fans as someone enters the room and turn off lights or fans if the room is unoccupied, generally saving energy. The same PIR motion sensors are also very crucial in the security system, triggering an alarm or buzzer as soon as unwanted motion is detected either during unwanted entry or at night. In order to control the climate, temperature and humidity sensors like the DHT11 are used for controlling the temperature either to warm or cool the surroundings and provide comfort inside. Additionally, gas and flame sensors are used and continuously monitor the air inside for any looming danger, triggering alarms or exhaust systems in case of gas leakage or fire.

Although highly dependable and flexible, this distributed BMS architecture is not without drawbacks either. Since all zones or floors are controlled by separate control units, the system demands the use of numerous microcontrollers, extensive cabling and communication cables, all leading to drastically high installation expenses. Maintenance and upgrades may also be nightmarish, as all control units must be individually programmed and calibrated. Another drawback is the potential lack of synchronization among various nodes within very large systems, unless proper precautions are exercised.

In general, although the Distributed BMS provides high levels of dependability, flexibility and control, the associated cost, cabling and maintainability are actually more appropriately suited to larger commercial or industrial projects, where autonomy within various distinct areas can be very desirable. In the case of smaller residential applications, this method may prove to be unnecessarily complicated and inefficient compared to more centralized methodologies.

4.2.2 Design Approach 02 (Centralized Building Management System)

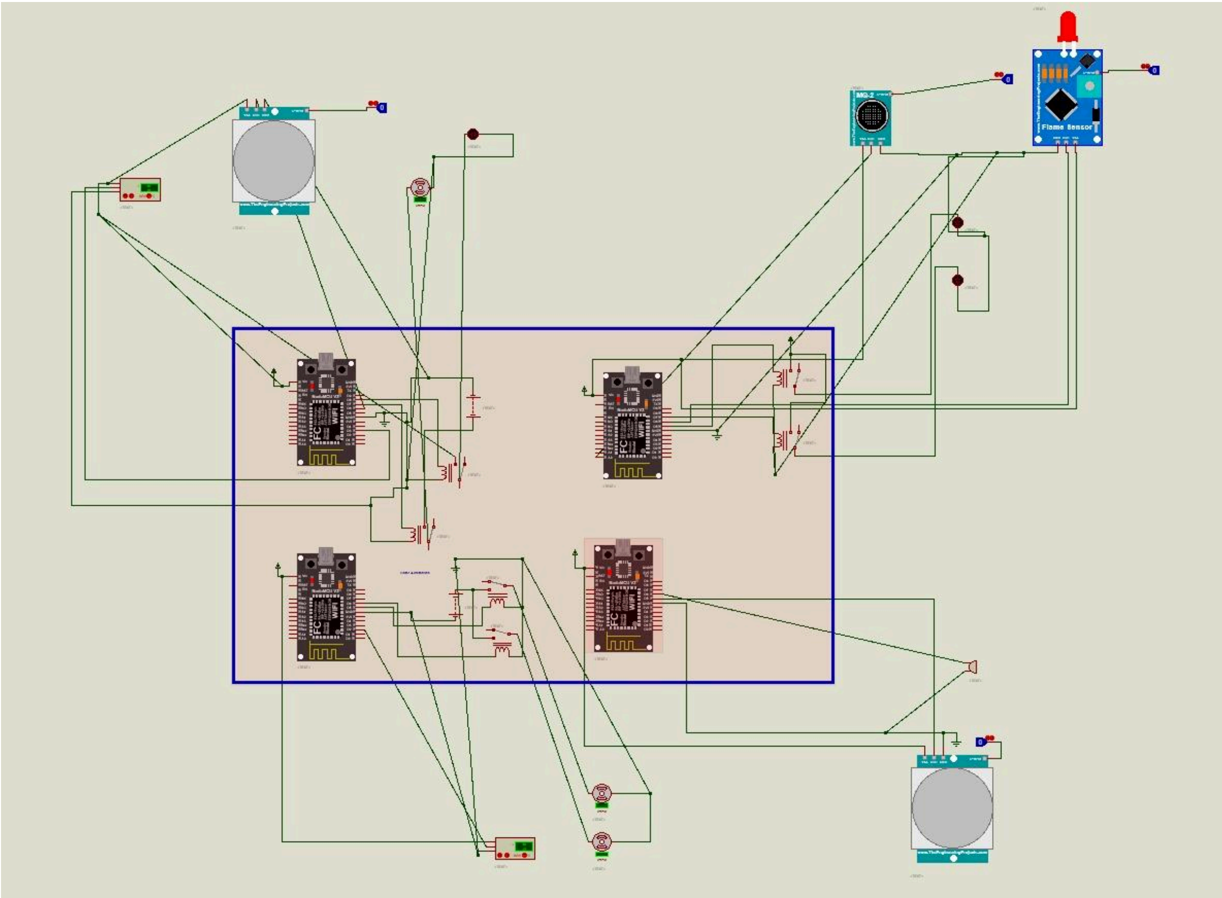


Figure: Centralized Building Management System Circuit.

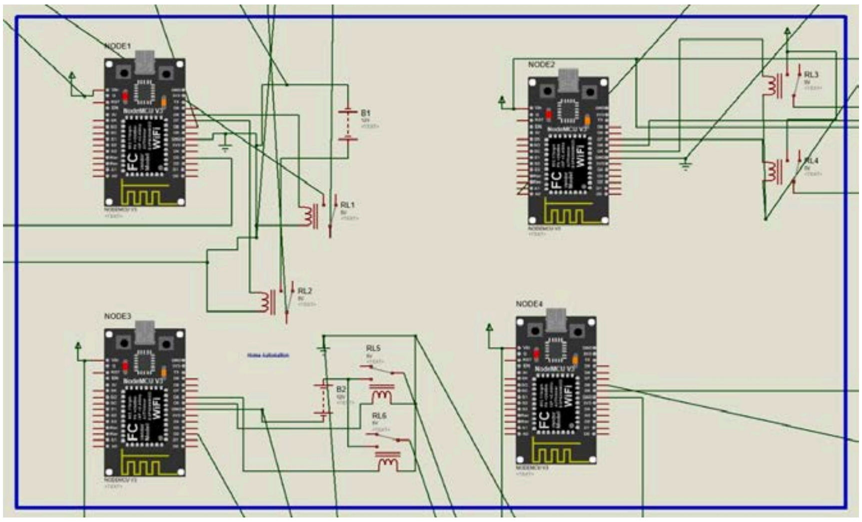


Figure: Centralized Building Management System Control Panel.

The architecture of the centralized Building Management System (BMS) enables all functions associated with building monitoring and control to be combined under the control of one single control node, known as the ‘master’. In this system, all light control, climate control and control of other functions like water level, security and safety functions are directly linked to the central control node, which is the ‘brain’ of the whole process, thereby creating an efficient automation process by enabling all functions to be carried out in one place.

The ESP8266 CH340 NodeMCU Wi-Fi Module (Lua V3) is our system's central controller, which plays an important role as a processor and communicator. All connected devices, including temperature and humidity sensors, PIR motion sensors, gas and flame detectors and relay modules provide real-time data to the NodeMCU. The controller will then process information to manage building operations intelligently. Since it has a built-in Wi-Fi system, users can monitor and control all household functions remotely via a web-based or smartphone platform or IoT, to bring about convenience and accessibility.

The system executes several critical automation tasks efficiently. Movement is detected by PIR sensors to switch lights and fans off automatically, consuming power only when rooms are being used. Temperature and humidity sensors adjust air conditioning and ventilation to maintain comfort in spaces and optimize power usage. Flame and gas detectors provide constant safety monitoring through alarm activation and actuation of extinguishing and solenoid valve relays in case of leaks or fire. It also has a centralized system with a security function based on PIR sensors to identify intruders, triggering an alarm or buzzer straight away to alert occupants or security guards. The major advantage of the central solution is its simplicity and low cost. With fewer lines of communication and microcontrollers, the wiring and installation are incredibly simpler and cheaper. Even maintenance will be easier since all operations are controlled from a single point. Architecture minimizes hardware redundancy and saves power in the system, while responsiveness at all modules remains high.

However, similar to all centralized networks, there comes a big disadvantage with this setup, in that when the primary controller goes down, all the systems connected to it can fail.

To limit this shortcoming, protective elements such as surge protection, circuit isolation and provision of backup power can be applied. Additionally, the system may also be limited in scalability, in which too many devices can be connected to overwhelm the central controller. Because of this, the centralized BMS model is primarily deployed in small to medium-sized residential installations where cost-effectiveness, space-friendliness and simplicity of handling are the most important considerations.

In brief, the Centralized BMS is a tidy, efficient and affordable automation solution that consolidates all home systems into one wise controller. It promises stable operation, real-time monitoring and improved energy management—ideal for residential smart homes that want a combination of performance, ease of use and affordability.

4.2.3 Design Approach 03 (Hybrid Building Management System)

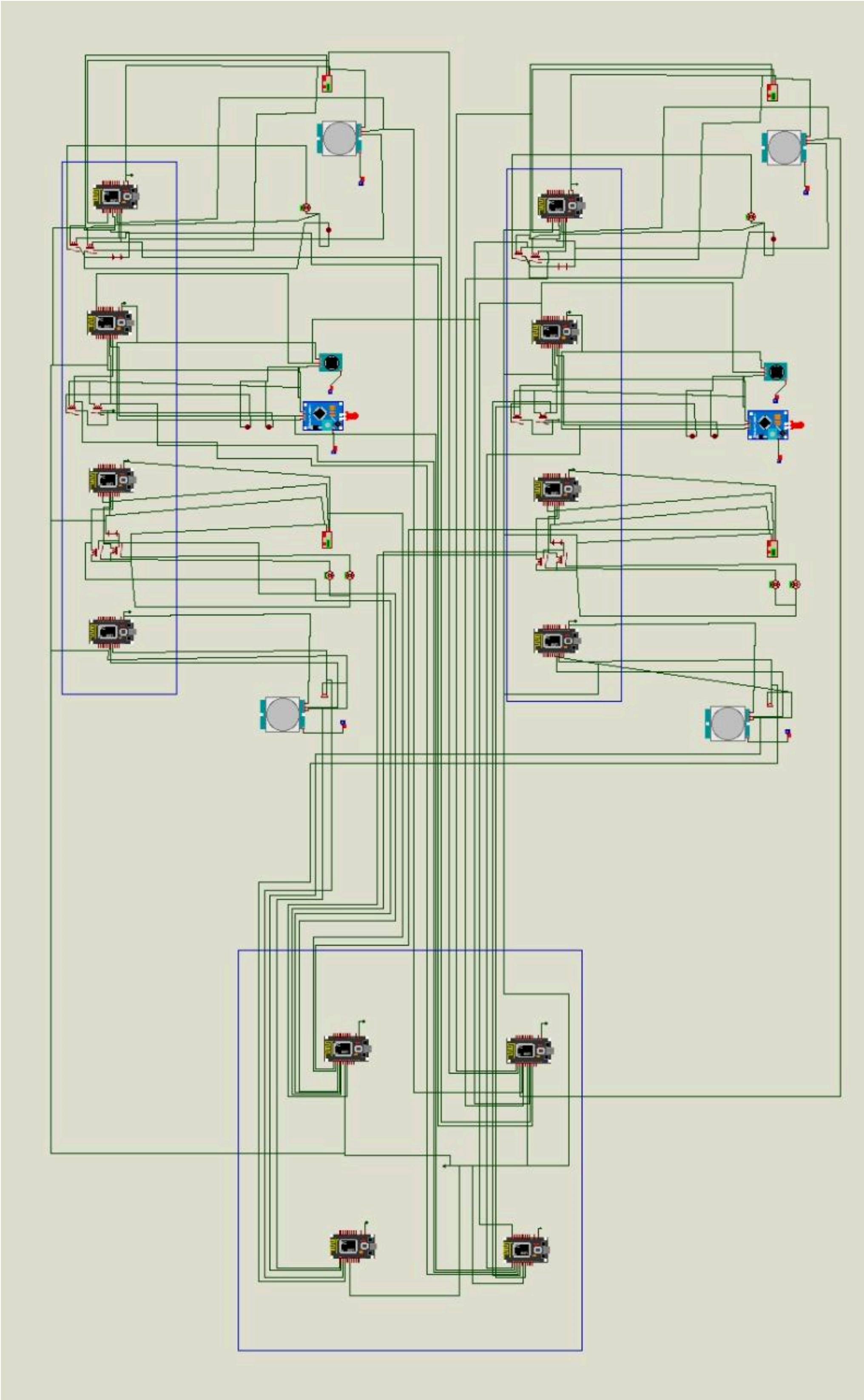


Figure: Hybrid Building Management System Circuit.

