IoT Based Smart Home Automation and Energy Management

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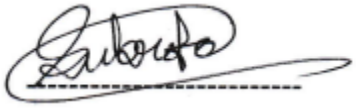
Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:



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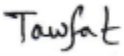

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Ethics Statement

We hereby declare that this thesis project on “IoT Based Smart Home Automation and Energy Management” has met the research criteria for completing the degree which has been written and completed without any copy. All the information and data are the reflection of our work. Also, the systems and software coding used here are being done by us. We sometimes have collected some information from other paper where it is properly cited. There is nothing in this paper that can be related to any project or paper. We have completed total work with our own effort and this unique work is done by taking some assistance from advisor and university. All the members of this group have been participated in their own way. We completely admit this project as a reflection of our own thesis research so that this project may have its own features.

Abstract

Internet of Things (IoT) is the network of interconnected devices, digital machines, vehicles, home appliances and other objects embedded with sensors, software, switches and connectivity which enable these things to connect to a network and collect and exchange data. The system creates the scope of connecting the non-internet-enabled physical devices and machines to be connected over the internet and remotely monitored and controlled. This research intends to propose architecture for home automation using near field and mobile communication along with a mobile application. The basic architecture or framework consists of connecting devices which will use protocol (Modbus or Zigbee) to connect Edge gateway; and cloud stores the data information using backend storage system. Along with smart control of the appliances, we will be focusing on energy consumption management system through which consumers can reduce excess energy consumption by remotely controlling the devices.

Keywords

1. IoT- Internet of Things
2. HAN- Home Area Network
3. EMS- Energy Management System
4. HOMER- Hybrid Optimization of Multiple Electric Renewable
5. HEMS- Home Energy Management System

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We are also thankful to our Senior Assistant Librarian of BRAC University- Md. Shahajada Masud Anowarul Haque who helped us to find the published papers and journals by accessing BRAC server.

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List of Acronyms

1. IoT- Internet of Things
2. NFC- Near Field Communication
3. AMQP- Advance Messaging Queuing Protocol
4. MQTP- Message Queuing Telemetry Protocol
5. COAP- Constrained Application Protocol
6. TOUP- Time of Use Pricing
7. RTP- Real Time Pricing
8. CPP- Critical Peak Pricing
9. DSM- Demand Side Management
10. HEMS- Home Energy Management System
11. RFID- Radio Frequency Identification
12. WSN- Wireless Sensor Network
13. HAN- Home Area Network
14. EMS- Energy Management System
15. SMA- Smart Metering Architecture
16. AMI- Advance Metering Infrastructure
17. VAC- Volt Alternate Current
18. HTTP- Hypertext Transfer Protocol
19. HTML- Hypertext Markup Language
20. CSS- Cascading Style Sheet
21. RTD- Resistance Temperature Detectors
22. LDR- Light Dependent Resistor
23. TCXO- Temperature Compensated Precious Stone Oscillator
24. HOMER- Hybrid Optimization of Multiple Electric Renewable

Chapter 1

Introduction

1.1 Introduction

Internet of Things (IoT) is the network of interconnected devices, mechanical and digital machines, vehicles, home appliances and other objects embedded with sensors, software, switches and connectivity which enable these things to connect to a network and collect and exchange data. The system creates the scope of connecting the non-internet enabled physical devices and machines to be connected over the internet and remotely monitored and controlled. A thing in the Internet of Things can also be a person with a heart monitoring implant or an automobile with obstacle sensor or home appliances connected to an application platform. This is also applicable to industrial machines like drill of an oil rig or a jet engine of an airplane. These things are assigned to an IP address and are able to transfer data over internet. Basically, this is the concept of connecting any devices or machines we can think of today with the internet.

Previously, home-mechanized gadgets were somewhat essential and basic, with choices running from light clocks to programmable indoor regulators. Presently, these frameworks are consolidating information from home exercises, neighborhood climate frameworks and then some; to acclimate to optimal way of life and help for better deal with home. Even better, they can interface with one another to shape a firm unit to enable to work entire house.

This research intends to propose architecture for home automation using near field and mobile communication along with a mobile application.The basic architecture or framework consists of connecting devices which will use protocol (MQTT or Zigbee) to connect Edge gateway; and cloud stores the data information using backend storage system. Along with smart control of the appliances, we will be focusing on energy consumption management system through which consumers can reduce excess energy consumption by remotely controlling the devices. This can save excessive use of any appliance energy, time and simultaneously abate extra wealth expenditure.

1.2 Internet of Things (IoT) Basic Concept

The intercommunication between device to device or machine learning connected through the internet with embedded technology systems using wireless sensors, actuators which is remotely controlled, monitor and optimized by the user for automation is referred as Internet of things (IoT). Here the term “Things” means physical devices such as chips, cameras, sensors and other such devices. These physical devices are responsible to communicate, collect information and

exchange data by connecting a network. The embedded technology of these physical devices makes this exchange of information each other possible. There are an assortment of home robotization includes that can help making life at home increasingly advantageous and simpler to oversee, particularly for occupied, huge families. Suppose you could consequently manage and control the gadgets that you ordinarily turn on and off each day. With a home computerization framework, you can manage appliances when you're out of the house and wondering if you remembered to turn off light or not, smart system will be there to answer the question. The developing nearness of the Internet of Things in individual's lives has made development and advancement in the savvy home space, enabling clients to associate their gadgets through the web to their phones and tablets, and make better than ever benefits for family units. In addition, as house owner are adjusting their gadgets to one focal application, gadget or center, they further understand the worth these home robotization items can bring to a family. It is the connectivity apart from the conventional devices using internet such as desktop, laptops, Smartphone, tablets etc.

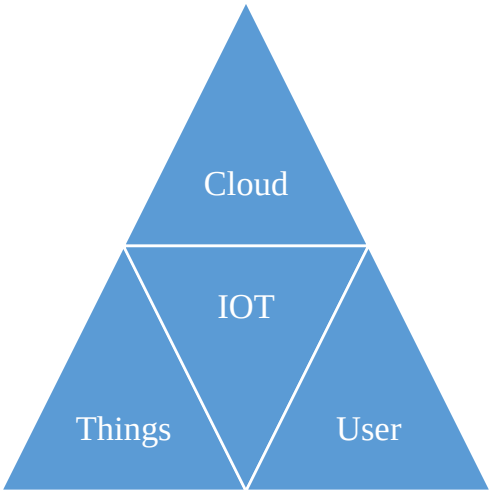


Figure 1.1 : IoT Basic Concept

1.3 IoT Characteristics

IoT is one of the most popular terms in this modern era of the world. Internet of things (IoT) explains the network of different devices like home appliances or office works that contains software, electronics, sensor and connectivity to allow them to exchange data with connections. Several sensors and actuators are used to connect those devices and give a feedback to them according self-operations. IoT has convinced the world with its worldwide features and human beings are fully dependable on it. In the near future, this IoT will make an unimaginable impact on the daily life of human beings which will make the life of human easier, smarter and safe. At present, it has already grabbed the promising and large digital fields of modernization which is rapidly increasing.

The characteristic of IoT includes the synthesis of hardware and software abiding by complex algorithm and computation technique which intelligence authorizes them to behave and act accordingly to the situations. The connectivity of IoT devices allows connecting various objects by creating network and comprehensive intelligence system. The dynamic nature of IoT devices tells the state of device whether it is on or off. An IoT device also collects dynamic change of data information from its neighboring environment. The essence of IoT is diversity and heterogeneity because of using distinct platform and network. Finally, security issues of IoT are being very important because of its delicate information and enormous action being taken to prevent security problems. In future IoT components enormity will increase in such level so that it becomes very difficult to deal or manage it.

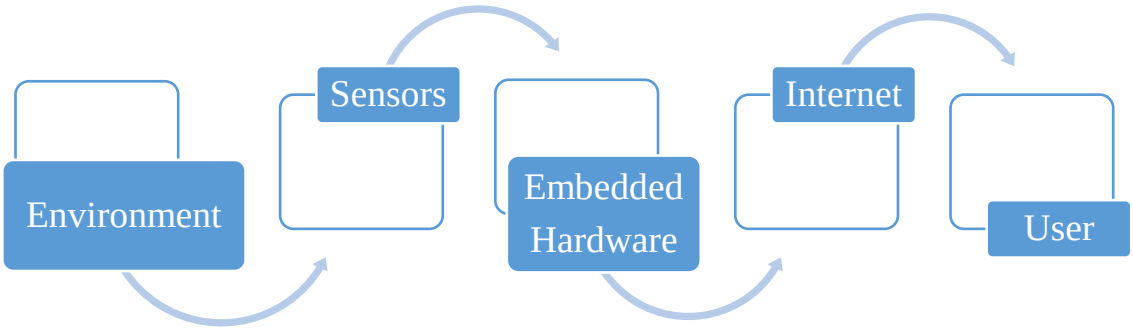


Figure 1.2: IoT Operating Technique

1.4 Why IoT is Booming?

In recent years, IoT plays a momentous role to reduce human exertions. Rapid growth of IoT devices and application day by day increasing which is disciplined by using internet and people are getting benefited. The scope of IoT is the amalgamation of physical world into computer base by amplifying efficacy of technology, abate human lessen and economic benefits. The basic characteristics of IoT devices are nearly identical and shared but technology behind every device specify from one device to another. Because of its having ambience intelligence and self-explanatory control makes IoT more popular now-a-days. In coming days, advanced technology of IoT devices becomes more intelligent, unimaginable, automatic systematized, non-determined to work independently anticipates on conditions and atmosphere.

Internet of Things (IoT) is going to be successful and very popular in near future. As the telecommunication sector is becoming more efficient and extensive, wireless and broadband internet connection is now widely available. With the advent of more sophisticated fabrication technology it is now much cheaper to produce devices and sensors with built-in Wi-Fi capabilities making connecting devices less costly [1]. Most importantly, the smart phone usage

has been increased to such a level that it is being used to every possible aspect of our life now a days. As for the IoT based systems there is no need of separate communication system rather we can use the existing technology through the smart phones which makes the system cheaper and highly achievable. Because of this technology now we can think of a fully automated home or a whole smart city with the monitoring of energy consumption rate or a traffic monitoring system for higher efficiency.

1.5 IoT Architecture

The basic architecture of IoT consists of some stages including device, gateway connectivity, data processing and cloud or user interface. Firstly, physical devices such as sensors, appliances, devices and actuators assemble raw data from neighboring environment and convert it into useful data. Actuator and sensors work as a transducer which converts energy into one form to another form are used in IoT architecture. Actuators convert energy into motion besides sensor which is a device that receives and respond to signal. In the meantime, there comes internet-gateway. Sensors use specific protocol like Modbus, ZigBee, Bluetooth, near field communication (NFC), Wi-Fi or along with that proprietary protocol to connect Edge gateway. Edge gateway converts raw data from analogue to digital using data acquisition system besides data aggregation. The internet gateway received aggregated data as an example preprocessing and provides routing detaining connectivity to cloud using system for instance web sockets, the event hub, edge analytics, advance messaging queuing protocol (AMQP), Message queuing telemetry protocol (MQTT), Constrained application protocol (COAP) or fog computing. Further, details analyzing of data and processing by IT systems onsite or offsite. Finally, data stored in the database or cloud. The cloud application handles the communication which transpires in all stages [2].

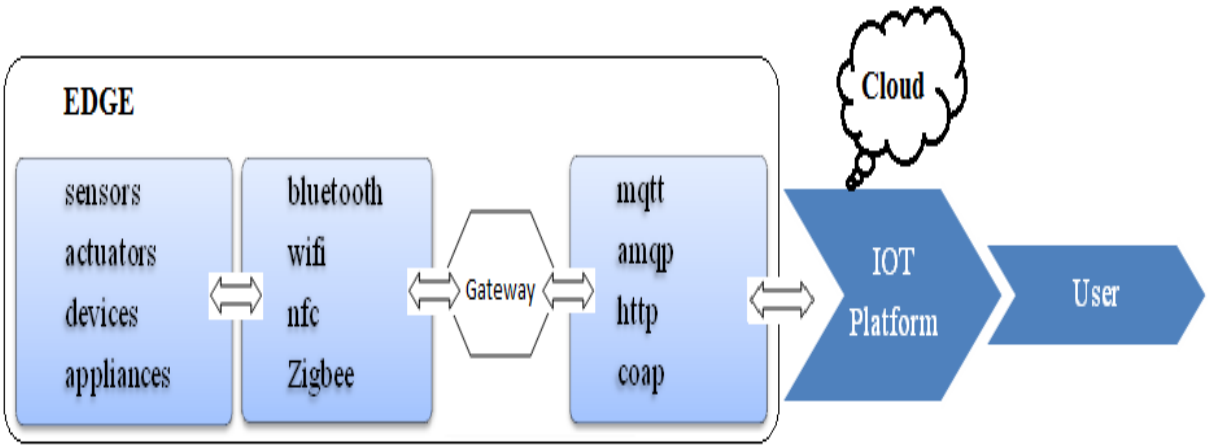


Figure 1.3: IoT Architecture

1.6 IoT Applications

IoT application changes our life and made our life easy, comfortable and simple. The sector and area that IoT covers are huge. IoT have extensive applications in different sectors for instance commercial, industrial, and medical and consumers. In all these cases IoT left its footprint and in future it surprises more. Here some of its real world application irradiates, which are smart home, smart city (parking, waste management), utilities (smart grid, smart metering), wearable gadgets, Transports & logistics (connected cars, fleet management, goods tracking), industrial (process monitoring & control, manufacturing, maintenance), agriculture (agriculture monitoring, climate, livestock tracking), telemedicine and healthcare, elder care, and environment(environment monitoring.

Smart home among them is the most wanted sector that people are trying to get in more modernized way day by day. We are focusing on smart home automation system to manage extra consumptions of energy and monitoring. A smart home means automated home which could manage and control smart device and other home appliances automatically or manually by the user. A smart home consists of so many things like as lighting, heating, air conditioning, domestic robot, thermostat, wireless speaker, home security and monitoring, smoke detector, water detector, washing machine, and refrigerator. The power consumption of smart home electrical device certainly change demand response (DR) to consumer and find good match not only demand for power but also for supply. DR actually responsible for finding better match by adjusting power against supply helps consumer to redeem auxiliary outlay. Consumer plays very vital role to reduce extra power consumption by participating and conducting their household.

At this present stage, human beings are consuming more and more energies like electrical or other sectors. The rapid growths of human beings are needed of these energies which is a part of their life. This unlimited consume of energies are in question as these energies are also in loss. Directly or indirectly, people are misusing energy like switching on electricity in a vacant room for several times etc. IoT is trying to reduce this energy loss that can make this more efficient. By using IoT devices, we can easily control the energy of a home automatically from a distant place. Our presence is not mandatory but an internet connection can make it possible with automation to reduce the excess energy loss and consume more effective energy. Like in the official hour, we do not need to switch on the devices of our home always. We can control it from our office by using an IoT system or device only via internet or wireless connection. That will save the energy definitely.

By doing optimal scheduling skill, user can save more energy and their extra expense of money at the same time. IoT home energy management system gives user maximum satisfaction against minimum cost. The demand model using demand response gives higher gratification using time interval optimization. Sometimes scheduling is not applicable for all users so need balance. This type of advantages not only can save the energy but also make our time more efficient for thinking about more things. Thus, we find the concept IoT based energy saving home automation system which is discussed in this paper in an easy and expense consuming way. We are focusing

on price response, time of use pricing (TOUP), real time pricing (CPP), critical peak pricing (CPP) and demand side management (DSM).

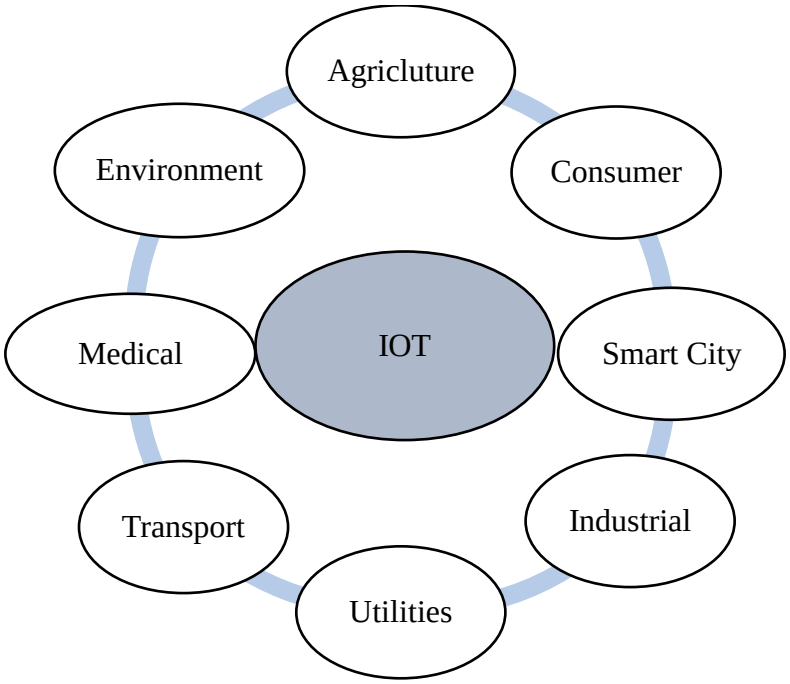


Figure 1.4: IoT Applications

1.6.1 Home Automation

Home Automation is the process which all the household appliances can be controlled, monitored and maintained automatically by the intelligence of device far from home regardless is typically called home automation which makes home smart. It connects everything in the network through internet. The idea of house being totally mechanized used to be numerous. Presently, it is a reality. Shrewd homes and penetrating home items are prominent in light of the fact that they offer more accommodation and security for family. User can check the update status of a device time to time. These gadgets can convey, track and send data, and react according to user command. In this technology we can control household appliances like lighting, AC, fan, washing machine, TV, Fridge, security system etc. By using artificial intelligence, it can also be self-controlled and monitored by itself. These frameworks additionally help increment home's vitality effectiveness, which can lessen vitality bill.

Figure 1.5: Home Automation

1.7 Project overview

The main focus of this project is – home automation and energy management from its artificial intelligence coordinateness of maintenance according to the need. An intelligent system which given timely update about the peak and off-peak hours; based on this if applied, user can save more than predetermined energy, the automation system which allows to assists the user. After maintaining the suggestion showing in the display about peak and off-peak hours, the more the assistive power and cash at the same time will be saved proportionally. Certainly, there will be a basic need of some appliances which user can't ignore which means that whatever the peak hour or maximum price of power is, user can use it. For handling this situation, the backup of green energy generation will provide support that certain time for standby the appliances [3]. After that the user will either not to be allowed to assist using appliances from grid power. This will be done for saving extra cash of the user.

At the beginning of the project, an automation technique which is used for the appliances for managing and maintenance being seen to ply inside prototype resident for equipment's. This was done in order to avoid hassle free household apparatus management with monitoring and most importantly finding all components together without having any problem, which can be time consuming for commercial user. On the following the generation of green energy generation for the existing system to implement the automation technique works in a scheduled manner. After installation of the apparatus and calculation of their nature, the prototype came under test where

its feasible execution was tasted and its efficiency over other similar automation project were assumed using practical data.

1.8 Summary

In the second chapter of this paper is discussed about the home automation and its vast area, the existing improved models and protocols also the management of energy for home, scheduling and difference of solar system and supply power of solar system efficiency. Following that third chapter describes about the automation process and its characteristics. Then chapter four is about the hardware and software implementation process and technique. Later, chapter five is development of control algorithms. Corresponding to each of this technique the solar power generation and simulation process are being discussed in chapter six. After that, the energy management, scheduling and power consumption calculation and analogy examine in chapter seven. Suddenly, the uniqueness, substantiate goal and how client will get benefited from this project sift canvas in chapter eight. Finally, in chapter nine the paper was compacted enlightening the home customization with power administration and the forthcoming work on this engineering.

Chapter 2

Literature Review

2.1 Introduction

Living in the age of internet, life has become smarter and more convenient for us today. The internet has brought unthinkable and remarkable options for the human being that is connecting us with the think of building automatic smart system. The automatic smart system concept came from rapid spread of internet can reduce the danger in any system as well as the human involvement. The worldwide researches are going on to consume the power of an electrical system or device efficiently so that the waste of it made by human involvement manually can be reduced. The efficiency of such energy management system can take us to the appropriate goal of automation system that can be used continuously with safety without the involvement of human beings. For this worldwide promising concept in electrical sector, a planning was going in our mind to work on this that can be useful in this area. Internet of Things (IoT) system has a vast area to research or work on. The home automation system is one of the most talkative, promising and worldwide researching sectors of IoT. This home automation system has already created a significant impact in our technological area that is now looking for reducing the total power wastage reduction theory. Home Energy Management System (HEMS) is now in headline to conduct reduction of the loss of power, dangerous system disaster and the life loss of human beings. So, many research papers and some projects from IEEE and online published sides share a broad and major idea on these things that how we can save our energy and reduce the danger of system. These concepts and their research made us to think on the vision of our research more widely. That's how the mission and goals to work on for this research paper has been aimed. These papers and journals concepts visualized the details of IoT, its applications and vast area of research, home automation, smart appliances at home, home energy management system, smart meters, scheduling with smart appliances, difference between supplied power and solar power, the power consumption of our country. All these concepts are effective for this thesis paper to come to a conclusion and make a decision on the project of total energy saving management.

2.2 IoT and Home Automation

As the IoT has a vast chamber to discuss on mentioned earlier, it has been described briefly in a moderate way to show the concept of it in several research papers. A journal on "IoT-Home Automation" researched by S Bharat et al., published on International Journal at Computer Technology and Research (IJCTR) in 2016 showed a detail home automation appliance with short and clear view writing [4]. The advantages on home automation, such as: - reduced installation cost, system stability, easy extension, aesthetical benefits, integration of mobiles devices are discussed here. The appliances of home automation like light and devices, webcam surveillance, magnetic doors etc. are needed to be present. Some of the hardware and software-

based applications and components like Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), addressing schemes are discussed too. This paper also suggests a model of utilization of home automation appliances properly at on and off-peak hours. Another paper on "Research and Applications on the Smart Home-Based Component Technologies and Internet of Things" written by Baoan Li and Jianjun Yu found in Sciverse Science Direct has elaborately discussed these RFID and WSN appliances [5]. The present research of USA, Europe, China, Korea and Japan on nanotechnology, sensor-based appliances, intelligence embedded technology, RFID's future appliances, and sea computing applications are being shortly involved in this paper to give us the idea of the broad application range of RFID. The paper focused on the security and intelligence system of home and offices of the foreign nations that have been developing day by day. Family automatic appliances, medical appliances, environmental automatic appliances are also mentioned here. Another paper on "The Internet of Things: How the Next Evaluation of Internet is Changing Everything"- authored by Dave Evans basically focused on the IoT aspects and its future. The author showed how the impact of IoT are is grabbing people and how the user of smart home appliances are increasing from 500 million to 50 Billion within just 15 years from 2005 to 2020. It also focused on the IoT covered fields, such as: - business, education, transport, energy, home, earth etc. In a word, there are hardly options that can't be covered by IoT or may be invisible. The author ended up with the emerging of IoT from the very early moment when the computer and spread of its appliances to the present vast areas of IoT based devices and sectors. There are also some journals and the trustworthy sources from internet have been visualized the same idea with these details regarding IoT and home automation concept. The basic concept of wireless connected network from device to device and human friendly channel that is presented as the term of IoT has been accepted gradually in societies. The impact of it has been significant in our world that it has covered all the sectors in our daily life. There are unlimited IoT applications that can't be covered definitely. In the sector of agriculture, education, industry, business, home, security and many more are directly related with IoT. The reason behind this boom is the smart and auto user friendly devices that are helpful, time consuming and riskless. The home automation concept- a major part of IoT has been flourished due to this consumption and user-friendly concept. It has deducted our manual home works to save time, less risk and automated command. We do not need to wait or stay in our home to operate everything now a day as home automation system is working smoothly with a user-friendly manual concept. Such advantages motivated on this thesis paper to think about outside work rather than thinking of home factors. At this present stage, more power consuming concept are in research as this IoT and home automation reduces rapidly the wastage of energy so that people can take the best benefit of IoT and home automation. Thus, the broaden concepts of IoT and its home automation through these journals, papers and internet embedded our concept that can lead to work with such concepts.

2.3 Home Energy Management System

To get the more efficient consumption result of IoT, we also need to think on the management system of IoT that are present in our home and buildings. These systems must be power efficient and consumer effective to get a better output as result. Several systems are being proposed everyday by researchers and students but all the systems are in further experiment for the highest reduction of power loss. Junyon Kim's "HEMS-Home Energy Management System" paper visualized a general automatic smart home picture in front of us that lists the basic components for home automation system [6]. Components like LED, CCTV, speakers, IR Sensors, Ultrasonic sensors, smart phones and devices for networking among and outside home have been used here to give a proper idea of a home automation management system. On our thesis paper, we were looking for the most effective concept to reduce energy management wastage. Ravi Kodali et al., created a user friendly smart home automation system operated by microcontroller and described it in their conference paper "IoT Based Smart Security and Home Automation System" which was presented on International Conference on Computing, Communication and Automation [7]. A microcontroller TI CC3200 launch pad operates the total security system of a home gets the command from PIR motion sensor by accessing network via wifi. This simple design can easily be figured out and give visualization of a simple circuit for our paper-based project in thesis. Thus, a conclusion can be obtained to create a very simple design for this project that can be accessible, cheap for everyone and further can be modified.

Home energy management system design is very important first to initialize and get the better project output but the output data needs to be more specific and conditional. For example, if we switch on a machine or device at on peak hour, the power consumption and further electric bill will be increased. If it can be used at off peak hour, then the pressure on the load will be decreased. Besides, supply power from the grid is more costly in this generation of solar. Though, it's little bit costly in the very first to build up a PV cell for a system, it can easily be operated with a very low maintenance cost further on. On the other hand, the power from grid supply is dependable on usage as more usage costs more bill. For these problems, it's in thought how to reduce the power loss or the efficiency of the system that people are on research. An IEEE paper "An Internet of Things Framework for Smart Energy in Buildings: Design, Prototypes and Experiments" written by Jianli Pan and Jain showed an year observed data of energy conversion for different times at home and official buildings in USA [8]. They observed the electricity consumed by people in two different places- office buildings and home of a certain area. The observation came for two different times- one for winter and another is for summer. After analyzing all these consumption rates, they came to a suggestion to use an alternate method so the pressure on supply grid minimizes and consumers get benefit on usage pay. This paper suggested an automation system like automatic switching on/off with the move of people in the room, manual operation by consumer after reading the peak hour rates etc. A brief on this paper focused the target on this project to minimize the energy loss with more appropriate automated features. It enlarged the work criteria to work on with automation for energy saving.

2.4 Scheduling

Another IEEE paper on “Survey on Smart Grid Technologies- Smart Metering, IoT and EMS” by Shobhit Jain et al., proposed a power scheduling based connecting protocol for home appliances connected over Home Area Network (HAM) receiving real time electricity price [9]. An Energy Management System (EMS) consists of Smart Metering Architecture (SMA) or Advance Metering Infrastructure (AMI) which enables two-way communications provides information to the consumer by measuring power consumption. It can provide the information remotely using IP based wireless network. All the mathematical calculations and data processing are controlled by microcontroller so the serial communication controller must be compatible with protocols like Zigbee, GSM, Wifi etc. Zuang [10]. That also visualized the smart meter efficiency on this field. There are also some journals for the scheduling method of smart home and smart home appliances like air conditioning, heating etc. Though, a view on Zigbee, DLMS, DPWS, 6LowPan and other wireless communication technologies were taken but it didn’t work in this project as they are costly and some are not available in the country.

2.5 Supplied Power and Solar Power in Bangladesh

An important IEEE paper that worked mostly for this project and broaden work criteria is “An Optimized Stand Alone Green Hybrid Grid System for an Offshore Island, Saint Martin, Bangladesh” written by Khandakar Haque et al., as it is for an island of our country and matches with the system of our country [11]. The paper enriched the difference between power supply and solar system energy management efficiency as they work on solar electric system of Saint Martin Island. The difference easily ensured a feedback on how the solar panel can be power and cost efficient especially for a developing country like ours. So, a view on the depth of that project paper led to set up this thesis project merging with PV solar management, power consumption and cost.