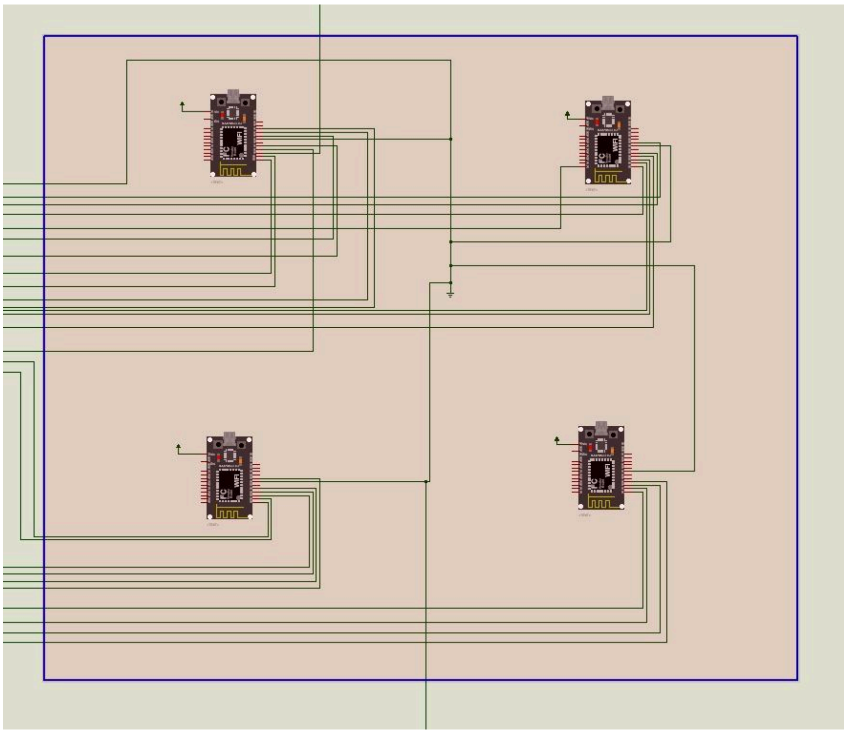


Figure: Hybrid Building Management System Centralized Control Panel.

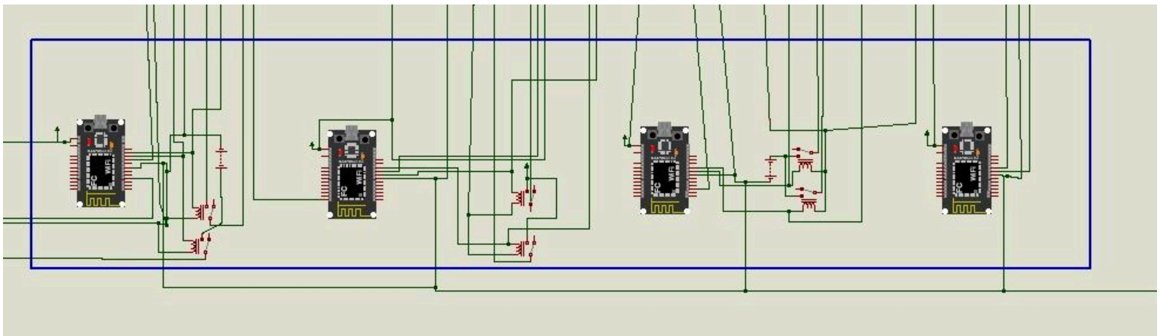


Figure: Hybrid Building Management System Distributed Control Panel.

In the Hybrid Building Management System, both centralized control and floor-level automations are incorporated to optimize both aspects. Each floor has a small controller that can manage all day-to-day operations such as switching lights and fans when there are people moving, changing HVAC settings based on temperatures and humidity and rapid responses to any danger of fire or gas. The overall central controller supervises all activities in the building. In both the central panel and floor panels, the same data from the sensor layer is applied; therefore, in the event of failure, the other controller can immediately function without affecting safety or comfort.

In cases of emergencies such as smoke, fire, or gas leaks, the floor controller responds immediately through alarms, exhaust fans, or closing the gas valve. In cases where the floor controller fails, the central controller can carry out these operations since it has real-time information. The HVAC process relies entirely on the floor for faster responses, but the central controller allows users to supervise from a distance and handle operations manually using the IoT app.

The security system also benefits from such a combined configuration. The PIR sensors are able to detect motion activity in the floors and send alarms to the floor controller, central panel and IoT dashboard. It enables residents or security personnel to know what is happening.

In summary, the Hybrid BMS System is well balanced and reliable. The local controllers ensure that there are no delays in the flow of operations in the automation process, while the central controller offers an additional level of safety and serves as a back-up or remote accessibility. Thus, it suits today's residential buildings.

4.3 Identify optimal design approach

Following an extensive analysis of Distributed, Centralized and Hybrid Building Management System (BMS) design models, the most optimized solution for our home automation project was concluded to be the Centralized BMS. The conclusion was drawn following a comparison of each method in terms of cost-effectiveness, reliability, complexity and scalability.

Centralized BMS design architecture is based on a single ESP8266 CH340 NodeMCU Wi-Fi Module (Lua V3), which is the central processing and communication unit of the entire building. The central controller has the sensors and actuators connected directly to it, which controls many important automation functions such as lighting, HVAC, water level, safety alarms and home security. The NodeMCU has integrated Wi-Fi capability and supports real-time monitoring, management and feedback through smartphone or web interface with central control and supervision to remotely manage all systems from a single point.

Another key feature of this streamlined centralized system is the integrated smart security function. The system employs PIR (Passive Infrared) sensors placed tactically in positions that are most likely to detect intruders for human movement or unauthorized occupation detection. When the movement is detected at an unauthorized time, the NodeMCU immediately triggers a sound buzzer or alarm, alerting the residents or the building's central monitoring panel. The real-time reaction enhances security without the need for separate hardware modules, setting an example of how multiple functions - protection and automation are united through a single effective control mechanism.

The optimization process revealed key findings in comparing all three BMS designs:

- The Distributed BMS was very reliable but required many microcontrollers, local wiring networks and fairly sophisticated maintenance procedures, thereby increasing the costs and installation time.

- The Hybrid BMS showed fault tolerance, flexibility, but tended to be over-engineered for residential applications of small and medium sizes, thereby providing more than necessary redundancy and system complexity.
- The Centralized BMS, however, offered the best balance between performance, affordability and management ease. Therefore, it was the most suitable and optimized solution for this project.

In the context of power control, the system utilizes AC and DC power supplies for optimum operation. Heavy-load devices such as fans, pumps and HVAC are allocated to AC power, while low-voltage control circuits and sensors utilize DC power. A buck converter converts 12V DC down to 5V or 3.3V in order to give stable and secure power supply to the ESP8266 and other electronic devices.

From an operational perspective, the centralized design provides fast response time, minimal latency and high operations reliability. It is easy to maintain since all control logic resides in one location and the system is expandable - new devices or sensors can be added without lengthy reconfigurations. The centralized interface also lends itself to real-time fault detection, informing the users in real time about any event of a system malfunction or anomalous sensor reading.

Overall, Centralized BMS is the most efficient and intelligent solution for modern residential environments. It minimizes wiring and hardware costs, simplifies installation, includes security and safety features and provides centralized control with remote access. Combining intelligent automation, energy efficiency and instant security response, the design ensures a reliable, extensible and user-friendly management system precisely designed for residential applications.

4.4 Performance evaluation of developed solution

The installed Centralized Building Management System (BMS) was tested and evaluated under real operating conditions to measure its functionality, reliability, responsiveness, energy efficiency and ease of use. The evaluation was to determine how efficiently the system performs automation, safety and security operations with convenience to users and low operating cost.

All major modules in the testing, including lighting control, HVAC automation, water management, fire and gas detection and motion-based security, were tested and controlled under a single ESP8266 NodeMCU Wi-Fi module. NodeMCU was able to talk to multiple sensors and actuators in real-time and demonstrated stable wireless performance with no noticeable delay in command execution. Sensor readings such as temperature, humidity and motion detection were projected in real-time on the central dashboard so that users could see system status in real-time either from a smartphone or web portal.

1. System Responsiveness and Reliability

Response time of the system was perhaps its most impressive aspect. Lighting and fans driven by PIR motion sensors responded extremely rapidly once movement presence was sensed. Similarly, smooth switching in fan and AC automation was delivered due to change in temperature, engaging the cooling equipment at precisely the moment that the temperature threshold was reached.

Regarding reliability, the centralized setup was stable under long-term operation because communication was through Wi-Fi. Wire faults were reduced and all the modules were continuously operating with minimal signal interference. Surge protection and circuit decoupling were also employed in the system to prevent controller failure, making it more reliable against electrical disturbances.

2. Security and Safety Performance

Security testing confirmed that the motion-sensitive alarm system was operating properly and reliably. The PIR sensors could correctly detect unwarranted movement and automatically activate the buzzer alarm, warning off while simultaneously notifying the alert on the central dashboard.

Moreover, flame and gas sensors worked perfectly, triggering alarms and exhaust systems automatically when they detected unsafe conditions. This combination of safety and security subsystems on a single centralized platform demonstrates the efficiency of the improved architecture.

3. Energy Efficiency and Cost Optimization

The centralized architecture was also energy-efficient. Sensor-driven automation allowed lights and fans to run only when required, resulting in quantifiable power consumption reductions. The one-controller approach avoided the need for multiple microcontrollers and extensive wiring runs, reducing material and power expenses.

In addition, the double power supply strategy - AC for high-load devices and DC for control circuits - maintained energy at its best. The buck converter's steady voltage regulation protected sensors and NodeMCU from unnecessary power loss as well as component overheating.

4. Comparison Performance Table

The following table is a comparison of the performance evaluation of the three BMS strategies on key parameters:

Parameter	**Distributed BMS**	**Hybrid BMS**	**Centralized BMS (Proposed)**
System Cost (BDT)	32,500	26,700	20,850
Control Complexity	High	Medium	Low
Energy Efficiency	Moderate	High	High
Maintenance Ease	Low	Medium	High
Scalability	High	High	Moderate
Fault Tolerance	High	High	Moderate
Real-Time Performance	Moderate	High	High
Security Integration	Moderate	High	High

This table highlights the fact that the Centralized BMS offers the best balance of cost-effectiveness, real-time, ease of maintenance and integration of security and thus is the most optimized solution for domestic application.