2.6 Summary

After reviewing all these and some more papers and journals, the concept of home automation system on IoT, its energy management system, scheduling energy management system and some alternate automation method to consume power in an effective way are mostly cleared. To establish a little project and paper for this thesis, those are quite enough to enlarge and fix vision at our work. Thus, the review of these papers and journals also point on the future works of the paper. A summary on these working papers and criteria that matched with our project paper are in next: -

Table 1: List of Review Papers

Topic	Paper Details	Reference no
Home Automation and IoT	Bharath,S., Pasha, M.Y., & Deepth, J.(2017, April). IoT-Home Automation. *International Journal of Computer Technology and Research*, *5*, 4-6.	4
	Li, B., & Yu, J. (2011). Research and application on the smart home based on component technologies and Internet of Things. *Procedia Engineering*, *15*, 2087-2092.	5
Home Energy Management System	Kim, J. (2016). HEMS (home energy management system) base on the IoT smart home. *Contemporary Engineering Sciences*, *9*(1), 21-28.	6
	Kodali, R. K., Jain, V., Bose, S., & Boppana, L. (2016, April). IoT based smart security and home automation system. In *2016 international conference on computing, communication and automation (ICCCA)* (pp. 1286-1289). IEEE.	7
	Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A., & Sha, M. (2015). An internet of things framework for smart energy in buildings: designs, prototype, and experiments. *IEEE Internet of Things Journal*, *2*(6), 527-537.	8
Scheduling	Jain, S., Kumar, V., Paventhan, A., Chinnaiyan, V. K., Arnachalam, V., & Pradish, M. (2014, March). Survey on smart grid technologies-smart metering, IoT and EMS. In *2014 IEEE Students' Conference on Electrical, Electronics and Computer science* (pp. 1-6). IEEE	9
	Zhao, Z., Lee, W. C., Shin, Y., & Song, K. B. (2013). An optimal power scheduling method applied in home energy management system based on demand response. *Etri Journal*, *35*(4), 677-686.	10
Power consumption System of our country	Haque, K. F., Saqib, N., & Rahman, M. S. (2019, March). An Optimized Stand-alone Green Hybrid Grid System for an Offshore Island, Saint Martin, Bangladesh. In *2019 International Conference on Energy and Power Engineering (ICEPE)* (pp. 1-5). IEEE.2019.	11

Chapter 03

Model Architecture

3.1 Automation and Features

The purpose of this work is to develop an automatic system which is ductile, cost effective, energy saving remote control of home appliances. The web application governs the system for maintenance. Automatic controlling and remotely monitoring system compose our everyday life more satisfied and simultaneously save unnecessary dissipation of electrical energy. For economic growth of any country electricity plays very vital role. Progressive country like Bangladesh does not have enough sufficiency of electricity. Due to having lack of natural resources and pecuniary exigency the up-gradation and launch more new power plant paramount abridgement. The reason behind rising energy cost is negative usage of energy and unawareness of optimization of energy usages. The consequence results, the power plants do not provide the demand of power within the capacity of power station. Although Bangladesh government continuously trying to increase its capacity by installing new power plants and the overall settled electricity production retention tumid 20,000MW (combining solar power) in energy sector. Another 2.4GW power plant which is known as “Rooppur Nuclear Power Plant” hoped to go in production in 2023. Especially the comprehensive power clients in Bangladesh are industries, residential sectors followed by commercial and agricultural sectors. Despite of having the limitation of power generation and increased demand the negligent use of heavy home appliances causes more impact on power grid. On our daily basis, we mostly repose the lights, fans and other electric household appliances on while it is no use or nobody is in the apartment. Indeed, sometimes we are in a hurry or sometime our inadvertency causes this wastage of energy. Whatever the condition is as a consequence the energy consumption requirement amplifies. To summaries, eliminate this entire residence problem this project shows a way out of this situation which save unnecessary energy consumption by the efficient use of home useable devices and appliances. We have designed a 2200 sq.ft. prototype floor plan to complete our project. Our project attributes are describing bellow.

3.2 Block Diagram

The figure shows the block diagram of smart energy management using automation system of IOT. In this block diagram several types of sensors being used inside the abode like as smoke detector, gas detector, temperature, ultrasonic, for diverse purpose and all these are connected directly to Arduino microcontroller. All the appliances are connected through the relay circuit to the controller. Some basic loads are managed by green solar energy with a 12V DC battery and sometimes suggested appliances can be used through this power when critical peak price is high. This prototype is energized in two different way either solar energy or normal grid. Most importantly the prime amenities in this prototype system is that it is connected to the internet so

the full system would be controlled, monitored and managed from any place of the world if it is connected to internet.

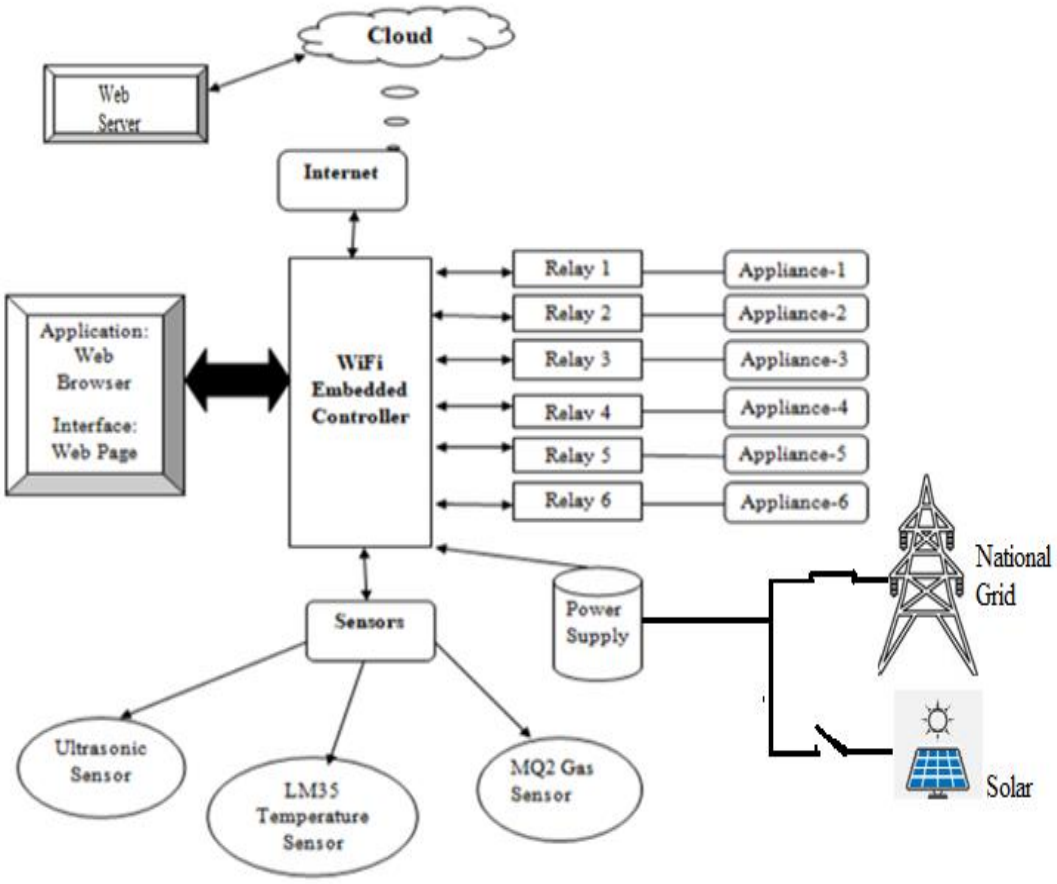


Figure 3.2: Block Diagram of HEMS using IOT

3.3 Prototype

The objective of this work is to develop an automated energy saving smart home integrated with IOT which signifies on the smart world. IOT application provides the user to check the status of all the appliances anywhere through internet using computer or phone. The figure 3.1.1 represents the prototype model of this project. In web application we can easily control the appliances and get the sensors data simultaneously. This project work is done on Arduino platform which communicate with the sensors by serial communication.

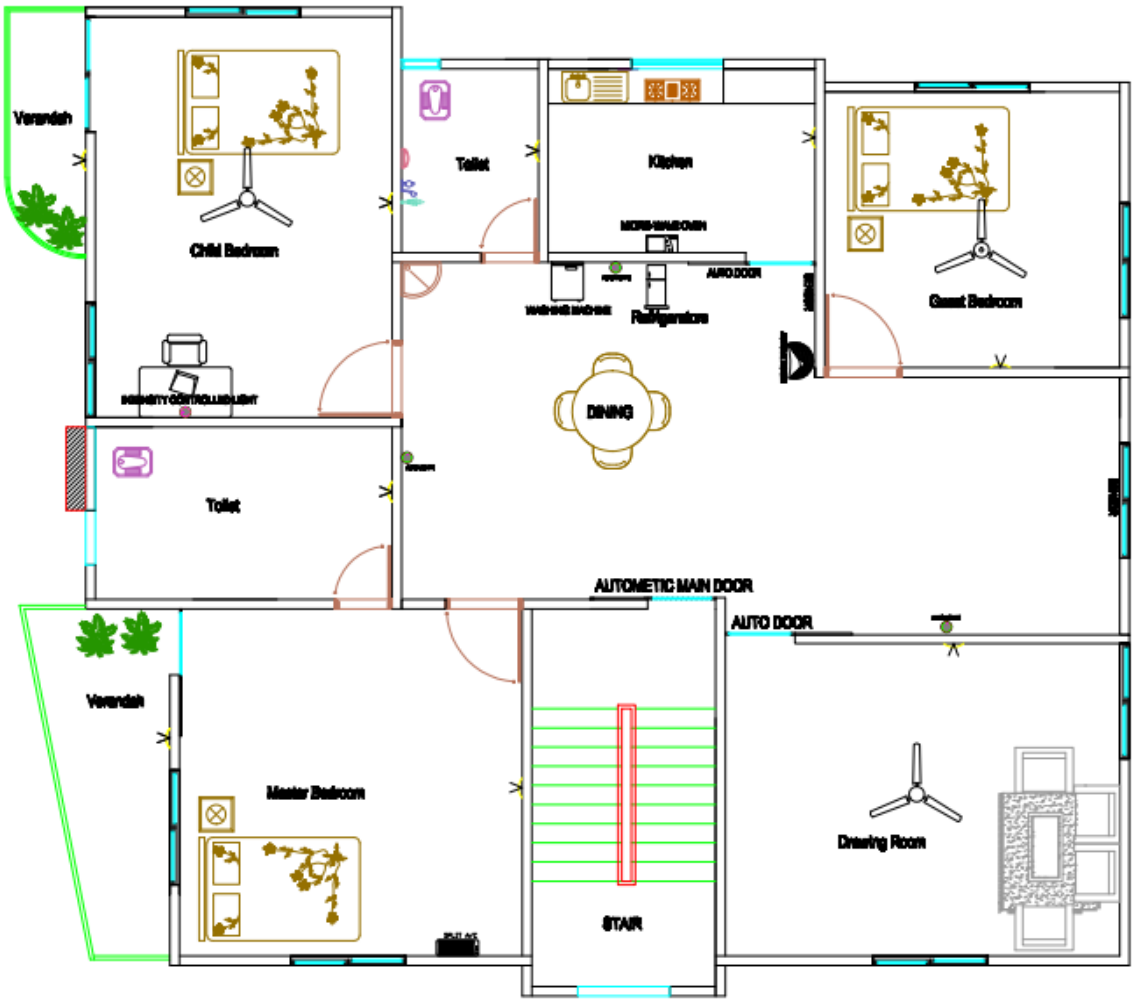


Figure 3.3: Home Automation Floor Plan Prototype

3.4 Project Features

1. Main door controlled
2. Temperature monitoring
3. Smart Water pump
4. Smart bin
5. Automatic light and door control
6. Intensity control light
7. AC load scheduling, controlling and monitoring
8. Smoke and Gas detector alarm

3.4.1 Main Door Controlling

Main door is a vital security part of any home. This project made the main door smart by using technology so that only authentic person can open the main door if they don't have master key with them. The project has made main door fully operational and control by a dedicated webpage assigned with defecated IP address and authentic login id password. This automatic door is designed by keeping in mind that now-a-days people are busy with their work and in rush hour all the time so considering on this situation they can easily forget to bring the master key of the main door with them. By solving the condition of this problem, we design this automatic website control main door. In spite of being not having the main door keys however a person can open the door if s/he has the webpage address and authentic login id password.

The structure of the automatic door which makes it operable is; the door is set by a servo motor that drives the door OPEN or CLOSE, servo motor directly connected to the Arduino the main control unites which reads the program or give command to operate the door. Arduino can determine the program to do work as it input is given. Then Arduino connected to node MCU WiFi module so that it can show and updates information to the web server which is controlled over the webpage.

3.4.2 Temperature Monitoring

A smart home automation needs to know the ambient temperature of its surroundings because of measuring the safety and precautions of a home. Temperature sensor informs to determine exact temperature and shows the details to the website for precautions.

Initially Arduino can take the input from the temperature sensor from its surroundings and with the help of node MCU it shows details to the main website. A temperature sensor gives us the information about ambient temperature of its adjacent area. We used ultra-low-cost digital temperature sensor. It is fairly simple to use but requires careful timing to grab the data. The only real drawback of this sensor is we can only get new data from it once in every 2sec. All the data from this sensor stored in the website and updated every now and then. So, we can easily get to know the actual temperature near-by.

3.4.3 Smart Water Pump

In residents we usually face a very common problem which is the availability of water and restrained water supply. Hence dwellers use roof top tank to save water and for this they need water pump which drives the water from basement into the roof top tank and stored. By setting up an automatic water pump that abridge the insufficiency of water problem and more amended besides water can be accustomed in more systematic way. Smart water pump is a fully functional and operated by itself because of its artificial intelligence system. By detecting the water level in the water tank, it runs an algorithm whether it would turn ON/OFF by itself. As we all know that water pump is very energy consuming, we found a solution for that. Before turning the pump on; it first checks the basement tank water level is adequate enough to pump the water than checks

the energy consumption rate of that time depending on it takes decision. If there is not sufficient water level on basement tank it may burn the pump. If the rate is high it will not turn on. Actually, at first it checks the percentage level if the level is below 15% then it turns on and if the level is more than 90% it will turn off in between it checks the energy consumption rate to make decisions whether it should turn ON/OFF. At times below 30% of water level it turns on if it finds the energy consumption rate is low. All data of the water tank and pump are shown in the website. So, we don't need to go and look for whether the water tank is empty or not and also don't need any kind of manual switches or any person to turn it on.