5. Monitoring and User Experience

User interaction when dealing with the system was intuitive and straightforward. Users were able to view sensor data, monitor appliances and view alerts on any connected device using the Wi-Fi dashboard interface. Instant feedback encouraged more reliance on the system being reliable with the centralized monitoring making it simpler to troubleshoot.

In the event of any failure of sensors or loss of communication, the central interface flashed warning messages automatically, allowing users or maintenance personnel to identify and correct faults quickly.

6. Overall System Evaluation

Overall, the deployed Centralized BMS worked flawlessly and efficiently under all test scenarios. It achieved all the project objectives - energy optimization, safety assurance, smart automation and security - within one, integrated system. Ease of system design with advanced features like motion-activated security, sensor-driven automation and wireless control positions it as a best-fit solution for modern residential applications.

In conclusion, the performance test ensures the Centralized BMS provides maximum cost, efficiency, functionality and security with a stable and future-proof smart building management solution.

4.5 Conclusion

The examination and deployment carried out during this chapter evidently demonstrate that the Centralized Building Management System (BMS) is the best optimized and cost-efficient design approach for our home automation project. By a concise comparison of Distributed, Hybrid and Centralized approaches, the Centralized approach was discovered to have superior performance to cost, scalability and simplicity in comparison to the other two architectures.

In contrast to the distributed system that required numerous microcontrollers and complex wiring, the centralized system kept everything in a single control unit - the ESP8266 NodeMCU Wi-Fi Module. The setup significantly minimized hardware redundancy, installation expense as well as maintenance and programming. Similarly, while the hybrid provided scalability and fault containment, it was unnecessarily complex for the residential scale and introduced additional system overheads that were not required for the project size.

The Centralized BMS integrated different functions into one integrated system, including HVAC control, lighting automation, water level control, safety monitoring and motion-based security. Adding PIR-registered security elements, gas detection and flame detection and smart alert notifications turned the system from a controller for an automaton to an all-sufficient safety and energy management system. Real-time observation and remote control through Wi-Fi connectivity also enhanced the users' experience, where individuals could effortlessly control and monitor their environment remotely through mobile or web interfaces.

Technically, the system was highly stable, had fast response times and good communication between sensors and actuators. The employment of double power supply arrangement - AC supply to high-power appliances and DC supply for control circuitry, ensured efficient power utilization and safe long-term operation. The utilization of buck converters to regulate the voltage also safeguarded the components against overvoltage as well as overheating and ensured stable system operation.

From the environmental and operational point of view, Centralized BMS also enables sustainable energy practices. With smart sensor-based automation, the system prevents wastage of power by running devices only when necessary. This means measurable reductions in power consumption and operating costs, which are aligned with today's concepts of efficiency in energy and intelligent living.

From the overall considerations, Centralized BMS is the optimal building automation structure for residential homes. It successfully integrates fundamental smart features - security, safety and automation into one system that is affordable and reliable. The project validates that with proper optimization, a single centralized solution can deliver the functionality and smarts of advanced BMS architectures without sacrificing on the complexity of big industrial rollouts. This approach not only fulfills current home automation needs but also provides a strong foundation to expand further and integrate with IoT, making it an entirely future-proof product for modern smart homes.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

After completing the optimization and assessment of each design solution, the Centralized Building Management System (BMS) was deemed the most suitable and efficient solution for the project. The centralized configuration provides a unified control platform that manages all the major building subsystems, such as light and fan automation, HVAC, safety and security monitoring. In addition to the ease of system coordination in the solution, overall dependability and energy efficiency are also enhanced.

The main emphasis during this stage was to integrate the optimized design within a working prototype that was capable of running in real time. This meant integrating sensors, control hardware and algorithmic software to provide seamless automation. Additionally, IoT connectivity through the Blynk platform was also established to enable remote monitoring and control of appliances through smartphone access, facilitating convenience and accessibility.

This chapter presents the complete process of completion of final design - spanning from hardware assembly to software programming and test of performance. It also specifies how each subsystem was tested, how component-to-component communication settled down and how the end system achieved the imagined functionality of a real centralized Building management solution.

5.2 Completion of final design

The final design of the Centralized BMS grouped all the functional subsystems into a unified controller unit, where ESP8266 NodeMCU Lua V3 (CH340) microcontrollers are dedicated to particular tasks. The controller unit was the intelligence of the system, with it taking inputs from sensors, processing control logic and communicating with both local actuators or relays and the Blynk IoT platform.

The layout was such that it built a system that is modular and compact so that future sensors or features can be added in a simple way. The integration process involved wiring every sensing and actuating component to the NodeMCU in a way that ensures proper power handling, signal conditioning and safe operation via relays.

Hardware Integration

All the prototype consisted of the following essential components:

- **ESP8266 NodeMCU:** Served as the main controller, undertaking all data processing, control actions and Wi-Fi communication with the IoT platform.
- **PIR Motion Sensor:** Used for detecting human presence, ensuring automatic lighting control based on occupancy. During motion detection in the low-light condition, lights automatically turned on and off when there was no activity, hence preserving energy efficiency.
- **DHT11 Temperature and Humidity Sensor:** Monitored ambient conditions for HVAC operation. The output of the sensor provided for automatic cooling unit

operation if the surrounding temperature exceeded a predetermined threshold, providing a comfortable indoor environment.

- **Flame and Gas Sensors:** Monitored for fire or gas leakage in real-time. Trip, these sensors provided alarm and emergency relay activation, providing early indication and protection to the building.
- **Relay Modules:** Acted as switches between the microcontroller and the high-power electrical appliances such as lights, motors and fans. They ensured safe and reliable control of household loads.

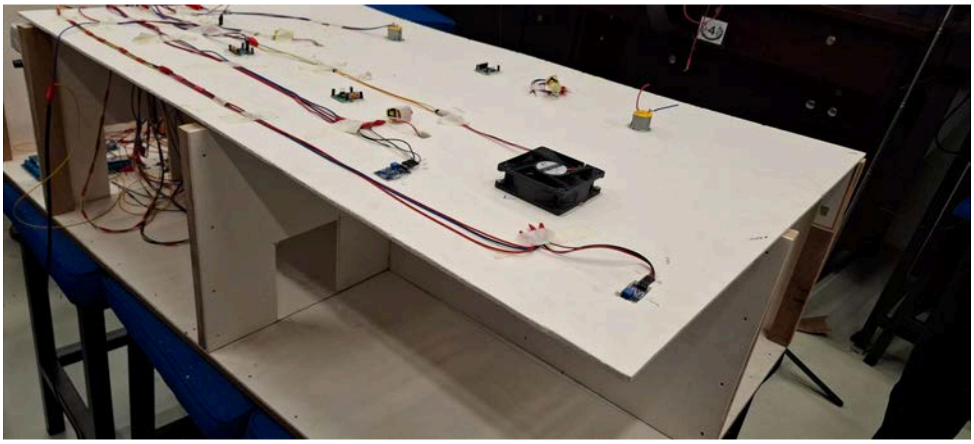


Figure: Prototype

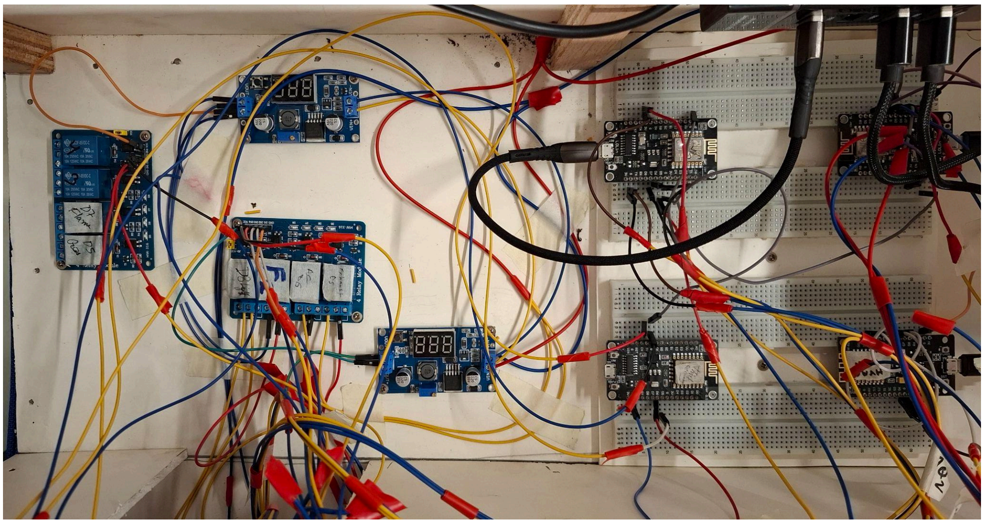


Figure: Control Panel

Hardware components were mounted on a test board and connected correctly to ensure clean isolation between high-voltage and low-voltage circuits. Cable management, grounding and decoupling techniques were effectively utilized to prevent signal interference and ensure system stability. Buck Converters are utilized to Power Relays, Microcontrollers. Microcontrollers run on 3.3V and Relays run on 5V. AC to DC adapters are used to convert DC current from AC current.

Software Development and IoT Integration

The control software was written in Embedded C with the Arduino IDE. Each subsystem - lighting, HVAC, safety and water control - was programmed separately prior to combining them into a single code. The general control logic was founded on conditional statements that determined the output actions based on sensor readings and threshold settings set by the user.

For remote access, Blynk was used as the IoT interface. The NodeMCU was programmed to connect to a Wi-Fi network and was interfaced with the Blynk cloud through an authentication token. The Blynk mobile application provided real-time monitoring of sensor data, manual control of appliances and automatic alert notifications. The users could directly observe temperature, humidity, water level and system status on their smartphones and thus the entire system was rendered interactive and user-friendly.

The incorporation of automation and IoT control made the BMS highly versatile. Even if a user was not present at home, appliances could be operated or monitored, giving a sense of comfort and control not available with traditional systems.

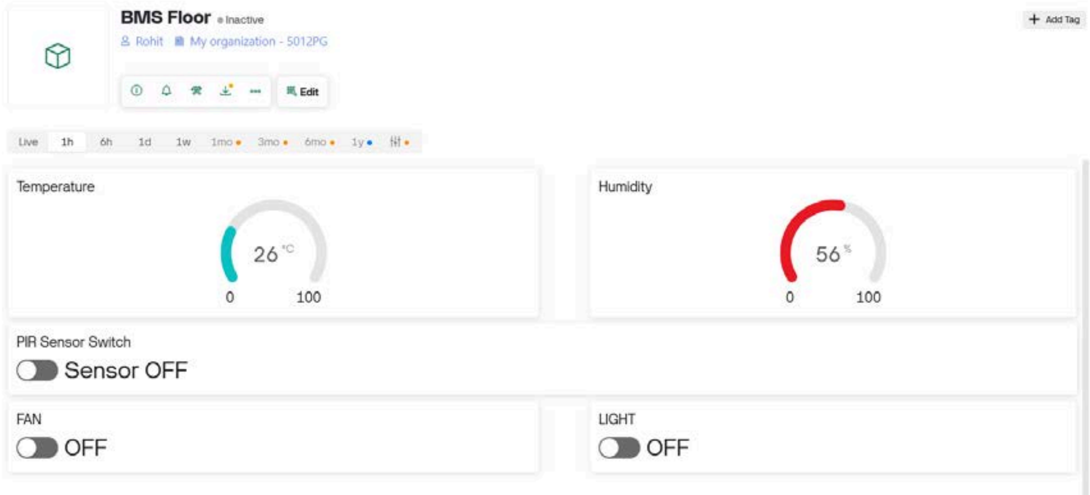


Figure: Blynk Dashboard of Floor Automation.