The designing of the system incorporates with an ultrasonic sensor to read the water level, an Atmega to make decision, a push button for switching auto/manual mode selection, an electromagnetic relay as the drive of the pumping motor. After taking the reading of the water level from ultrasonic sensor, the control unit Atmega runs the algorithm to make decision of turning the power of motor pump. The controls unite directly connected with Node MCU aid to upload the present situation or the data to the web server so that we can check current situation of the water tank by visiting into our dedicated webpage remotely.

3.4.4 Smart Bin

Smart bin is such type of bin which automatically detects the percentage level of its emptiness. In smart home smart bin guidance, the user to inform without seeing the bin in their bare eyes whether the bin is empty or full. If the bin percentage level becomes more than 90% it will give a notification to the dedicated webpage to empty the bin.

For making the smart bin operable we used ultra-sonic sensor to measure the percentage level of the bin connected with Arduino. Ultra-sonic sensor measures the amount of fill up of the bin. Depending on percentage level Arduino give warning into the webpage.

3.4.5 Automatic Light and Door Control

Automatic light and door of smart home is very simple, helpful and safe also important because of its energy efficiency and smartness. Automatic light actually used for turning ON or OFF and the door is like as same OPEN or CLOSE by sensing the presence of person. If any person enters in a room the system automatically turns ON the light and if no person present in the room system automatically turns OFF the light. Similarly, if any person comes in front of the door, the door automatically opens by detecting the presence of person.

Automatic door open and close again is expectancy in apartment buildings. Pressing on door handles or rotating door knobs, pulling doors and closing doors again after passing through. After a certain time, this becomes so nagging. Because of having lack time people sometimes forget to close the doors after themselves, in particular. Moreover, a very few people like children, wheelchair user, older people and those who are disable it becoming outrageous to open the door and closing it again and again. Therefore, automatic door which allows everyone to have easy and expedient entry to rooms, something that is growingly appreciated and even

prospective. It allows the free access, exit and passage in room without having any kind of hindrance. This automatic door deliberated virtually standard for home.

Ultrasonic sensor works as a detector which sends information to open or close command and transfer it to the control unit. Sensor monitors the path of the door leaves and the closing edges. Arduino mega is the main control unit or the brain of the system, settings for opening and closing command also holding time by detecting human presence from the ultrasonic sensor. The door drives using a servo motor force to open the door. The drive pulls the door open and then closes it again.

Automatic light saves extra use of energy consumption and also as extra money at the same time [12]. The unnecessarily waste of energy consumption in a vacant room cause unnecessary cost, besides the power consumption of lighting in a typical house is a factor which cannot be ignored. Whereas some situation creates where user forgets to turn OFF the lights and this deliberate factor consider one of the primary reasons that causes an unnecessary energy waste. Automatic control system allows turning ON or OFF the light based on detecting the presence of person in the space. It is an automatic light controlling technique which provides energy savings and security advantages. The controlling system composes our daily life easier, comfortable and save extra inessential waste of energy consumption. Therefore, we develop a system which optimize in such an affordable and efficient way to conserve energy. Because of having automation system technique of powering ON/OFF by detecting persons presence makes the home smarter and efficient. For this, the person does not need to have any switch or button to turn ON/OFF the lights. So, it helps the person to move easily without hesitation and does not have to keep in mind whether the room light is turned ON or OFF left behind.

For this system design we used ultrasonic sensor and motion detector through Arduino which detect the person and then allow which light should get to turn on/off also as door. Ultrasonic sensor which detects the presence of person at a certain range and depending on the range it send information of its control unit to turn on the specific light within the range. Then the control unit known as Arduino mega collects the information from the sensor of specific range and command to turn ON the light in that specific range. If the person passes the range and enters into another range the control unit turn OFF the previous light and turn on new range light.

3.4.6 Intensity Controlled Light

Intensity control light is more efficient and necessary appliance for any smart home. It allows glowing the light with more power or less power by measuring the intensity of the room light to how much it needed. It is necessary because the room intensity depends on sunlight; sometimes it becomes lighter and sometimes it becomes low light in the room in that situation intensity control light is very useful and also saves energy. After detecting the shine of ambient atmosphere intensity to demonstrate different seasons have different brightness intensity. In this case, in winter there is fog everywhere the brightness is faint collate in monsoon season the surroundings remain dark. When the light intensity of a room is high the light glow as dim and when the intensity is low the light glow with more power [13].

In this system development we used intensity sensor connected with Arduino which helps to determine how much the light should glow by measuring the intensity level. First, we took some data of light intensity measurements, by comparing the measurements of the intensity level Arduino runs an algorithm to instruct the light how much the light should glow with how much power.

3.4.7 AC Load Scheduling, Controlling and Monitoring

AC loads which is very high energy consuming appliance of a home. We developed such system which control and monitor all 240-volt alternate current (VAC) so that we can minimize the energy consumption and also save extra expenses of money. Continuous uses of these appliances cost unnecessary waste of energy and expense at the same time. This appliance is controlled and monitored by a webpage of its energy consumption rate by scheduling with the real time energy consumption price. If we want turn on AC during peak hour of energy consumption rate it will show us a notification about high energy rate and advise us to turn on after peak hour. It shows the details in the webpage about the energy cost by its use so we calculate extra cost of AC load. As AC load is directly operable through the website so we can easily control the load remotely if we left it turn on.

The development of the system is connected a relay directly through the Arduino which the help of node MCU to update in the website.

3.4.8 Smoke and Gas Detector Alarm

Method of detecting gas leakage becomes a problem after discovering the impacts of damaging gases on human welfare. Gas detector is such device which detects the presence of gases around its ambience atmosphere. Mainly this equipment's help to detect flammable gas leakage and give an alarm to be warn the user [14]. This device gives an alarm to the residents in the place where it’s occurring and gives scope to leave or to take action against it. Detection of gas leakage is the method by which sensors identify possibly potentially harmful gas leaks. Usually these sensors use an audible to warn individuals when a hazardous gas is identified.

A smoke detector is a smoke sensing tool, typically as a fire indicator. As part of a fire alarm system, security devices send a signal to a fire alarm, while household smoke detectors, also known as smoke alarms, usually send a local audible or visual alarm from the detector itself. Sensitive alarms can be used to detect smoking in fields and thereby prevent it. In households with working smoke alarms; the risk of dying in a home fire is reduced in half. In some households have no alarms for smoke but this tool helps to take careful measures.

The process of this program design we used gas detector and smoke detector both connected with an alarm connected with Arduino to determine the gas and smoke; and give a safety alarm blow.

3.5 Protocols

3.5.1 Transmission Control Protocol (TCP)

Transmission control protocol is a transport layer protocol which is defined for segmentation and reassembly of data, multiplexing, connection control, flow and error control of data. In this layer data unit is known as segments. To control the flow of segments a port address and sequence number is assigned with the data unit.

3.5.2 Internet Protocol (IP)

Internet Protocol is predefined rule and convention which is used to govern the communication of digital data between a huge numbers of devices connected through the internet by assigning IP addresses to every single one. This is Network layer protocol and data unit at this layer is known as Packets. So, to exchange packets between exact sender and receiver a unique IP address is required for every device which given by the internet service providers (ISP) and governed by the Internet Engineering Task Force (IETF). An IP address is created by 32-bit long binary number and written in four dotted decimal notations. For example, here 192. 168. 12.1 each decimal is represented by 8 bits.

3.5.3 MQTT

MQTT (Message Queue Telemetry Transport) is a protocol used commonly in IoT apps for publish-subscribe messaging. The purpose of this protocol is to transfer information between machines with restricted network bandwidth and authority. For microcontroller projects that send information over the internet, it is highly recommended.

3.5.3.1 MQTT Working Process

It’s a binary based protocol which communicates with a server called "broker" to distribute messages to customers on the basis of a specific "subject". Initially publisher sends the broker information while subscribers read the broker's information. A typical MQTT link requires a host name, port, and identification of the customer, username and password.

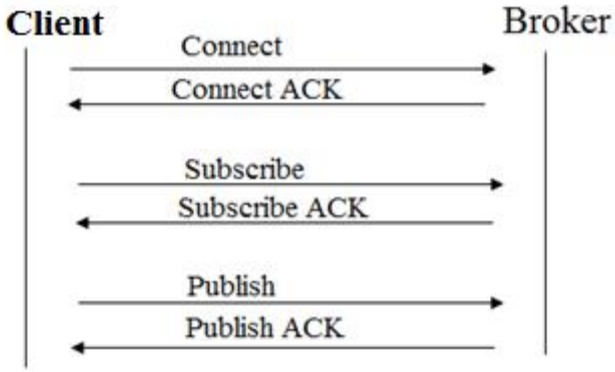


Table 2: Sample MQTT Control Message

Name	Value	Direction of the flow	Description
Reserved	0	Forbidden	Reserved
Connect	1	Client to the server	Client request to connect the server
Connack	2	Server to Client	Connect acknowledgment
Publish	3	Client to the server	Publish message

MQTT Packet Type

Control header	Packet length	Variable length header	Payload

3.5.3.2 MQTT Messages Type

- Connect: Waits to make a connection with the server and generates a connection between the nodes.
- Disconnect: Prepares for the MQTT client to complete any job they need to do and to disconnect the TCP / IP session.
- Publish: Arrives to the application thread promptly after the request is transferred to the MQTT customer.

MQTT is the best for IoT because with M2 M communication, neither HTTP nor Web socket have been intended specifically.

3.5.4 Hypertext Transfer Protocol (HTTP)

Hypertext Transfer protocol is the set of rules that is used for the interpretation between the web server and the web-page. This is a very important application layer protocol which paves the way for human to communicate with the server through the webpage. To show text, picture, audio and video data, different hyperlinks in a web page from a distant server HTTP protocol is required.

3.6 Interface Working Procedure

In data innovation, the (UI) is everything planned into a data gadget with which an individual may collaborate. This can incorporate showcase screens and the appearance of a desktop. It is additionally the path through which a client cooperates with an apparatus on site.

Our interface is a webpage. This webpage consists of HTML and CSS. Web server is a spot which stores, procedures and conveys site pages to Web customers. Web customer is only an internet browser on our workstations and cell phones. The correspondence among customer and

server happens utilizing an extraordinary convention called Hypertext Transfer Protocol (HTTP). In this convention, a customer starts correspondence by making a solicitation for a particular website page utilizing HTTP and the server reacts with the substance of that page or a mistake message if unfit to do as such (like renowned 404 Error). Pages conveyed by a server are for the most part HTML reports. Perhaps the best element ESP8266 gives is that it can't just interface with a current WiFi system and go about as a Web Server, however it can likewise set up its very own system, enabling different gadgets to associate straightforwardly to it and access site pages. This is conceivable on the grounds that ESP8266 can work in three unique modes: Station mode, Soft Access Point mode, and both in the meantime. This gives probability of structure work systems. The ESP8266 that makes its own WiFi system and goes about as a center (Just like WiFi switch) for at least one station is called Access Point (AP). In contrast to WiFi switch, it doesn't have interface to a wired system. Along these lines, such method of activity is called Soft Access Point (delicate AP). Additionally, the most extreme number of stations that can associate with it is restricted to five. In AP mode ESP8266 makes another WiFi system and sets SSID (Name of the system) and IP address to it. With this IP address, it can convey website pages to every associated gadget under its own system. When you type a URL in an internet browser and hit ENTER, the program sends a HTTP demand (a.k.a. GET demand) to a web server. It's work of web server to deal with this solicitation by accomplishing something. You may have made sense of it at this point we are going to control things by getting to a particular URL. For instance, assume we entered a URL like http://192.168.1.1/ledon in a program. The program at that point sends a HTTP solicitation to ESP8266 to deal with this solicitation. At the point when ESP8266 peruses this solicitation, it realizes that client needs to turn the LED ON. In this way, it turns the LED ON and sends a dynamic website page to a program indicating LED status: ON As simple as Pie!

For the advancement of the Web application, as respects the user part, HTML advances were utilized. Information that advice about the GPIO ports that are being used or the gadgets associated with each room. For the execution of the Web application at first all the status catches are incapacitated and are shaded dark. This demonstrates the status of every gadget has not yet been gotten from the server. When the server acquires status information, the marker lights will change shading and the comparing status catches will be actuated. On the off chance that for instance a gadget is opened, at that point the comparing status catch will turn green and its operational OFF catch will be activated. On the other hand, in the event that a gadget is shut, at that point the comparing status catch will turn red and its operational ON catch will be actuated. The data about the status of every gadget is moved, progressively with the server.

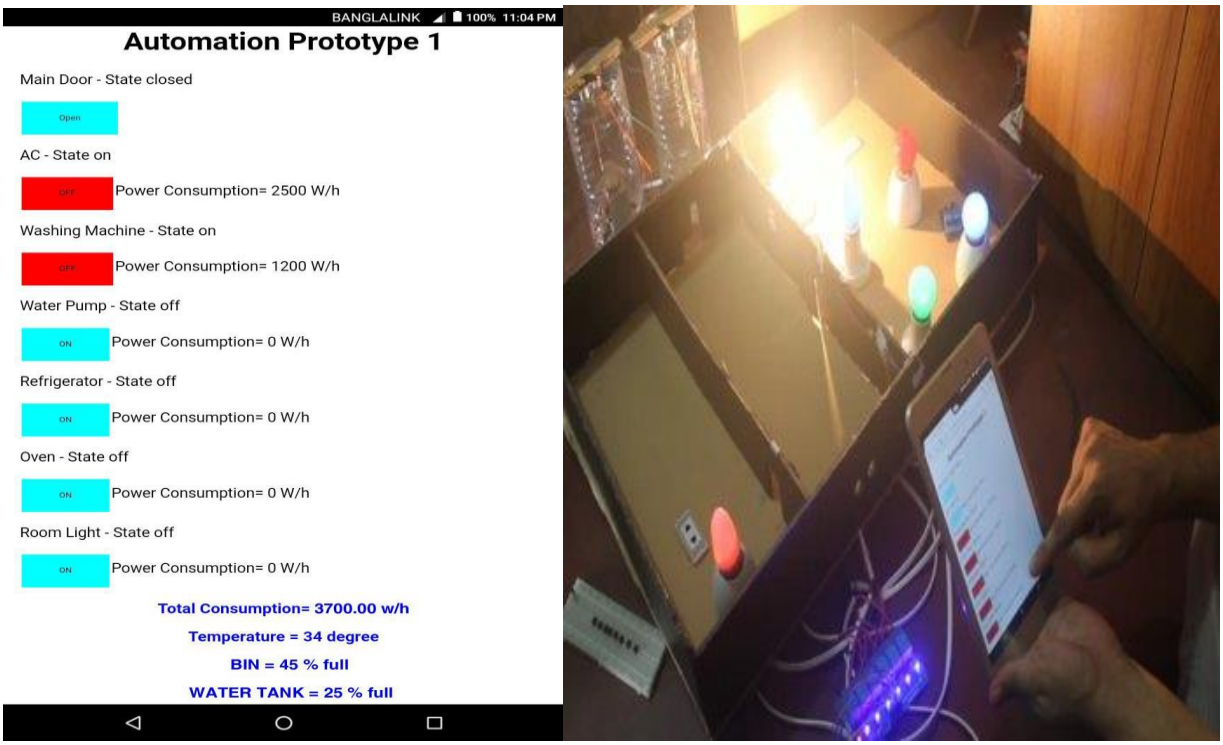


Figure 3.6: Webpage Interface Connected with Prototype

HTML:

HTML is a language for portraying the structure of Web pages. HTML represents Hyper Text Markup Language. Site pages comprise of markup labels and plain content.

CSS:

CSS represents Cascading Style Sheet. Cascading templates are utilized to arrange the design of Web pages. They can be utilized to characterize content styles, table sizes, and different parts of Web pages that beforehand must be characterized in a page's HTML. CSS helps Web engineers make a uniform look over a few pages of a Web site.

CSS can be added to HTML components in 3 different ways:

- Inline - by utilizing the style quality in HTML components.
- Inward - by utilizing a <style> component in the <head> segment.
- Outer - by utilizing an outside CSS record.

In our webpage, we have buttons to open or close main door and it also show the state of main door. Furthermore, it shows us the states of six AC loads and it also has the buttons to switch six loads.

3.7 Schematic Simulation Diagram

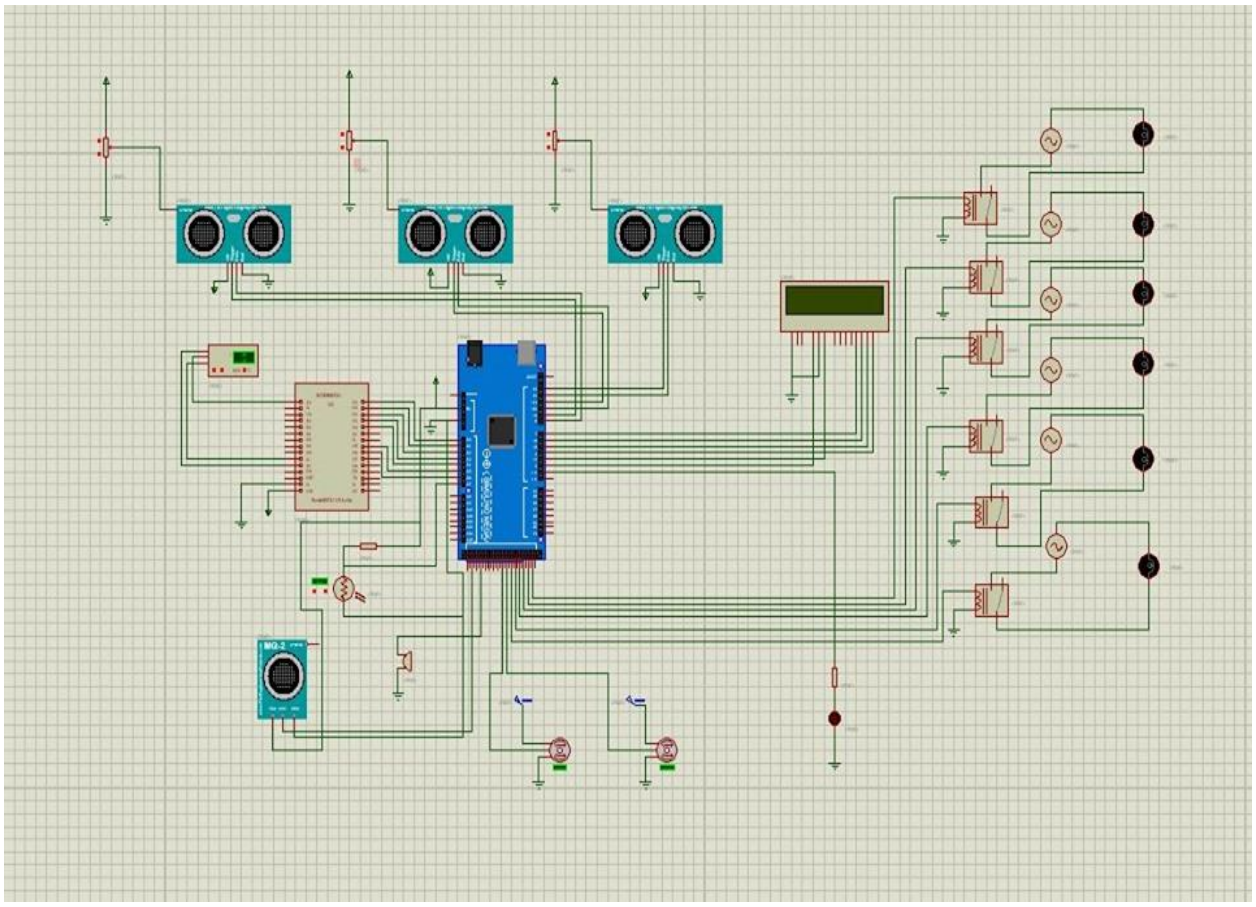


Figure 3.7: Schematic Simulation Circuit

Chapter 04

Hardware and Software

IOT Elements

4.1 Hardware Implementation

4.1.1 ESP 8266 NodeMCU

In our project we use many devices like ESP 8266 NodeMCU module v3. The ESP8266 is the name of a micro controller structured by Espressif Systems. The ESP8266 itself is an independent Wi-Fi organizing arrangement offering as an extension from existing smaller scale controller to Wi-Fi and is likewise fit for running independent applications. This module accompanies an inherent USB connector and a rich arrangement of stick outs. With a smaller scale USB link, you can associate NodeMCU devkit to our laptop and glimmer it with no inconvenience, much the same as Arduino. It is likewise promptly breadboard inviting.

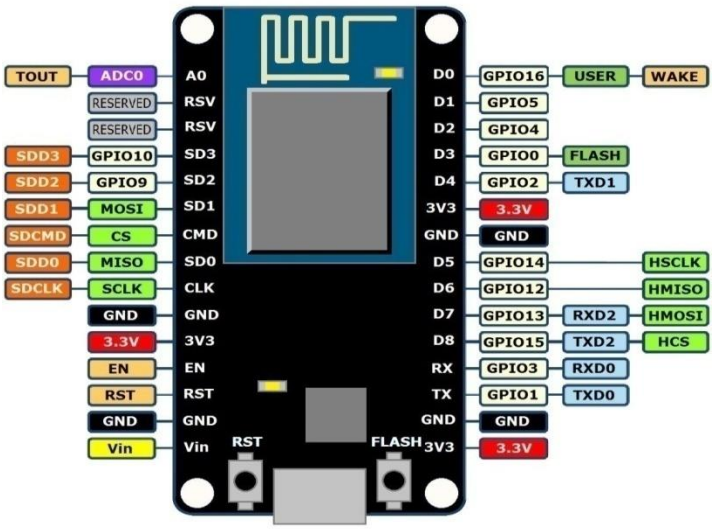


Figure 4.1.1: ESP8266 Node MCU

Specification:

• Voltage: 3.3V.
• Wi-Fi Direct (P2P), soft-AP.

• Current consumption: 10uA~170mA.
• Flash memory attachable: 16MB max (512K normal).
• Integrated TCP/IP protocol stack.
• Processor: Ten silicaL106 32-bit.
• Processor speed: 80~160MHz.
• RAM: 32K + 80K.
• GPIOs: 17 (multiplexed with other functions).
• Analogue to Digital: 1 input with 1024 step resolution.
• +19.5dBm output power in 802.11b mode
• 802.11 support: b/g/n.
• Maximum concurrent TCP connections: 5.

4.1.2 Arduino MEGA

We also use Arduino MEGA. The Arduino MEGA 2560 is intended for activities that require more I/O lines, more sketch memory and more RAM. With 54 advanced I/O pins, 16 simple information sources so it is reasonable for the intricate undertakings like 3D printers and apply autonomy ventures.

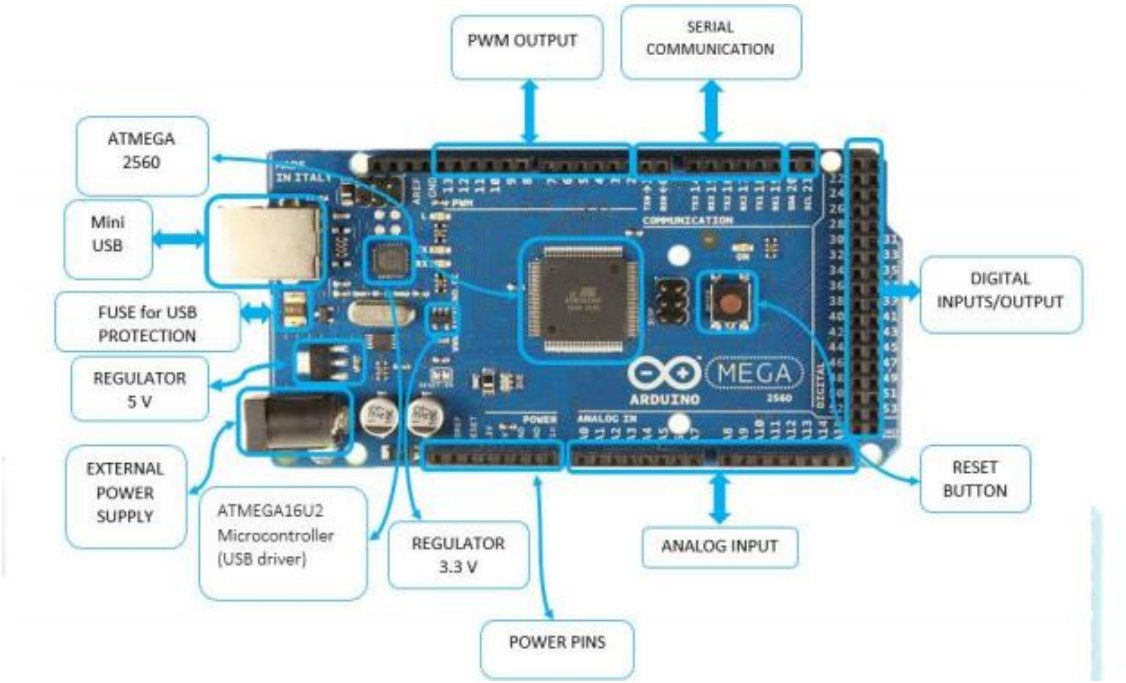


Figure 4.1.2: Arduino MEGA

Arduino MEGA Physical Components:

Features

1. 8-Bit Microcontroller
2. High Performance, Low Power

3. Advanced RISC Architecture

- 135 Powerful Instructions
- Most Single Clock Cycle Execution 2
- 32 × 8 General Purpose Working Registers
- Fully Static Operation
- Up to 16 MIPS Throughput at 16MHz
- On-Chip 2-cycle Multiplier

High Endurance Non-volatile Memory Segments

- 64K/128K/256KBytes of In-System Self-Programmable Flash
- 4Kbytes EEPROM
- 8Kbytes Internal SRAM
- Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
- Optional Boot Code Section with Independent Lock Bits

We also use six light, six relay switch board, DC power source, Jumper wire, Bread Board, Six light holder, AC Supply Connection Wire.

4.1.3 Ultrasonic Sensor

In our project we use Ultrasonic Sensor.An Ultrasonic sensor is a gadget that can gauge the separation to an object by utilizing sound waves. It measures distance by sending a sound wave at a particular recurrence and tuning in for that sound wave to skip back. Understand that a few objects probably won't be recognized by ultrasonic sensors.

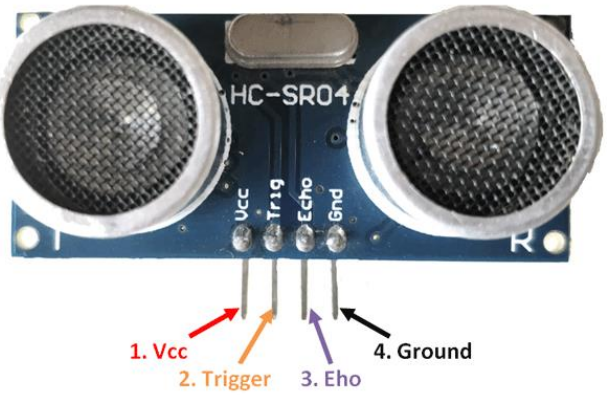


Figure 4.1.3: Ultrasonic Sensor

Ultrasonic Sensor Pin Configuration

Pin Number	Pin Name	Description
1	Vcc	The Vcc pin powers the sensor, typically with +5V
2	Trigger	Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave.
3	Echo	Echo pin is an Output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor.
4	Ground	This pin is connected to the Ground of the system.

4.1.4 LM35 Temperature Sensor

We also use LM35 temperature sensor. The LM35 arrangement are accuracy coordinated circuit temperature gadgets with a yield voltage directly corresponding to the Centigrade temperature. The low-yield impedance, straight yield, and exact intrinsic adjustment of the LM35 gadget make interfacing to readout or control hardware particularly simple.