5 Datastreams

ID	Name	Pin	Color	Data Type	Units	Is Raw	Min	Max	Decimals	Actions
1	PIR Sensor Switch	V0		Integer		false	0	1	--	
2	Temperature	V2		Integer	°C	false	0	100	--	
3	Humidity	V3		Integer	%	false	0	100	--	
4	Fan	V5		Integer		false	0	1	--	
5	Light	V6		Integer		false	0	1	--	

Figure: Blynk Dashboard of Floor Automation Virtual Pins.

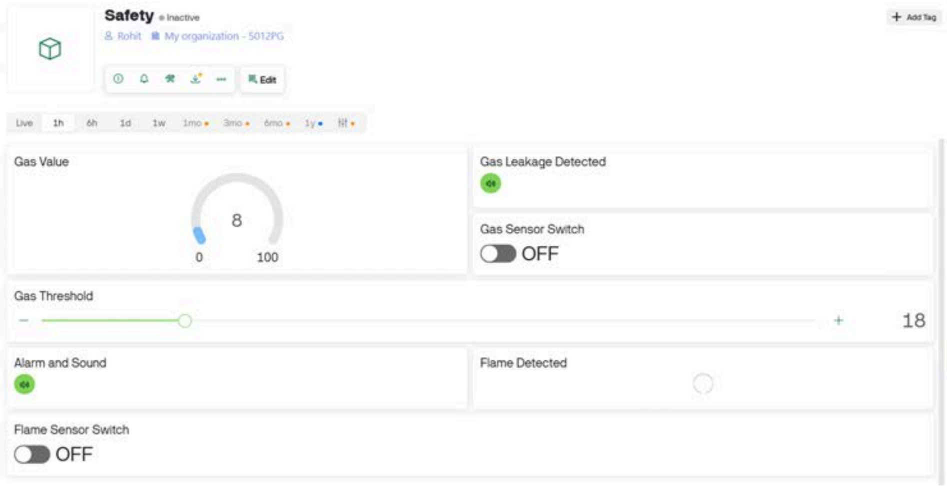
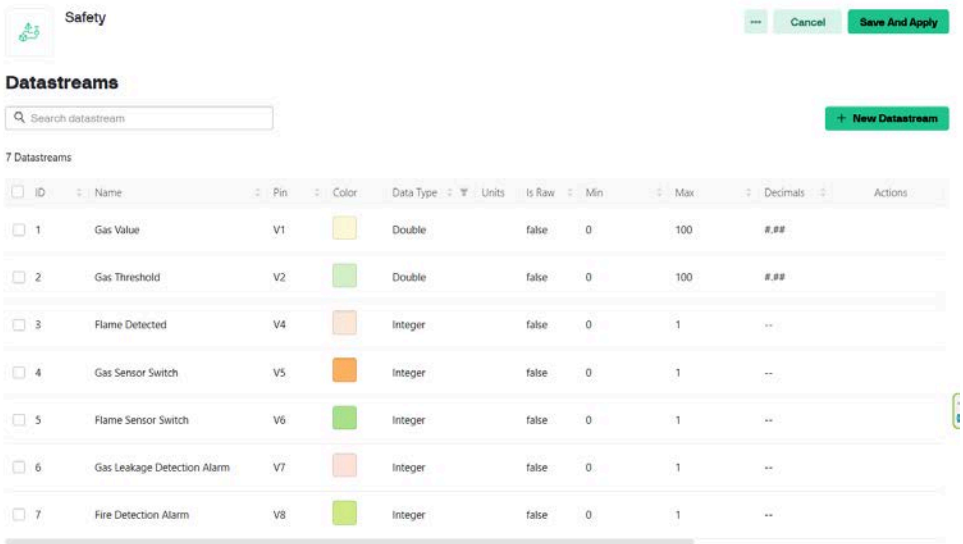


Figure: Blynk Dashboard of Safety System.



ID	Name	Pin	Color	Data Type	Units	Is Raw	Min	Max	Decimals	Actions
1	Gas Value	V1		Double		false	0	100	#.##	
2	Gas Threshold	V2		Double		false	0	100	#.##	
3	Flame Detected	V4		Integer		false	0	1	--	
4	Gas Sensor Switch	V5		Integer		false	0	1	--	
5	Flame Sensor Switch	V6		Integer		false	0	1	--	
6	Gas Leakage Detection Alarm	V7		Integer		false	0	1	--	
7	Fire Detection Alarm	V8		Integer		false	0	1	--	

Figure: Blynk Dashboard of Safety System Virtual Pins.

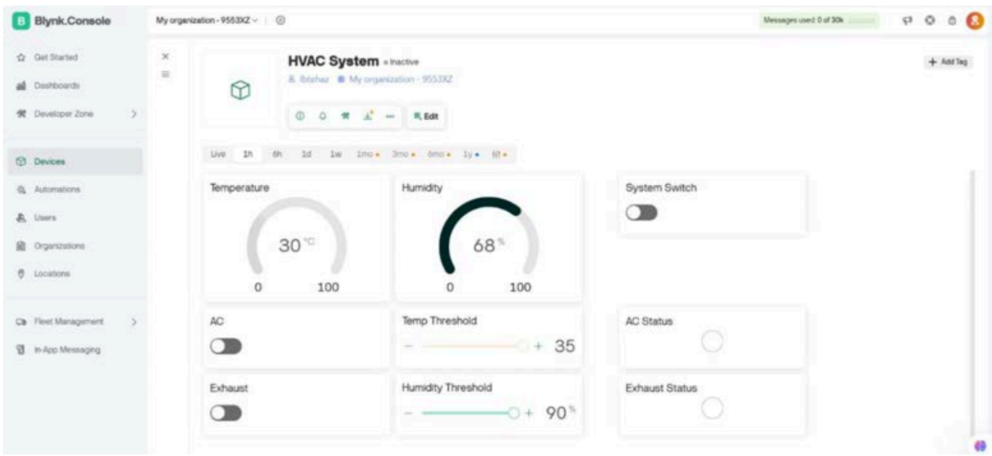


Figure: Blynk Dashboard of HVAC System.

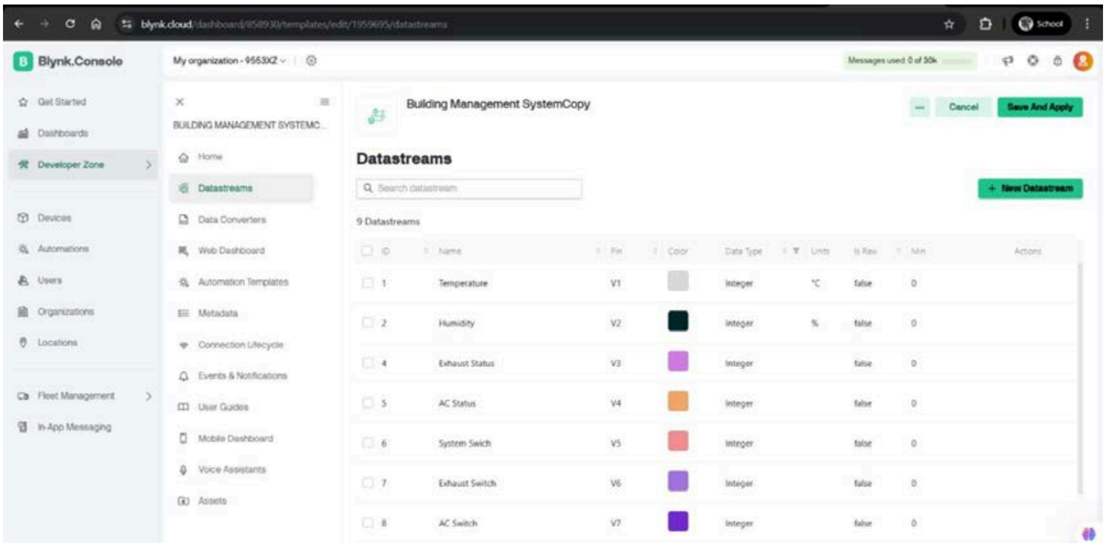


Figure: Blynk Dashboard of HVAC System Virtual Pins.

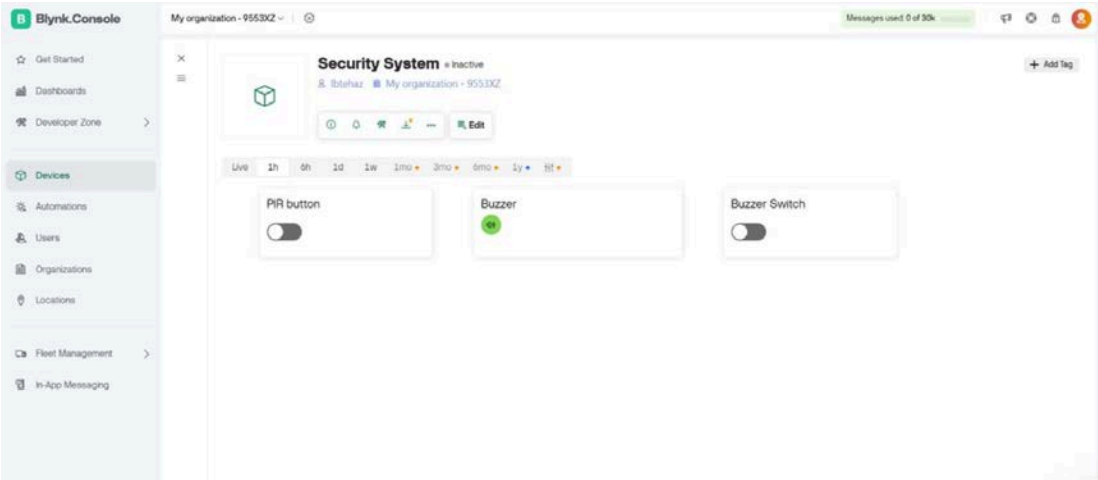


Figure: Blynk Dashboard of Security system.

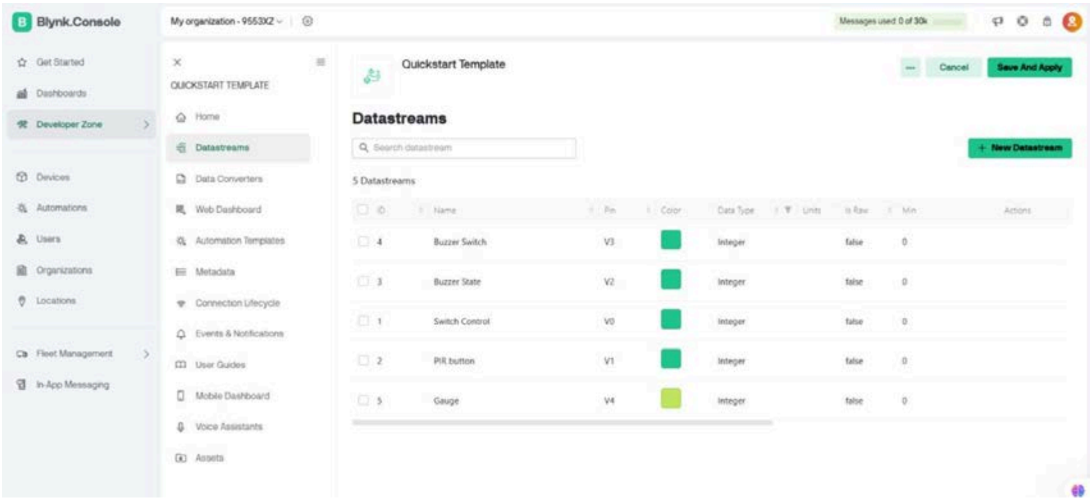


Figure: Blynk Dashboard of Security system and Virtual Pins.