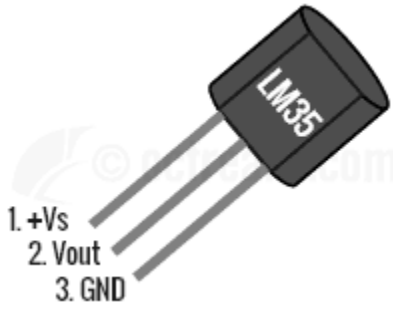


Figure 4.1.4: LM35 Temperature Sensor

Temperature sensor is a gadget, to quantify the temperature through an electrical sign it requires a thermocouple or RTD (Resistance Temperature Detectors). The thermocouple is set up by two divergent metals which create the electrical voltage by implication corresponding to change the temperature. The RTD is a variable resistance, it will change the electrical opposition in a roundabout way relative to changes in the temperature in an exact, and almost direct way.

The estimation of the temperature sensor is about the hotness or coolness of an article. The working base of the sensors is the voltage that perused over the diode. On the off chance that the

voltage builds, at that point the temperature rises and there is a voltage drop between the transistor terminals of base and producer, they are recorded by the sensors. In the event that the distinction in voltage is enhanced, the simple sign is produced by the gadget and it is straightforwardly relative to the temperature.

4.1.5 Light Dependent Resistor

We also use Light Dependent Resistor. A Light Dependent Resistor (LDR) or a photograph resistor is a gadget whose resistivity is a component of the episode electromagnetic radiation. Henceforth, they are light delicate gadgets. They are likewise called as photograph conductors, photograph conductive cells or essentially photocells. They are comprised of semiconductor materials having high obstruction. There are various images used to demonstrate a LDR, one of the most regularly utilized image is appeared in the figure beneath. The bolt demonstrates light falling on it.

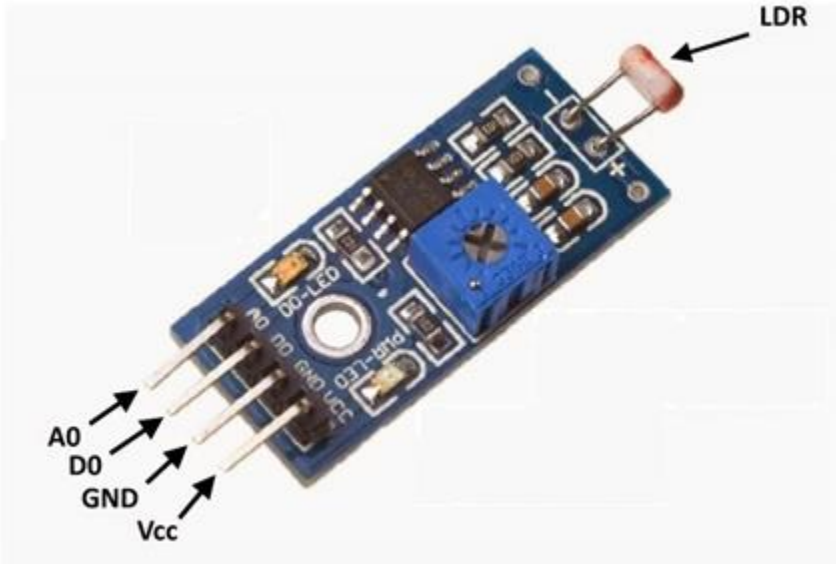


Figure 4.1.5: LDR Sensor

A light reliant resistor deals with the guideline of photograph conductivity. Photograph conductivity is an optical marvel where the materials conductivity is expanded when light is consumed by the material.

At the point when light falls for example at the point when the photons fall on the gadget, the electrons in the valence band of the semiconductor material is eager to the conduction band. These photons in the occurrence light ought to have vitality more noteworthy than the band hole of the semiconductor material to make the electrons hop from the valence band to the conduction band. The after-effect of this procedure is an ever-increasing number of currents begin moving through the gadget when the circuit is shut and henceforth it is said that the obstruction of the gadget has been diminished. This is the most well-known working rule of LDR.

4.1.6 Servo Motor

In This project we also use servo motor 9g. It is small size servo and very suitable to control.

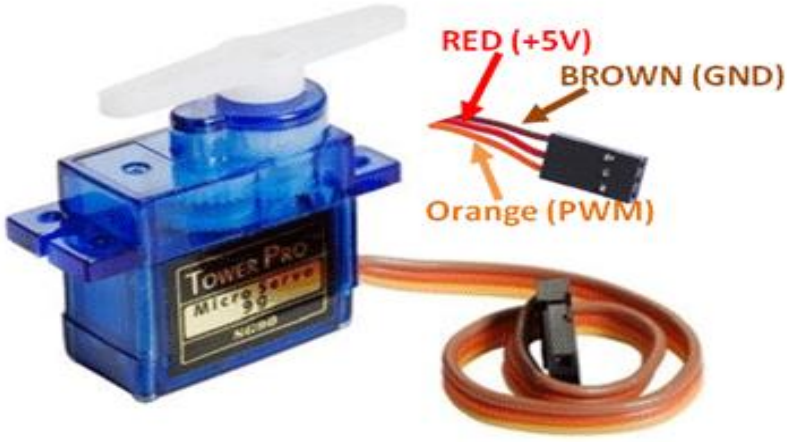


Figure 4.1.6: Servo Motor

We also use the DS3231 is a minimal effort, very exact I2C continuous clock (RTC) with a coordinated temperature compensated precious stone oscillator (TCXO) and gem. The gadget consolidates a battery input, and keeps up precise timekeeping when principle capacity to the gadget is intruded. The incorporation of the gem resonator improves the long-haul precision of the gadget also as decreases the piece-part includes in an assembling line. The DS3231 is accessible in business and mechanical temperature goes, and is offered in a 16-stick, 300-mil SO bundle.

4.1.7 A 5-220 v Relay

Relay is an electromagnetic gadget which is utilized to segregate two circuits electrically and interface them attractively. They are valuable gadgets and enable one circuit to switch another while they are totally discrete. They are frequently used to interface an electronic circuit (working at a low voltage) to an electrical circuit which works at exceptionally high voltage. For instance, a relay can make a 5V DC battery circuit to switch a 220V AC mains circuit. In this manner a little sensor circuit can drive, say, a fan or an electric bulb.

A relay switch can be partitioned into two sections: input and output. The input section has a coil which produces magnetic field when a little voltage from an electronic circuit is connected to it. This voltage is known as the working voltage. Generally utilized transfers are accessible in various design of working voltages like 6V, 9V, 12V, 24V and so on. The output section

comprises of contactors which interface or detach precisely. In a fundamental hand-off there are three contactors: normally open (NO), normally close (NC) and normal (COM). At no input state, the COM is associated with NC. At the point when the working voltage is connected the relay coil gets empowered and the COM changes contact to NO. Different relay arrangements are accessible like SPST, SPDT, DPDT and so forth, which have distinctive number of changeover contacts.

Figure 4.1.7: Relay

4.1.8 MQ2 Gas Sensor

Figure 4.1.8: MQ2 Gas Sensor

For the gas leakage identification, this MQ2 gas sensor is used in home and industrial sides. Due to its high sensitivity and fast response, measurement can be done as soon as possible. Its sensitivity can be adjusted by potentiometer. Gases like Hydrogen, Carbon Mono-oxide, Hydro carbon, Fuel gases and smoke can be easily detected by this sensor. The wide detecting scope, higher sensitivity and long life time stability features make this sensor widely used in different professional and home sectors.

In this project, this gas sensor is used to identify the gas leakage in a room at home so that it can send alert via wireless connection to the user. A buzzer is connected to notify the alert to the user or home living people. The gas sensor here is operated by arduino.

Specification

- Working voltage from 4.9-5.1 V
- Heating consumption 0.5-800 mW
- Sensing resistance 3-30 kΩ

4.1.9 Digital Buzzer Module MOD-00055

Figure 4.1.9: Digital Buzzer Module MOD-00055

This simple digital buzzer module, model: MOD-00055 is used here to alert user and others when this buzzer gets command from gas detector sensor MQ2. This buzzer has 3 pins with ground and VCC which operates at 5V. Another pin is switching pin for the connection with sensor.

4.1.10 DS3231 Real Time Clock Module

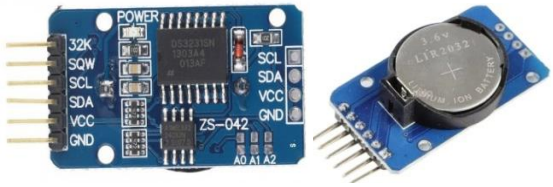


Figure 4.1.10: DS3231 Real Time Clock Module

DS3231 Real Timer Clock Module is used to remember real time and date in the absence of external power supply. It has its own battery setup for up to date time and date automatically even if the device is switched off. The implementation of it in this project is for same cause. To get the real time value, it is connected with arduino to save the data of real time and date when the external power generation is switched off.

There are total 10 pins including VCC and GND. A pin of 32 kHz is the output oscillator to give the output. This RTC module collects the serial data in SDA pin. The SCL pin is to collect the time measurement data. To get the square wave output, another pin SQW is placed just beside output pin of 32 kHz.

Specification

- This RTC counts hours, minutes, seconds and years
- Digital temperature sensor with +/- 3-degree accuracy
- Accuracy: +2ppm to -2ppm for 0 to 40-degree Celsius, +3.5ppm to -3.5ppm for -40 to +85 degree Celsius.
- 400 kHz I2C interface
-Automatic power failure battery switch circuit
- Low power consumption, potable size and 3 years lifetime support
- DCC operation: 2.3-5.5 V
- Consumes 500nA battery backup
- Maximum voltage: VCC +0.3 V

4.2 Software

4.2.1 Arduino IDE for Controller and ESP Programming

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a content manager for composing code, a message region, a content comfort, a toolbar with buttons for normal capacities and a progression of menus. It associates with the Arduino and Genuine equipment to transfer programs and speak with them.

Projects composed utilizing Arduino Software (IDE) is called outlines. These representations are written in the word processor and are spared with the record augmentation. The editorial manager has highlights for cutting/gluing and for looking/supplanting content. The message territory gives criticism while sparing and sending out and furthermore shows mistakes. The comfort shows content yield by the Arduino Software (IDE), including total mistake messages and other data. The base right-hand corner of the window shows the designed board and

sequential port. The toolbar catches enable you to confirm and transfer programs, make, open, and spare portrays, and open the sequential screen.

4.2.2 Homer pro for Simulation

HOMER (Hybrid Optimization of Multiple Electric Renewable). At its center, HOMER is a simulation model. It will endeavor to simulate a viable framework for every single imaginable blend of the hardware that you wish to consider. Contingent upon how you set up your concern, HOMER may reproduce hundreds or even a large number of frameworks. HOMER simulates the activity of a half and half micro grid for a whole year, in time ventures from one minute to 60 minutes.

4.2.3 Texmaker

Texmaker is a modern cross platform LaTeX editor used free for linux, macosx and windows systems. It integrates many tools in one application to develop documents with LaTeX. Texmaker includes Unicode support, code fielding, spell check, auto completion and a built-in pdf viewer. This app uses wizard for tasks like- generate new documents, create tables, tabular, and figure environments and export LaTeX document via TeX4ht. It automatically locates errors and warnings detecting in log file after compilation. This editor is very easy to use and configure.

In this project-based research, we used this “Texmaker” app to write the logarithm. Texmaker automatically took all the code and transfer it to output in its original structure of coding we needed. It’s very easy for this work as this app didn’t create problem to format the coding in its mathematical shape.

4.2.4 ThingSpeak

ThingSpeak is an IoT application and an API that is open source for storing and retrieving data from hardware and sensor devices. It utilizes the Internet or LAN HTTP protocol to communicate with it. MATLAB databases are included to evaluate and simulate hardware or sensor device information obtained. We use this open-source cloud because we do not have any purchased domain and our webpage is not open thus for surveillance, we use ThingSpeak server.

Chapter 05

Control Flow & Algorithms

Introduction

System has a central controller acting as central processing unit which is connected with a portable PCB unit consists of web server and sensors. Central processing unit (CPU); here controller is also connected with the electrical home appliances through electrical relays and some other different loads like motors and distant on-site sensors. Central controller follows different algorithms to collect information, compare and make decisions, show results and control appliances. To create a web server esp-8266 module has been used which has a central processing unit as well, storage for data and wifi module in a single chip. Central processing unit of esp-8266 module takes the name of the wifi network and the password of that network as input from the user and then establishes connection with the network. According to the load list a web page is written and designed and already stored in the memory of the esp-8266 module. Once esp-8266 is connected to a network then it is ready to show the states of electrical loads and different results and also take command from the client to control the appliances through the web page. To execute our desired applications used algorithms are as follows.

5.1 Controlling a Single Electrical AC Load

If a client presses the button to ON load-1 from the web page then the esp-8266 sends 3.3V signal to the central controller and controller stores the voltage value under the variable called load-1 and then compares the value that it is more than 3V or not. If it is equal or greater than 3V then controller sends 5V signal to the corresponding relay for the load-1. If the voltage value stored in load-1 is less than 3V then the controller sends 0V to the corresponding relay for the load-1. When relay gets 5V as input it shorts the 220V supply line with the load-1 at its output side. And when relay gets 0V as input it opens the 220V supply line from the load-1 consequently load-1 stops working.

Algorithm 1 Controlling a single Electrical AC Load

Require: Voltage signal from esp-8266

```
load-1 = incoming voltage value from esp-8266
if (load-1 ≥ 3V) then
    return 5V to the relay of load-1
else
    return 0V to the relay of load-1
end if
```

By following the algorithm user can control multiple electrical home appliances. Though, the number of appliances to be controlled will depend on the number of output pins of the central or main controller.