System Assembly and Testing

Following the integration of hardware and software, the whole system was assembled and incrementally tested. Each module was verified to be functional independently to ensure that sensors provided accurate readings and actuators responded accordingly to control commands.

System integration took particular care to ensure that there was a stable connection between the microcontroller and all the devices attached to it. Wi-Fi connectivity was also repeatedly tested to ensure seamless data transmission to the Blynk platform.

The floor-by-floor testing process guaranteed that each zone could communicate optimally with the central NodeMCU without interference. The system was in constant operation with all devices reporting in real time. This phase guaranteed that the final prototype had the optimum combination of responsiveness, reliability and power optimization.

5.3 Evaluate the solution to meet desired need

Validation was carried out in order to ensure that the Centralized BMS developed embodied all the design specifications, including accuracy of automation, performance regarding safety, remote access and energy efficiency. System behavior over diverse operating conditions was observed through a series of experiments.

Light and Fan Automation:

The light & fan system responded immediately to human activity detected by the PIR sensor. During dark environments, the lights automatically turned on when an individual entered a room and de-energized when the individual left. This reduced reliance on manual operation as well as created appreciable energy savings for extended-duration tests.

HVAC Automation

The DHT11 sensor gave accurate room temperature and humidity measurement, thereby the system automatically maintained comfort levels. At the increase of temperature above the given limit, the AC or fan system began and kept running until the desired condition was reached. This feature eliminated the requirement for manual control and reduced power consumption.

Safety Monitoring

The flame and gas sensors were also tested with controlled stimuli to simulate hazardous conditions. The system successfully detected the occurrence of smoke or gas in seconds and produced audible alarms through the buzzer, while relaying de-energized critical loads to prevent escalation. Tests proved that the safety module was fast, responsive and consistent.

IoT Monitoring and Control

The addition of Blynk provided tremendous functionality to the system usability. Real-time sensor values such as temperature, humidity and water levels were displayed on the Blynk dashboard. Furthermore, override of devices manually was also facilitated by the application along with real-time notification in case of abnormal conditions such as gas leak or water over flow. Delay time for the application command to the response of the system was negligible, thus confirming good cloud connectivity.

During testing, the system was very consistent and reliable. Manual and computer control comparison indicated a significant reduction in energy usage and improved safety responsiveness. The centralized design enabled all modules to work together in coordination without loss of information and delay in communication. The outcomes verified that the system was capable of achieving all important design objectives - automation, energy efficiency, safety and distant accessibility on the basis of IoT.

5.4 Conclusion

Successful implementation and testing of the Centralized Building Management System (BMS) confirm that it is feasible to employ modern microcontrollers and IoT solutions to install an efficient, cost-effective and scalable automation system. The use of the ESP8266 NodeMCU, Blynk platform and low-cost sensors turned out to be a good foundation for smart home management applicable for daily use.

The finished prototype proved to be stable in every module, including lighting control, HVAC control, security monitoring and safety monitoring. The centralized architecture simplified communication and coordination among the subsystems, with IoT connectivity provided adding flexibility and ease of use for consumers. Modular design for the system also offers simple scalability - additional sensors, devices or functions can be added without much alteration.

In conclusion, the Centralized BMS prototype answers all the project's goals completely: automation, safety, security, energy saving and smart control. Through the addition of future upgrades such as AI-based data analysis, predictive maintenance, cloud storage and voice command features, the system is capable of evolving into a complete Building Automation system. The project verifies that a Building automation system is possible through an economical, stable and user-friendly design - making smart living more real.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

In addition to technological challenges, engineering solutions must also be beneficial to the environment, society and general sustainability. The wider influence and sustainability of the Residential Building Management System (BMS) created for the project are examined in this chapter. In addition to environmental sustainability and long-term ecological benefits (CO4), assessment involves societal, health, safety, legal and cultural conditions (CO3).

6.2 Assess the Impact of the Solution

The planned Building Management System was designed to improve residing conditions, security and energy efficiency of residential apartments. Its implications are addressed below from different aspects.:

1. Societal Impact

The project resolves major social issues like the wastage of energy, excessive electricity bills and domestic fire hazards. It encourages judicious consumption of energy and increased convenience in terms of automated lighting and building safety limit monitoring. Society at large benefits due to overall reduction in electricity use and lightened national grid load, but homeowners receive the advantages of increased levels of comfort and lower running costs. Bangladesh's sustainable development targets (SDG 7: Affordable and Clean Energy) are in consonance with this

2. Health and Safety Impact

To provide pre-alarm alerts in dangerous situations like fire or gas leakage, the system has smoke and gas detectors. This reduces the chance of accidents or fatalities and directly enhances occupant safety. Automatic control systems also reduce the risks of electrical overloads, short circuits and overheating. Compliance with IEEE and IEC safety requirements using certified electrical parts, good grounding and protection circuits guarantees that the safety of user health and electrical safety is of top concern.

3. Legal and Regulatory Impact

Design conforms to Bangladeshi building regulations and applicable electrical installation regulations. The installation satisfies legal and professional requirements because of safety features, load limitation and protection from surges following accepted engineering practices. Furthermore, in accordance with new data protection legislation, all the system's data - temperature, occupancy and power consumption is localized and stored safely, safeguarding residents' privacy.

4. Cultural and Ethical Considerations

By enabling manual override, the system respects Bangladeshi residential cultural norms by allowing users to be in complete control of appliances and lighting. Automation is meant to support human decision-making, not displace it. Enabling technological usability within socioeconomic levels and prioritizing affordability guarantees that the solution is flexible and comprehensive enough to accommodate urban as well as semi-urban dwellers.

6.3 Evaluate the Sustainability of the Solution

Sustainability is central to the project's design philosophy, focusing on energy efficiency, renewable integration and long-term maintainability.

1. Environmental Sustainability

By intelligent use of light, fans and appliances, the BMS saves the environment by utilizing less power than needed. Thermoelectric Generators or TEGs are deployed in the system for the sole function of recovering waste heat energy from domestic appliances and transferring it to useful electrical power. With its low output, TEG shows how micro-energy recovery systems can someday be used to supplement renewable power sources.

2. Resource Efficiency

The system promotes efficient use of electricity via power consumption pattern monitoring and auto-on/off control of power-intensive appliances. The parts were chosen for durability and low power usage in order to reduce e-waste and maximize the lifespan of the product. Over the long term, the modular design reduces material waste via upgrade or repair instead of replacing the entire system.

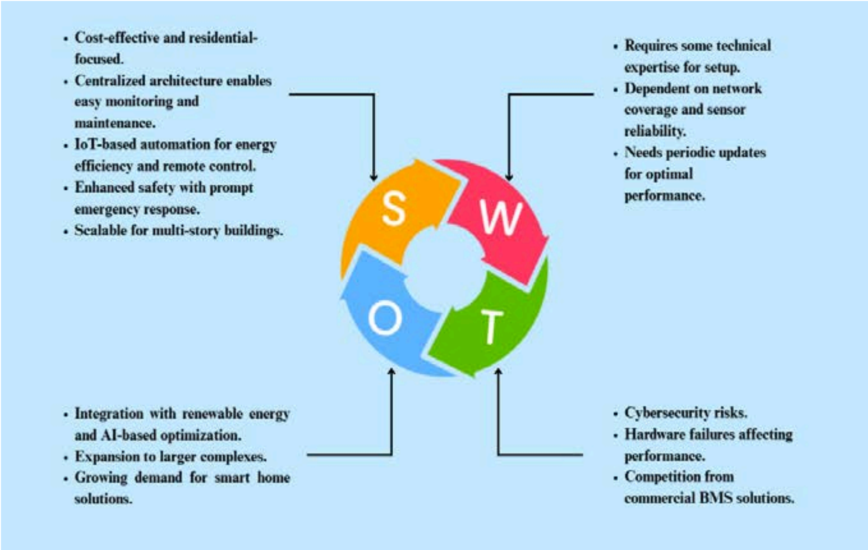
3. Economic and Operational Sustainability

The plan will continue to be affordable for middle-class households because of low implementation cost. The system will be financially sustainable while cutting down on its carbon footprint and encouraging responsible consumption and an estimated two to three years of payback period from energy savings.

4. Social and Institutional Sustainability

The suggested BMS facilitates efficient living and energy conservation. It improves the lifestyle of residents as well as decreases the environmental footprint of urban living by integrating efficiency, convenience and security. With expansion of the project, developments can accommodate national energy control programs and promote the widespread adoption of smart home technology.

5. SWOT Analysis



The above SWOT analysis gives an overview of the sustainability aspects of the proposed IoT-based Building Management System (BMS). Its strengths highlight cost efficiency, centralized watching, enhanced security and scalability for tall buildings. Its weaknesses are the technical know-how involved in installation, dependency on the network and the necessity for frequent updates. Its opportunities are incorporating renewable energy and AI optimization, expanding to larger complexes and meeting growing demand for smart home solutions. However, threats such as cybersecurity attacks, potential hardware malfunctions and competition from long-established commercial BMS providers hinder long-term sustainability and reliability.

6.4 Conclusion

With guaranteed legal, cultural and ethical norms, the Residential Building Management System largely supports safety, energy efficiency and quality of life (CO3). Maxing out the consumption of energy and encouraging the use of renewable energy, the project is also ecologically sustainable (CO4). The system is a working prototype of an engineering solution that weighs technical superiority against the underlying principles of professional practice in engineering—social responsibility, environmental responsibility and long-term sustainability—by design, implementation and operating philosophy.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Effective project management ensures the successful completion of an engineering design project within given time, cost and quality parameters. Project management concepts in engineering were used for this project, Design and Implementation of a Residential Building Management System (BMS), to establish the project scope, assign resources, track its progress and deliver it in time. All the project life cycle phases of initiation, planning, execution, monitoring and closure were followed in the management process.

7.2 Define, plan and manage engineering project

The team established the project objectives at the onset and they were to develop the BMS of a six-story residential building that was economic, energy efficient and safe. Energy monitoring, light automation and gas and smoke detection were all included in the project.

Project Planning:
Every stage of the project was scheduled with a comprehensive Gantt chart that allowed time for design, component procurement, coding, prototyping and testing. To allow for an equitable workload and responsibility, the group divided members into positions based on their areas of expertise, which included hardware design, computer programming, circuit layout, documentation and data analysis.

Resource Management:
Specific resources from the approved Bill of Materials (BOM) were allocated to individual stages. The budget initially pegged at BDT 46,600 was controlled by recycling lab equipment whenever feasible and sourcing components locally. For accountability, purchases and expenditures were recorded in a shared spreadsheet.

Risk Management:
Preemptive identification of possible hazards involved software bugs, communication breakdown and component failure. In order to ensure operational reliability, mitigation strategies involved local storage of sensor data, versioned firmware and redundant sensors.