5.2 Measuring the Temperature and Controlling the Air Conditioner

To measure the temperature, temperature sensor (lm35) has been used which is connected to the main controller. Controller collects the sensor value from lm35 and stores it under the variable named temp-Celsius. This is a voltage signal value stored under temp-Celsius that came from lm35 sensor. To convert it to the respective temperature controller multiplies temp-Celsius by 500 and then divides it by 1023 and finally stores the result under the variable named temp (500 and 1023 are data-sheet value for our controller). Now, the stored value in temp is the measured room temperature. Then controller compares that the stored value in temp is equal or greater than 25 degree or not (here we take 25 degree as the scheduling temperature of the air conditioner but user can set any temperature according to their own need). If the value of temp is equal or greater than 25 degree then controller will send 5V to the corresponding relay for the air conditioner. If temp value is not equal or greater than 25 degree then controller will send 0V to the corresponding relay. However, to control the air conditioner we must keep a manual switch between the AC voltage supply line and the relay for the air conditioner to prevent the case like temperature is greater than 25 degree but there is no one in the room. In this case user must switch off the manual switch before leaving the room so that controller will send 5V to the corresponding relay as the temperature is greater than 25 degree but the air conditioner will not get the supply line voltage as the manual switch is off. Again, user must switch on the manual switch to provide the supply voltage and then the controller will control the air conditioner according to the temperature.

Algorithm 2 Measuring the Temperature and controlling the Air Conditioner

Require: LM-35 sensor value

```
1: temp-celsius = LM-35 sensor value
2: temp = [ temp-celsius * 500 ] / 1023
3: if (temp ≥ 25 degree) then
4:     return 5V to the relay of the ac
5: else
6:     return 0V to the relay of the ac
7: end if
```

5.3 Controlling Corridor Lights

In our designed floor plan, there are three lights in the corridor which are 357cm, 528cm and 954cm away from the ultrasonic sensor. Three lights and the sensor are connected with the central controller. Controller calculates the distance between incoming or outgoing objects and the sensor and then according to the object's position turns on the respective corridor light. To calculate an object's distance, we have used ultrasonic sensor. Ultrasonic sensor constantly transmits sound wave and receives the reflected sound wave if there is an object in front of it. Finally, the sensor determines the total time elapsed in between sending and receiving the wave and sends the time as sensor value to the controller.

Controller collects the time value from the ultrasonic sensor and stores it under the variable name duration1. And then divide the duration1 by 33 (as sound wave velocity in air is 330 m/s; we take 33 so that the distance will be calculated in cm) and again divide by 2 as the wave is travelling the same distance two times. Finally, controller stores the calculated distance value under the variable name distance1.

Algorithm 3 Controlling corridor Lights

Require: Ultrasonic Sensor Value

```
duration1 = ultrasonic sensor value
distance1 = [ duration1 / 33 ] / 2
if (distance1 ≤ 357 cm) then
    return 5V to the relay of light2
else
    return 0V to the relay of light2
end if
if (357 cm < distance1 ≤ 528 cm) then
    return 5V to the relay of light3
else
    return 0V to the relay of light3
end if
if (528 cm < distance1 ≤ 954 cm) then
    return 5V to the relay of light1
else
    return 0V to the relay of light1
end if
```

5.4 Controlling the Automatic Door's Motor

In our floor plan there is an automatic door which is installed for the guest room. The door will be opened and closed by a dc servo motor. There is a sonar sensor over the door. If someone stands in front of the door then his/her distance will be around 5cm to 45cm from the sonar sensor. If the person's position is in between 5cm to 45cm from the sonar sensor then the controller will drive the motor's rotor to position one (let's say rotor position one is defined for opening the door and it will depend on size and weight of the door). Otherwise the motor's rotor will remain on position two (let's say position two is defined for closing the door).

However, to set up an automatic door we must put sonar sensors on both sides of the door (front and back) so that anyone can enter into the room and can exit from the room as well. Another impotent thing is that the door motor will be driven by the dc voltage stored in the battery. So, user must know that the battery has enough voltage or not. Low voltage will affect the motor functionality.

Algorithm 4 Controlling the automatic door's motor

Require: Ultrasonic Sensor2 Value

```
duration2 = ultrasonic sensor2 value
distance2 = [ duration2 / 33 ] / 2
if (5 cm ≤ distance2 ≤ 45 cm) then
    drive the motor for rotor position one
else
    drive the motor for rotor position two
end if
```

5.5 Controlling Home's Main Door from the Web Page

There is a button in the web page for opening and closing the main door of the house. If user clicks the button to open the main door then esp-8266 sends 3.3V to the central controller. Controller then drives the servo motor of the door to its opening position. If user clicks the button to close the main door then esp-8266 sends 0V to the controller. And controller drives the servo motor to its closing position.

Algorithm 5 Controlling Home's Main Door from the web page

Require: voltage signal from web server (esp-8266)

```
door-voltage = incoming voltage from esp-8266
if (door-voltage ≥ 3 V) then
    drive the motor2 for opening position
else
    drive the motor2 for closing position
end if
```

5.6 Controlling Water Pump According to the Water Level in Tank

As water pump is connected to the central controller through an electrical relay, we can schedule it based on the amount of the water reserved in the water tank and the time varying electricity price. To measure the water level in the tank we have used a sonar sensor. A typical 5,000L water tank height is around 230 cm. In our algorithm we will take 225cm for the condition of 100% full. So, for every cm tank will be 0.44% full. When water level is below 15% controller will turn on the water pump. When water level is in between 15% and 50% controller will check whether it is peak hours or not. If it is peak hour controller will not turn on the water pump. If it is off-peak hour then controller will turn on the water pump. Finally, when water level is greater than 95% controller will turn off the water pump.

To keep tracks of the time and date and to schedule a device depending on peak hours or off-peak hours we have used a Real Time Clock (RTC) DS-3231 in our system. Once DS-3231 is connected to the controller and associate library is uploaded then we can schedule electrical loads using this time. Here, we are assuming peak hours 6pm to 11.59 pm.

Algorithm 6 Controlling Water Pump According to the water lever in tank

Require: Sonar sensor value, real time from DS-3231

```
duration3 = sonar sensor value
time = incoming DS-3231 value
distance3 = [ duration3 / 33 ] / 2
water-level = distance3 * 0.44
if (water-level ≤ 15 percent) then
    return 5V to the relay of the water pump
else (15 percent < water-level ≤ 50 percent)
    if (18.00 ≤ time ≤ 23.59) then
        return 0V to the relay of the water pump
    else
        return 5V to the relay of the water pump
    end if
end if
if (water-level ≥ 95 percent) then
    return 0V to the relay of the water pump
else
    return 0V to the relay of the water pump
end if
```

5.7 Automatic Bin

Bin has a sonar sensor that is connected to the controller. Controller takes the sonar sensor value and calculates the position of the objects inside of the bin. We are assuming a typical waste bin height is 90 cm. So, for every cm waste bin is 1.11 % full. And the algorithm is as follows,

Algorithm 7 For Automatic Bin

Require: Sonar sensor value

1: duration4 = sonar sensor value
2: distance4 = [`duration4` / 33] / 2
3: wastage-level = `distance4` * 1.44
4: Show wastage level in the display

5.8 Controlling Intensity of a Light

To control intensity of a light first we have to measure the actual room light intensity. So, to measure room light intensity we used light dependent resistor (LDR). According to the LDR value we will send different Pulse Width Modulated (PWM) signal to the light.

Algorithm 8 Controlling Intensity of a light

Require: ldr signal value

1: intensity = ldr signal value
2: **if** `(intensity` $\leq$ `800 mV)` **then**
3: return 33 percent PWM signal to the light
4: **else** `(800 mV` $<$ `(intensity` $<$ `900 mV)`
5: return 66 percent PWM signal to the light
6: **end if**
7: **if** `(intensity` $\geq$ `900 mV)` **then**
8: return 100 percent PWM signal to the light
9: **end if**

5.9 Detecting Smoke and Flammable Gas

To detect smoke and flammable gas MQ-2 sensor has been used. MQ-2 sensor is sensitive to smoke and following flammable gases: LPG, Butane, Propane, Methane, Ethane, Alcohol and Hydrogen. MQ-2 detects the concentration of smoke/gas level in the atmosphere and outputs a voltage signal accordingly. If smoke/gas level is high then the output voltage is high. When smoke/gas level is low then the output voltage is low. Here, threshold voltage for this sensor is

400 mV. If the sensor value is more than 400mV then the central controller will send 5V to the buzzer and the buzzer will be buzzing to notify the user about the rise of the smoke/gas level.

Algorithm 9 Detecting Smoke and Flammable Gas

Require: MQ-2 sensor value

```
threshold-voltage = 400 mV
smoke/gas-level = MQ-2 sensor value
if ( smoke/gas-level ≤ threshold-voltage)
then
    return 0V to the buzzer
else
    return 5V to the buzzer
end if
```

5.10 Data Monitoring

In this project, we will use the ThingSpeak IoT server to sneak and inspect temperature data over the internet. So, we can view the website's logged information and graph over time. It is produced from WiFi module ESP8266 and temperature sensor LM35.ESP8266 WiFi chip reads the present data from LM35 temperature using ADC and sends it from anywhere in the globe to ThingSpeak server for continuous monitoring.

Figure 5.10.1: Temperature Control Monitoring using LM35 Sensor

Using NodeMCU, we'll use an LDR to plot the light intensity level on ThingSpeak. NodeMCU will be programmed to read and store the LDR information in a variable and then upload it to ThingSpeak using its channel name and API key.

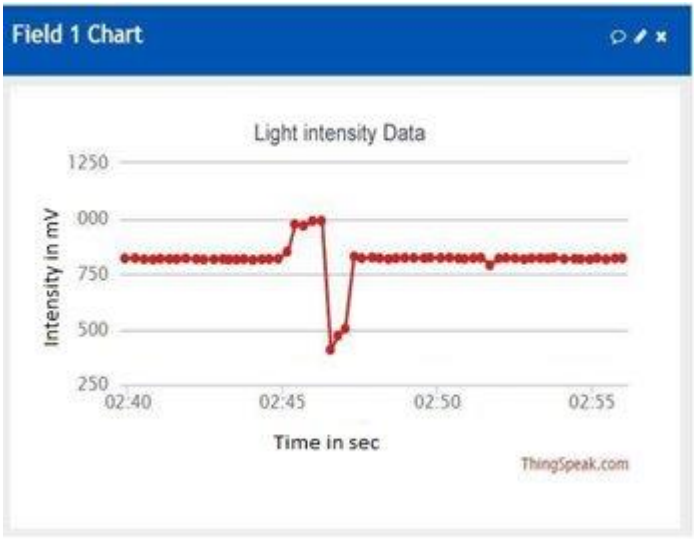


Figure 5.10.2: Light Intensity Monitoring

Chapter 06

Power Generation Simulation

Introduction

Homer (Hybrid Optimization Model for Multiple Energy Resources) is simulation software for electricity generation and micro grid system. It can simulate hybrid green energy generation processes and calculate the generation cost [15]. Electrical loads, components to be used, solar radiation data, wind speed profile and technical details of the components are to be provided to the software to design the system. Homer uses the geographical location of Dhaka city for calculating the solar radiation data. Monthly average global radiation data of the Dhaka city has been taken from NASA (National Aeronautics and Space Administration). Then HOMER synthesizes solar radiation values of 8760 hours for each year using the Graham algorithm [16]. HOMER then performs simulations based on the given data to find the most cost efficient and optimized system. Homer also provides the sensitivity analysis to see the impact of each and every factor like wind speed, solar exposure, components longevity and fuel price. It also performs the economic analysis to rank the system based on their Net Present Cost (NPC). Finally, it indicates the most efficient result along with all other possible results. The result contains much important information like capital cost, production cost, repairing/maintenance cost, economic comparison, annual production and graphs.

6.1 Green Energy Source

For a single household we have proposed a 3.3 kWh power generation system using solar panel, battery and converter. Our proposed power generation system is 100% green because there is no emission of carbon-di-oxide and no sound pollution.

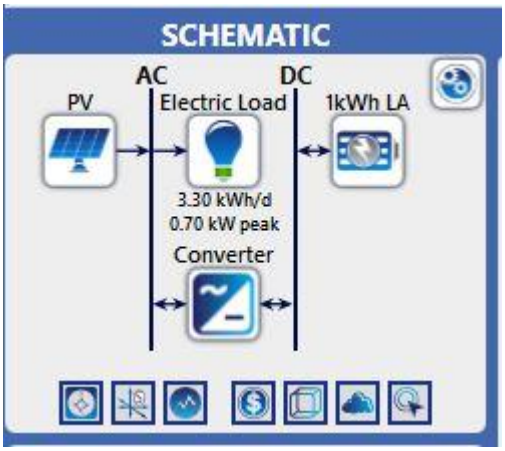


Figure 6.1: Hybrid Green Energy System

6.2 Components and Parameters for Power Generation Simulation using Solar Energy and PV Cell

Table 3: Appliance for Single Household (Summer)

Appliance Type	Capacity in watt	Duration Of use	Consumption	
			Daily	Monthly
Water pump	360 W	20 min/day	108W	3.24 kWh
Refrigerator	150 W	24 hours/day	3600W	108 kWh
Oven	2150 W	20 min/day	645W	19.35 kWh
Air Condition	1000 W	8 hours/day	8000W	240 kWh
Light (12)	20 W	6 hours/day	1440W	43.2 kWh
Fans (3)	40 W	14 hours/day	1680W	50.4 kWh
Washing Machine	500 W	4.5 hours/week	-	9 kWh
Blender	200 W	1.2 hours/week	-	1.06 kWh
Iron	100 W	2 hours/week	-	0.8 kWh
Rice Cooker	200 W	2 hours/week	-	1.6 kWh
Television	150 W	6 hours/day	900W	27 kWh
Laptop	50 W	8 hours/day	400W	12 kWh
				Total = 515.65 kWh

If we take all the power from the solar panel that means to meet the total consumptions of 515 kW from the PV cell then what would be the cost. To calculate the cost, we have simulated in HOMER pro which gives us approximately cost of $48,000. And the simulation result is given below.