7.3 Evaluate project progress

Regular meetings and milestone reviews were used to ascertain the progress of the project. Every participant gave an update of his or her tasks, issues and next steps. Based on milestone attainment the project advisor gave periodic evaluation and feedback.

Some of the significant progress indicators included:

- percentage completion of hardware and software integration.
- adherence to scheduled deadlines.
- testing and debugging reports.
- monitoring expenditure and resource usage.

Communication effectiveness, teamwork quality and individual contribution were evaluated by the group using a peer evaluation form. This helped to guarantee that each person worked on the project and that the workload was distributed evenly.

Figure 7.3.1: Gantt Chart.

Timeline: The project will be completed over **4 months** with structured phases and milestones. Below is a breakdown of the expected timeline:

Task/Phase	Duration	Start Date	End Date	Responsibility
Phase 1: Research & Requirements	3 month	November 1, 2024	Jan 31, 2025	- User (for gathering building data) - Team (literature review and documentation)
Phase 2: Design & System Architecture	3 month	Feb 1, 2025	May 30, 2025	- Team (system design, component selection and architecture) - Mentor review
Phase 3: System Development & Implementation	2.5 month	June 1, 2025	August 15, 2025	- Team (developing hardware and software components, coding) - Mentor support
Phase 4: Testing & Validation	25 Days	August 16, 2025	September 10 2025	- Team (system testing, debugging and performance evaluation) - User validation
Phase 5: Documentation & Final Report	1.5 month	September 11, 2025	October 28, 2025	- Team (final report writing)- Mentor review

7.4 Conclusion

The project was completed on schedule and within cost thanks to efficient definition, planning and administration. While teamwork and communication (CO14) enabled successful project completion, application of project management principles (CO11) allowed quality control and controlled progress monitoring. This proved that the team could apply sensible project management practices in a multidisciplinary engineering setting.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

A critical aspect of engineering project development is economic analysis, as it enables decision-makers to consider the possible return on investment (ROI), cost-effectiveness and financial sustainability of a given solution. Through the application of cost-benefit analysis and financial feasibility analysis, this chapter appraises the financial and economic aspect of the project.

8.2 Economic analysis

The prototype cost of the BMS was estimated to be BDT 46,600 in total. In order to offer a realistic estimate, additional installation and wiring costs were separately calculated. Taking into account the probable energy saving and the installation cost, the financial feasibility of installing the whole system for an entire residential complex was analyzed.

- Estimated energy savings: From occupancy and day lighting usage, 15–25% of electricity should be saved through automated appliance and lighting control.
- Due to the modularity of the sensor design and local automation functionality, maintenance is extremely low.
- Payback period: The system should pay back its cost within 2.5–3 years for a typical 3-story building, mostly from the savings in electricity bills.

Cost benefit analysis:

Power Saving Segment/Floor Automation

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
ESP8266 NodeMCU	3	240	720
PIR Motion Sensors (HC-SR501)	9	65	585
Temperature and Humidity Sensors (DHT11)	9	90	810
1-Channel Relay Modules	18	80	1440
Buck converter	1	220	220

Subtotal for Power Saving Segment**: BDT 3,775**

Safety Segment

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
Smoke Detector Sensor MQ-2	3	110	330
Flame Sensor Modules	12	40	480
Solenoid Valve (Gas Shutoff)	1	2,250	2,250
ESP8266 NodeMCU	1	240	240
1-Channel Relay Modules	10	80	800
Buck converter	1	220	220

Subtotal for Safety Segment**: BDT 4320**

Security System

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
ESP8266 NodeMCU	1	240	240
Buzzer	3	150	450
Buck converter	1	220	220
PIR Sensor	3	65	195

Subtotal for **Security System: BDT 1105**

HVAC System:

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
ESP8266 NodeMCU	1	240	240
DHT11	9	90	810
Buck converter	1	220	220
1-Channel Relay Modules	21	80	1680

Subtotal for **HVAC System: BDT 2950**

Total Budget

Total = BDT **3,775** (Power Saving) + BDT **4320** (Safety) + BDT **1105** (Security)+ BDT **2950** (**HVAC System**)

Grand Total = **BDT 12,150**

Expected Benefits:

- Annual energy bill reduction (approx.) = 18–20% per flat.
- Reduction in maintenance costs due to early fault detection.
- Improved occupant comfort and safety—intangible but critical value.

8.3 Evaluate economic and financial aspects

The economic study took into consideration the cost of investment, operational costs and the anticipated energy savings in order to guarantee project feasibility. Thanks to its modularity, the system may be installed piecemeal, initially installing one floor and then spreading out in increments. Even with conservative projections, the IRR remains enticing to owners of residential buildings who are interested in enhancing their energy-efficient systems.

8.4 Conclusion

Scalability and cost-effectiveness of Residential BMS are supported by the cost-benefit analysis. With systematic estimation and economic rationale, the project illustrates how to assess the economic and financial aspects of an engineering project (CO12, PO k3), ensuring the engineering solution is technologically viable and financially worthwhile.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Practice in sound engineering depends on ethics and professional accountability. Professional codes and ethical standards were adhered to for the aims of guaranteeing integrity, security and overall well-being in an effort to ensure the same throughout the design and development of the Residential Building Management System. The ethical concerns, professional needs and conformity to pertinent standards applicable to the project are identified in this chapter.

9.2 Identify ethical issues and professional responsibility

The key ethical considerations identified were:

Safety: Ensuring that all electrical and electronic components meet safety standards to prevent fire, shock, or failure hazards.

Honesty in Reporting: All project data, results and performance measurements were recorded truthfully without fabrication or manipulation.

Intellectual Property (IP): External sources, circuits and code snippets were properly cited ensuring academic integrity.

Environmental Responsibility: The design promotes energy efficiency and uses renewable components (TEGs) to reduce environmental impact.

Data Privacy: Any data collected (e.g., occupancy, usage patterns) remains local and secure to protect resident privacy.

9.3 Apply ethical issues and professional responsibility

The team actively practiced professional responsibility by:

Following IEEE and IEC Standards: Safety, surge protection and interoperability standards were reviewed (IEEE 1547, IEEE 519, IEEE C62.41).

Maintaining Integrity: All documentation and reports were prepared by the team without plagiarism.

Professional Conduct: Tasks and responsibilities were shared fairly and all conflicts were resolved through mutual discussion and respect.

Compliance and Standards Review (CO2): The project complied with engineering codes and building safety standards applicable to electrical installations. Standards and regulations relevant to the system design were identified and applied during circuit design and component selection.

9.4 Conclusion

The project maintained high ethical and professional standards from conception to completion. By upholding honesty, safety and compliance with engineering standards, the team demonstrated the ability to apply ethical principles and professional responsibilities (CO13, CO2). The system was designed not only for functionality but also for public safety and long-term sustainability, fulfilling the ethical obligations of the engineering profession.

Chapter 10: Conclusion and Future Work.

10.1 Project summary/Conclusion

The Residential Building Management System (BMS) project shows a practical use of electrical, electronic and computer engineering principles to build a smart home that is sustainable, automated and secure. From the idea stage to implementation, the project tackled the increasing demand for energy efficiency, safety and automation in homes. It supports national and global goals for sustainable urban living.

The project identified key challenges in conventional residential energy management. These include inefficiency, waste and the absence of real-time monitoring. The systematic design process evaluated three approaches: Distributed, Centralized and Hybrid BMS. It can be concluded that the Centralized BMS provided the best result for balance of cost, efficiency, scalability and simplicity for residential applications.

The use of modern IT and engineering tools like Proteus, Arduino IDE and Blynk IoT made it easier to simulate, test and optimize. This integration showed that affordable and accessible technologies could effectively design a reliable automation system. The selected Centralized model performed well in terms of efficiency, energy use and user convenience. It ensured real-time monitoring and responsive control over lighting, HVAC, safety and security systems.

Successful system validation proved that the Centralized BMS prototype can meet automation, safety and sustainability goals in real-world conditions. The system was tested for responsiveness, energy efficiency, fault tolerance and IoT communication. All these aspects performed reliably within expected limits.

The impact and sustainability analysis showed how the project helped with environmental preservation, energy saving and social well-being. It not only improved electricity use but also increased residents' comfort, health and safety, supporting SDG 7 (Affordable and Clean Energy).

From a management perspective, structured planning, teamwork and efficient use of resources helped complete the project on time and within budget. This showed the team's skill in using project management methods effectively. The financial analysis confirmed that the project was economically viable, with a reasonable setup cost and an estimated payback period of 2 to 3 years due to substantial energy savings. Lastly, ethical concerns emphasized that the project was carried out with academic honesty, professional integrity and adherence to IEEE standards, ensuring safety, reliability and data privacy.

In conclusion, the Residential BMS project is a sustainable and smart engineering solution aimed at tackling modern urban challenges with innovation and responsibility. It combines automation, energy efficiency and safety in one system, connecting smart technology with everyday life. This work meets its academic and technical goals. It also plays a significant role in improving smart, green and safe residential infrastructures for future generations.

10.2 Future work

While the project successfully met its objectives, there remain several opportunities for further improvement and expansion in future iterations. Key recommendations include:

1. **Integration of Artificial Intelligence (AI) and Machine Learning (ML):**
   Incorporating AI-based predictive algorithms can enable intelligent decision-making, such as forecasting power usage trends, detecting anomalies and optimizing appliance operation based on user behavior and environmental data.
2. **Advanced Data Analytics and Cloud Connectivity:**
   Expanding data storage to cloud-based systems will allow long-term trend analysis, performance monitoring and real-time remote diagnostics, improving scalability and predictive maintenance capabilities.
3. **Enhanced Security and Data Privacy:**
   Future designs can adopt blockchain-based IoT security frameworks or encrypted data transmission methods to protect against cyberattacks and unauthorized access, ensuring the confidentiality and integrity of user information.
4. **Wireless communication between module and sensor:**
   Implementing wireless communication between sensors and modules to further improve accuracy of the input and efficiency of the system.
5. **Microwave Detection:**
   Further improve and include a system to detect microwaves for kitchen safety.
6. **Narrow down the use of microcontrollers:**
   Usage of a minimal number of microcontrollers to have more efficiency.
7. **PCB implementation:**
   PCB is required to nullify any effect or occurrence due to the over presence of wiring.

Chapter 11: Identification of Complex Engineering Problems and Activities.

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	√
P3	Depth of analysis required	√
P4	Familiarity of issues	
P5	Extent of applicable codes	√
P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	√

Note: Project must have P1 and some or all from P2-P7

P1: Depth of Knowledge Required

Reason: The project involves integrating several engineering fields, including electronics, automation, renewable energy and safety systems. Understanding microcontroller programming, sensor integration and meeting IEEE standards requires deep knowledge across different engineering areas.

Justification: It's essential for all complex engineering problems. The project definitely meets this requirement.

P2: Range of Conflicting Requirements

Reason: There are trade-offs between cost, energy efficiency, system complexity and user convenience. For example, automating HVAC and lighting can save energy but may increase system cost and complexity. Ensuring safety features like gas detection is important but it should not compromise cost or ease of use.

Justification: Balancing these conflicting needs is essential for finding a practical and workable solution.

P3: Depth of Analysis Required

Reason: The project requires analyzing complex scenarios like:

- Optimizing sensor placement for accuracy and reliability.
- Evaluating the trade-offs between centralized, distributed and hybrid BMS approaches.

Justification: These analyses require careful calculations, running simulations and making decisions.

P5: Extent of Applicable Codes

Reason: Our project follows several important standards, such as:

- IEEE 1547 for distributed energy resources.
- IEEE 519 for harmonic distortion.
- IEEE C62.41 for surge immunity testing.

Justification: Meeting these standards shows the important role of codes and compliance in ensuring system performance, reliability and safety.

P6: Extent of Stakeholder Involvement and Needs

Reason: Multiple stakeholders influence the project:

- **Building residents:** Need user-friendly, cost-effective systems.
- **Engineers:** Require compatibility and scalability for design and implementation.
- **Regulators:** Ensure compliance with safety and environmental standards.

Justification: The system design must account for the diverse needs and constraints of various stakeholders.

P7: Interdependence

Reason: The subsystems in the project rely on each other by:

- Sensors providing data to microcontrollers.
- Automation algorithms controlling actuators and devices using sensor input.

Justification: Effective coordination and integration of these subsystems are crucial for the project to work as planned.

Attributes of Complex Engineering Activities (EA)

	Attributes	Put tick (√) as appropriate
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	

Note: Project must have some or all of the characteristics from attributes A1 to A5

A1: Range of Resources

Reason: The project involves a variety of resources, including:

- Hardware components: Sensors (e.g., LM35, MQ-2), microcontrollers (e.g., ESP32), actuators.
- Software tools: Node-MCU, Proteus and Blynk IoT.
- Human resources: Engineers, testers and building users.

Justification: Managing these different resources and making sure they fit well into the system shows a broad variety of resources.

A2: Level of Interaction

Reason: The project involves important technical and human-system interactions:

- **Technical Interactions:** Sensors, microcontrollers and actuators communicate in real-time for automation and fault detection. Subsystems like energy recovery, safety systems and centralized BMS controls work together to maintain operational efficiency.
- **Human-System Interactions:** Residents use interfaces such as mobile apps and control panels to monitor and manage building systems. Maintenance teams depend on fault notifications and system diagnostics for smooth operations.

Justification: These multi-layered interactions ensure smooth integration of components. They also support effective automation and create a user-friendly experience. This makes this attribute a key part of the project's complexity.

A4: Consequences for Society and the Environment

Reason: The project has major effects on both society and the environment:

- **Social Impact:** It improves energy efficiency, safety and convenience for people living in residential buildings.

- **Environmental Impact:** It lowers carbon footprint by using energy recovery and integrating renewable energy.

Justification: The project helps to meet sustainability goals (SDGs) and improves the quality of life for residents.

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Appendix

Logbook

FYDP (P) Summer 2025 Summary of Team Log Book/ Journal

Log Book				
Date	Attendee	Summary of meeting	Responsible	Comment by ATC
13/11/24	All members	Discussion preparing concept note	All	N/A
19/11/24	All members	Discussion and preparation for progress presentation	All	Guidelines on slides
04/12/24	All members	Preparation of final concept note	All	N/A
26/12/24	All members	Discussion on draft project proposal	All	N/A
30/12/24	Samir Md. Takky Ibtehaz	Discussion with ATC	All	Guidelines on preparing the draft project proposal
02/01/25	Samir Md. Takky Ibtehaz	Discussion with ATC	All	Review on draft project proposal and correction of mistakes

FYDP (D) Summer 2025 Summary of Team Log Book/ Journal

Log Book				
Date	Attendee	Summary of meeting	Responsible	Comment by ATC
10/02/25	Md. Takky Ibtehaz Samir Fidaul	Discussion with ATC	All	Show plans of work.
20/02/25	Md. Takky Samir	Discussion with ATC	All	N/A
04/03/25	All Members	Discussion and collecting resources	All	N/A
16/03/25	All Members	Discussion and Trial on Revit.	All	N/A
26/03/25	All Members	Discussion and research on other softwares.	All	N/A
05/04/25	All Members	Discussion and finding research papers related to BMS designing	All	N/A
17/04/25	Ibtehaz Md. Takky	Discussion and following research paper prepare a design plan	All	N/A
22/04/25	Ibtehaz Md. Takky	Discussion and solving design related problems	All	N/A
24/04/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Start working on Proteus	Md. Takky	N/A
26/04/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Sensing unit and receiving unit design	Md. Takky	N/A
28/04/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Automated pump and automated	Md. Takky	N/A

		generator design in proteus		
30/04/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Distribution BMS design in proteus	Md. Takky	N/A
02/05/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Centralized BMS design in proteus	Md. Takky	N/A
04/05/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Hybrid BMS design in proteus	Md. Takky	N/A
05/05/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Arduino IDE code for sensing unit, receiving unit, automated generator.	Md. Takky	N/A
06/05/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and Complete Arduino IDE code for Centralized and Hybrid BMS.	Md. Takky	N/A
07/05/25	Ibtehaz Md. Takky Samir Fidaul	Discussion and prepare slide for presentation	Ibtehaz Fidaul Samir	N/A
10/05/25	All	Report task distribution	All	N/A
16/05/25	All	Discussion on Report task progress	All	N/A
22/05/25	All	Discussion on Final Report	All	N/A

FYDP (C) Summer 2025 Summary of Team Log Book/ Journal

Log Book				
Date	Attendee	Summary of meeting	Responsible	Comment by ATC
05/07/25	All Members	Discussion on Preparation for FYDP-C	All	N/A
07/07/25	Md. Takky Samir Ibtehaz Fidaul	Discussion with ATC	All	Guidelines on preparing the model for the showcase
10/07/25	All Members	Discussion and distribution of work	All	N/A
11/07/25	All Members	Designing of the model for showcase	All	N/A
15/07/25	Md. Takky Samir	Purchase of components	Md. Takky Samir	N/A
16/07/25	Ibtehaz	Purchase of components	Ibtehaz	N/A
20/07/25	Md. Takky Samir Ibtehaz Fidaul	Preparation and gathering of components for model	Md. Takky Samir Ibtehaz Fidaul	N/A
10/08/25	All Members	Completion of the outer structure for the BMS model demonstration	All members	N/A
14/08/25	Md. Takky Samir Ibtehaz Fidaul	Feedback from ATC about the outer structure	Md. Takky Samir Ibtehaz Fidaul	Guidelines for further progress in the project
20/08/25	Ibtehaz Md. Takky	Discussion on work for Blynk	Ibtehaz Md. Takky	N/A
27/08/25	All Members	Discussion on the first tryout testing of the model	All Members	N/A
28/08/25	All Members	Testing of the working of the model	All Members	N/A

31/08/25	Md. Takky Samir Ibtehaz Fidaul	Feedback from ATC on the first tryout testing	Md. Takky Samir Ibtehaz Fidaul	Reduction in over use of unnecessary sensors and guideline on circuit planning
01/09/25	All Members	Testing after modification as per guideline	All Members	N/A
02/09/25	Md. Takky Samir Ibtehaz Fidaul	Further testing and modifications	Md. Takky Samir Ibtehaz Fidaul	N/A
03/09/25	Md. Takky Samir Ibtehaz Fidaul	Further testing and modifications	Md. Takky Samir Ibtehaz Fidaul	N/A
04/09/25	Md. Takky Samir Ibtehaz Fidaul	Review from ATC	Md. Takky Samir Ibtehaz Fidaul	Further guidelines for required modification
06/09/25	Md. Takky Samir Ibtehaz Fidaul	Further testing and modifications	Md. Takky Samir Ibtehaz Fidaul	N/A
07/09/25	Md. Takky Samir Ibtehaz Fidaul	Further testing and modifications	Md. Takky Samir Ibtehaz Fidaul	N/A
08/09/25	Md. Takky Samir Ibtehaz Fidaul	Further testing and modifications	Md. Takky Samir Ibtehaz Fidaul	N/A
09/09/25	All Members	Final review from ATC	All Members	Approval for all the modifications and requirements for the model
10/09/25	All Members	Final testing and decoration	All Members	N/A
11/09/25	All Members	Showcase Day	All Members	

Related code/theory

Floor Automation

```
#define BLYNK_TEMPLATE_ID "TMPL6dLeTzTyK"

#define BLYNK_TEMPLATE_NAME "Building Management System Project"

#define BLYNK_AUTH_TOKEN "QKXiadQPsRe0swICaTPRSUuJVlBEfJ3G"

#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

#include <DHT.h>

char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "Ibtehaz";      // Your WiFi SSID

char pass[] = "kabirIbtehaz261";    // Your WiFi Password

// DHT11 Sensor

DHT dht(D3, DHT11); // D3 as data pin for DHT11

BlynkTimer timer;

bool pirbutton = 0;

// Define component pins

#define PIR D6
```

```
#define relay1 D7

#define relay2 D8

// PIR Enable button from Blynk

BLYNK_WRITE(V0) {

  pirbutton = param.asInt();

}

void setup() {

  Serial.begin(9600);

  // Set pin modes

  pinMode(PIR, INPUT);

  pinMode(relay1, OUTPUT);

  pinMode(relay2, OUTPUT);

 // Initialize relays as OFF

  digitalWrite(relay1, HIGH);

  digitalWrite(relay2, HIGH);

// Connect to Blynk

  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);

  dht.begin();

 // Call sensor functions periodically
```

```
  timer.setInterval(1000L, DHT11sensor);

  timer.setInterval(1000L, pirsensor);

}

// DHT11 Sensor (Temperature & Humidity)

void DHT11sensor() {

  float h = dht.readHumidity();

  float t = dht.readTemperature();

  if (isnan(h) || isnan(t)) {

    Serial.println("Failed to read from DHT sensor!");

    return;

  }

  Blynk.virtualWrite(V2, t); // Temperature

  Blynk.virtualWrite(V3, h); // Humidity

Serial.print("Temp: ");

Serial.print(t);

Serial.print(" °C, Humidity: ");

Serial.print(h);

Serial.println(" %");

}
```

```
// PIR Motion Sensor

// PIR Motion Sensor with Light & Fan Control

unsigned long lastMotionTime = 0;

const unsigned long MOTION_TIMEOUT = 15 * 1000; // 30 sec auto-off

void pirsensor() {

  bool value = digitalRead(PIR);

 if (pirbutton == 1 && value == 1) { // PIR enabled & motion detected

    Blynk.logEvent("motion_detected", "Motion detected! Light & Fan ON");

    Serial.println("Motion Detected → Turning ON Light & Fan");

// Turn ON relays

    digitalWrite(relay1, LOW);  // Light ON

    digitalWrite(relay2, LOW);  // Fan ON

    Blynk.virtualWrite(V5, 1);

    Blynk.virtualWrite(V6, 1);

    lastMotionTime = millis(); // Save time of last motion

  }

  // Auto OFF after timeout

  if (pirbutton == 1 && value == 0) {

    if (millis() - lastMotionTime > MOTION_TIMEOUT) {

      digitalWrite(relay1, HIGH); // Light OFF
```

```
      digitalWrite(relay2, HIGH); // Fan OFF

      Blynk.virtualWrite(V5, 0);

      Blynk.virtualWrite(V6, 0);

      Serial.println("No motion → Auto OFF Light & Fan");

    }

  }

}

// Relay 1 control (V5)

BLYNK_WRITE(V5) {

  bool RelayOne = param.asInt();

  digitalWrite(relay1, RelayOne ? LOW : HIGH);

}

// Relay 2 control (V6)

BLYNK_WRITE(V6) {

  bool RelayTwo = param.asInt();

  digitalWrite(relay2, RelayTwo ? LOW : HIGH);

}

void loop() {

  Blynk.run();

  timer.run();}
```

Safety

```
#define BLYNK_TEMPLATE_ID "TMPL60AJx8K7G"

#define BLYNK_TEMPLATE_NAME "Safety"

#define BLYNK_AUTH_TOKEN "YpZuCLvsSnA7KyO4ftNn3uQWc6EUOkSd"

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

// WiFi credentials

char ssid[] = "Ibtehaz";       // Your WiFi SSID

char pass[] = "kabirIbtehaz261";  // Your WiFi Password

// Pin definitions

#define MQ2 A0           // Gas sensor (analog)

#define flameSensor D6   // Flame sensor (digital)

#define relay1 D5        // Relay1 → Gas

#define relay2 D7        // Relay2 → Flame

BlynkTimer timer;

int threshold = 10;  // Default threshold

// Sensor activation flags

bool gasSensorActive = true;

bool flameSensorActive = true;

//  Slider for threshold (V2)
```

```
BLYNK_WRITE(V2) {
  threshold = param.asInt();
  Serial.print("New Threshold set to: ");
  Serial.println(threshold);
  Blynk.virtualWrite(V3, threshold); // Display threshold in app
}
// Gas Sensor Activator (V5)
BLYNK_WRITE(V5) {
  gasSensorActive = param.asInt();
  Serial.print("Gas Sensor Active: ");
  Serial.println(gasSensorActive);
}
//  Flame Sensor Activator (V6)
BLYNK_WRITE(V6) {
  flameSensorActive = param.asInt();
  Serial.print("Flame Sensor Active: ");
  Serial.println(flameSensorActive);
}
//  Gas Sensor
void gassensor() {
```

```
  if (!gasSensorActive) {
    digitalWrite(relay1, HIGH);   // Ensure relay OFF
    Blynk.virtualWrite(V7, 0);    // Gas Alarm OFF
    return;                       // Skip sensor reading
  }
  int value = analogRead(MQ2);
  value = map(value, 0, 1024, 0, 100);
  Serial.print("Gas Sensor Value: ");
  Serial.println(value);
  if (value > threshold) {
    digitalWrite(relay1, LOW);    // Relay1 ON
    Blynk.virtualWrite(V7, 1);    // Gas Alarm ON
    Blynk.logEvent("gas_leak", " Gas Leak Detected!");
  } else {
    digitalWrite(relay1, HIGH);   // Relay1 OFF
    Blynk.virtualWrite(V7, 0);    // Gas Alarm OFF
  }
 Blynk.virtualWrite(V1, value);  // Gas value
}
//  Flame Sensor
```

```
void flamesensor() {
  if (!flameSensorActive) {
    digitalWrite(relay2, HIGH);   // Ensure relay OFF
    Blynk.virtualWrite(V8, 0);    // Flame Alarm OFF
    return;                       // Skip sensor reading
  }
  int flameValue = digitalRead(flameSensor);
  Serial.print("Flame Sensor Value: ");
  Serial.println(flameValue);
  if (flameValue == LOW) { // Active LOW
    digitalWrite(relay2, LOW);   // Relay2 ON
    Blynk.virtualWrite(V8, 1);   // Flame Alarm ON
    Blynk.logEvent("flame_alert", " Flame Detected!");
    Blynk.virtualWrite(V4, 1);   // Flame status ON
  } else {
    digitalWrite(relay2, HIGH);  // Relay2 OFF
    Blynk.virtualWrite(V8, 0);   // Flame Alarm OFF
    Blynk.virtualWrite(V4, 0);   // Flame status OFF
  }
}
```

```
void setup() {
  Serial.begin(9600);
  pinMode(relay1, OUTPUT);
  pinMode(relay2, OUTPUT);
  pinMode(flameSensor, INPUT);
  digitalWrite(relay1, HIGH);  // Relays OFF at startup
  digitalWrite(relay2, HIGH);
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
  timer.setInterval(2000L, gassensor);
  timer.setInterval(2000L, flamesensor);
}
void loop() {
  Blynk.run();
  timer.run();
}
```

Security System

```
#define BLYNK_TEMPLATE_ID "TMPL6KNdXhDTq"
#define BLYNK_TEMPLATE_NAME "Security System"
#define BLYNK_AUTH_TOKEN "YwJMh_FV0h7cSVug1lDcJREwLI7pBIxp"


#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

// WiFi credentials
char ssid[] = "Ibtehaz";
char pass[] = "kabirIbtehaz261";

// Pin definitions
#define PIR D5       // PIR Motion Sensor
#define BUZZER D6    // Buzzer or relay driving buzzer

BlynkTimer timer;

bool pirActive = true;       // PIR sensor activator
bool buzzerOn = false;       // Track buzzer state
unsigned long buzzerStart = 0;  // Store time when buzzer turned on
const unsigned long buzzerDuration = 30000; // 30 seconds

//  PIR Activator Switch (V1)
BLYNK_WRITE(V1) {
  pirActive = param.asInt();
  Serial.print("PIR Sensor Active: ");
  Serial.println(pirActive);

  if (!pirActive) {
    digitalWrite(BUZZER, LOW);
    buzzerOn = false;
    Blynk.virtualWrite(V2, 0); // Update app alarm state
  }
}
```

```
//  Manual Buzzer Control (V3)
BLYNK_WRITE(V3) {
  int state = param.asInt();
  if (state == 1) {
    digitalWrite(BUZZER, HIGH);
    buzzerOn = true;
    buzzerStart = millis();
    Blynk.virtualWrite(V2, 1);
    Serial.println(" Buzzer manually turned ON");
  } else {
    digitalWrite(BUZZER, LOW);
    buzzerOn = false;
    Blynk.virtualWrite(V2, 0);
    Serial.println(" Buzzer manually turned OFF");
  }
}

//  Check PIR Motion
void checkPIR() {
  if (!pirActive) return;
  int motion = digitalRead(PIR);
  if (motion == HIGH && !buzzerOn) {
    Serial.println(" Motion Detected!");
    digitalWrite(BUZZER, HIGH);
    buzzerOn = true;
    buzzerStart = millis();   // Start 30s timer
    Blynk.virtualWrite(V2, 1);
    Blynk.logEvent("motion_alert", " Motion Detected Outside!");
  }
  // Auto turn off buzzer after 30s
  if (buzzerOn && (millis() - buzzerStart >= buzzerDuration)) {
    digitalWrite(BUZZER, LOW);
    buzzerOn = false;
    Blynk.virtualWrite(V2, 0);
    Serial.println(" Buzzer auto turned OFF after 30s");
  }
```

```
}

void setup() {
  Serial.begin(9600);

  pinMode(PIR, INPUT);
  pinMode(BUZZER, OUTPUT);
  digitalWrite(BUZZER, LOW);  // Ensure buzzer is OFF at start

  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  timer.setInterval(500L, checkPIR); // Check PIR every 0.5s
}

void loop() {
  Blynk.run();
  timer.run();
}
```

HVAC System

```
#define BLYNK_TEMPLATE_ID "TMPL6p5UnWbPw"
#define BLYNK_TEMPLATE_NAME "Building Management SystemCopy"
#define BLYNK_AUTH_TOKEN "M1AApp3TdtmwNWJIOjsthkqzZSVN68pk"

#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <DHT.h>

// WiFi credentials
char ssid[] = "Ibtehaz";
char pass[] = "kabirIbtehaz261";

// Pin setup
#define DHTPIN D2
#define DHTTYPE DHT11
#define RELAY_EXHAUST D5   // Dehumidifier / Exhaust Fan
#define RELAY_AC D6        // Air Conditioner

DHT dht(DHTPIN, DHTTYPE);
BlynkTimer timer;

// Thresholds (default values)
int humidityThreshold = 75;  // %
int tempThreshold = 25;      // °C

// States
bool systemEnabled = true;   // Central system switch
bool manualExhaust = false;  // Manual override for exhaust
bool manualAC = false;       // Manual override for AC

// --- Central Switch (V5) ---
BLYNK_WRITE(V5) {
  systemEnabled = param.asInt();
  Serial.print("Central System: ");
  Serial.println(systemEnabled ? "ON" : "OFF");
```

```
  if (!systemEnabled) {
    digitalWrite(RELAY_EXHAUST, HIGH);
    digitalWrite(RELAY_AC, HIGH);
    Blynk.virtualWrite(V3, 0);
    Blynk.virtualWrite(V4, 0);
  }
}

// --- Manual Exhaust Switch (V6) ---
BLYNK_WRITE(V6) {
  manualExhaust = param.asInt();
  if (manualExhaust) {
    digitalWrite(RELAY_EXHAUST, LOW); // ON
    Blynk.virtualWrite(V3, 1);
    Serial.println("Exhaust manually ON");
  } else {
    digitalWrite(RELAY_EXHAUST, HIGH); // OFF
    Blynk.virtualWrite(V3, 0);
    Serial.println("Exhaust manually OFF");
  }
}

// --- Manual AC Switch (V7) ---
BLYNK_WRITE(V7) {
  manualAC = param.asInt();
  if (manualAC) {
    digitalWrite(RELAY_AC, LOW); // ON
    Blynk.virtualWrite(V4, 1);
    Serial.println("AC manually ON");
  } else {
    digitalWrite(RELAY_AC, HIGH); // OFF
    Blynk.virtualWrite(V4, 0);
    Serial.println("AC manually OFF");
  }
}

// --- Humidity Threshold Slider (V8) ---
```

```
BLYNK_WRITE(V8) {
  humidityThreshold = param.asInt();
  Serial.print("New Humidity Threshold: ");
  Serial.println(humidityThreshold);
}

// --- Temperature Threshold Slider (V9) ---
BLYNK_WRITE(V9) {
  tempThreshold = param.asInt();
  Serial.print("New Temperature Threshold: ");
  Serial.println(tempThreshold);
}

// --- Read DHT and Control HVAC ---
void readDHT() {
  float h = dht.readHumidity();
  float t = dht.readTemperature();

  if (isnan(h) || isnan(t)) {
    Serial.println(" Failed to read from DHT sensor!");
    return;
  }

  Serial.print("Humidity: ");
  Serial.print(h);
  Serial.print("% | Temp: ");
  Serial.print(t);
  Serial.println("°C");

  Blynk.virtualWrite(V1, t);
  Blynk.virtualWrite(V2, h);

  if (!systemEnabled) return; // Central OFF → no automation

  // --- Exhaust Automation (only if not manual override) ---
  if (!manualExhaust) {
    if (h > humidityThreshold) {
```

```
      digitalWrite(RELAY_EXHAUST, LOW);
      Blynk.virtualWrite(V3, 1);
    } else {
      digitalWrite(RELAY_EXHAUST, HIGH);
      Blynk.virtualWrite(V3, 0);
    }
  }

  // --- AC Automation (only if not manual override) ---
  if (!manualAC) {
    if (t > tempThreshold) {
      digitalWrite(RELAY_AC, LOW);
      Blynk.virtualWrite(V4, 1);
    } else {
      digitalWrite(RELAY_AC, HIGH);
      Blynk.virtualWrite(V4, 0);
    }
  }
}
void setup() {
  Serial.begin(9600);

  pinMode(RELAY_EXHAUST, OUTPUT);
  pinMode(RELAY_AC, OUTPUT);

  digitalWrite(RELAY_EXHAUST, HIGH);
  digitalWrite(RELAY_AC, HIGH);

  dht.begin();
  Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);

  timer.setInterval(2000L, readDHT); // Every 2 sec
}
void loop() {
  Blynk.run();
  timer.run();
}
```