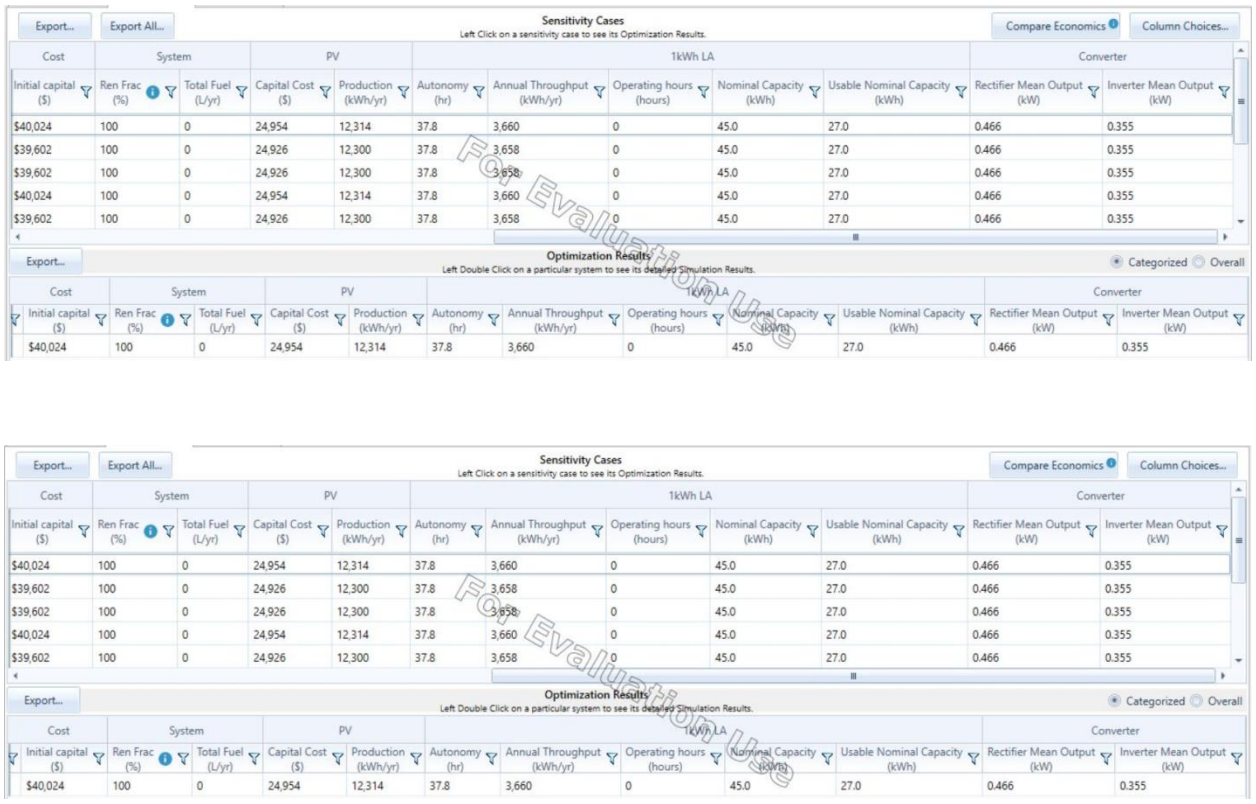


Figure 6.2: Sensitivity Cases & Optimum Results in Homer pro

As from the result we can see that the cost of 515 kW per month energy production will cost around $48,000 which is very expensive. So, we are going to select only basic appliances for affordability.

Table 4: Optimized Load List

Appliances	**Load (Watt/h)**	**Average Work**	**Average Work Hour Per Day**	**Average Power Consumption Per Day**
Light (9)	20	6 hrs./day	6	1.08 kWh
Fan (3)	40	14 hrs./day	14	1.68 kWh
Blender (1)	200	15 min/2 days	0.12	0.024 kWh
Iron (1)	100	30 min/2 days	0.25	0.025 kWh

Rice Cooker (1)	200	30 min/day	0.5	0.10 kWh
Laptop (1)	50	8 hrs./day	8	0.4 kWh
				Total = 3.3 kWh

The above table is about average power consumption per day of home appliances that will be operated on solar energy. Around 9 lights of 20 watt each are in the home. Average working hours of these lights are 6 hours each. So total power consumed by these lights are 1.08 kWh per day. Besides, 3 fans of 40 watt each are being used as 14 hours per day. So, total power consumption of them is 1.68 kWh per day. Along with other loads like blender, iron, rice cooker and laptop the total average consumption per day is 3.3 kWh.

Generic Flat Plate PV Cell

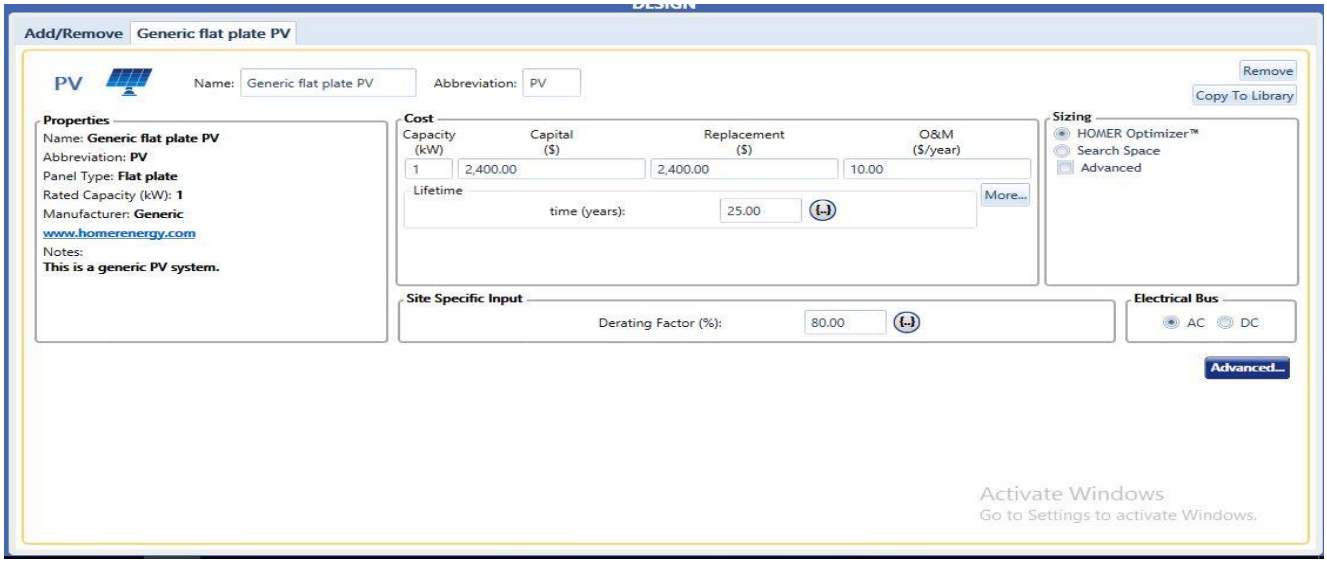


Figure 6.2.1: Generic Flat Plate PV Specifications

Table 5: Cost of PV Cell

No	PV Cost Criteria	Cost
01	Capital Cost	2400 $
02	Replacement Cost	2400 $
03	Operation and Maintenance Cost	10 $ / Year
04	Lifetime	25 Year

05	De-rating Factor	80%
06	Tracking System	No

This chart shows us the PV module cost and its maintenance cost we have proposed in our project. The capital cost is 2400 $ and its replacement cost is also same in 25 years running tenure. There is no tracking system but for operation and maintenance, around 10$ approximately will be needed per year [17].

Solar Panel Benefits

- Equipment's longevity
- Hardly any servicing hassles
- Magnificent investment come back
- Security and alternatives guaranteed
- Smarter and easier to use
- Proper installation and service
- Peace of mind from the time lock home to the time come back

Therefore, a smart home automation system powered by solar energy doesn't just think and advice, but also assures of many rewarding and joyful advantages.

Converter

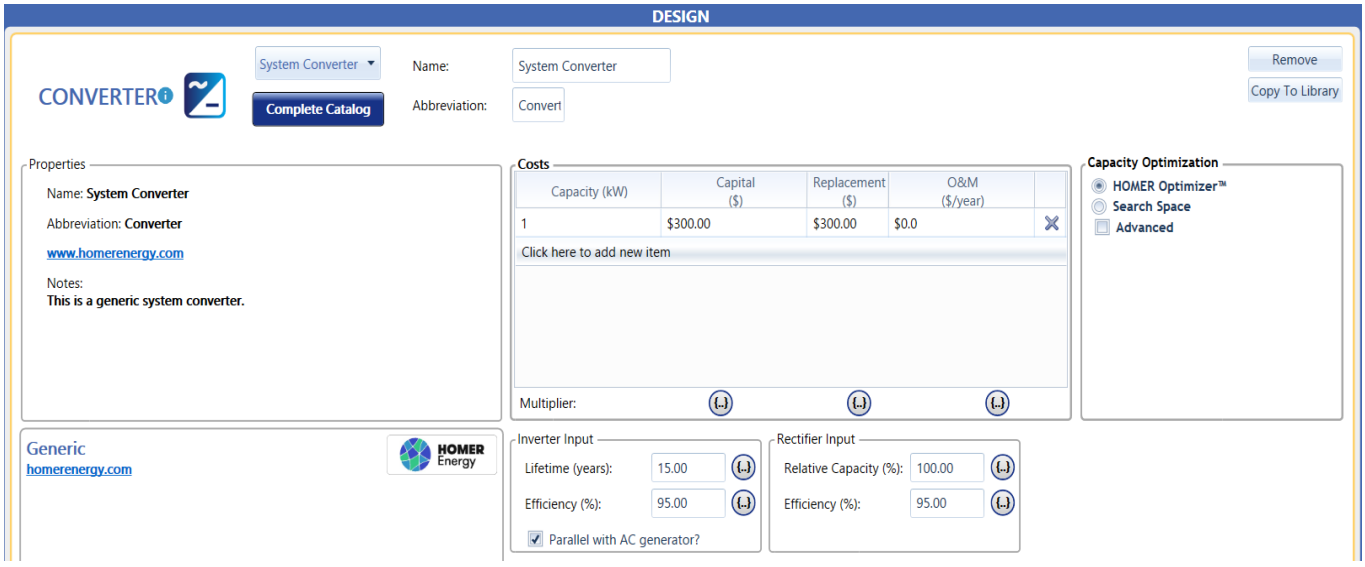


Figure 6.2.2: Converter Cost and Specifications.

Table 6: Cost of Converter for PV Cell

No	Converter Cost Criteria	Cost
01	Capacity	1 kW
02	Capital Cost	300 $
03	Replacement Cost	300 $
04	Lifetime	15 Years
05	Efficiency	95%
06	Relative Capacity	100%

We also need a converter in this system to operate the total power consumption flow smoothly. This converter has 1kW capacity with 100% relative capacity. Around 95% efficiency can be gotten from these 15 years lifetime converter. Only 300 $ is needed with a replacement cost of same to purchase this converter.

Battery

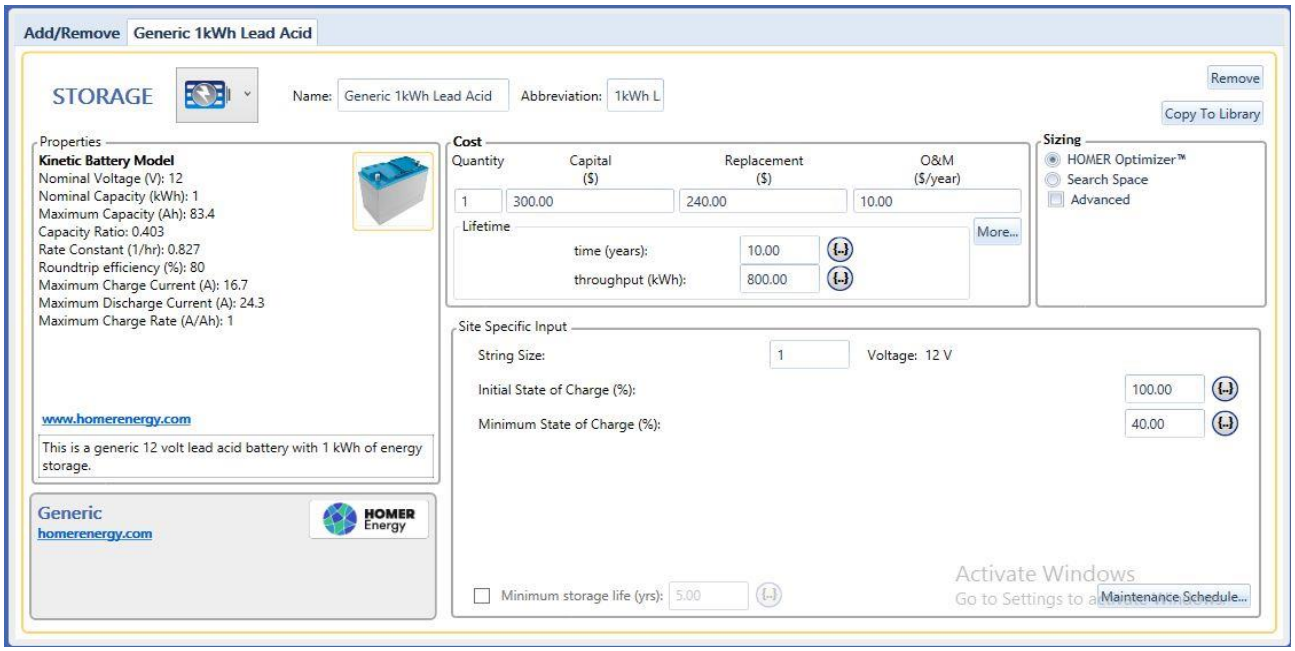


Figure 6.2.3: Generic 1kwh Lead Acid Battery Specifications.

Table 7: Cost of Battery for PV Cell

No	Battery Features	Cost
01	Nominal Voltage	12 V
02	Nominal Capacity	1 kW/h
03	Maximum Charge Current	16.7 A
04	Round Trip Efficiency	80%
05	Minimum State of Charge	40%
06	Capital Cost	300 $
07	Replacement Cost	240 $
08	Operational and Maintenance Cost	10 $/ Year
09	Lifetime	10 Years

To operate the whole system, we must need a battery with a nominal voltage of 12V and capacity of 1kW per hour. Maximum current charged here is 16.7A almost. The round-trip efficiency of this battery is 80%. Here, 300$ is the capital cost of this 10 years lifetime battery with a replacement cost of 240 $.

Electric Load Profile

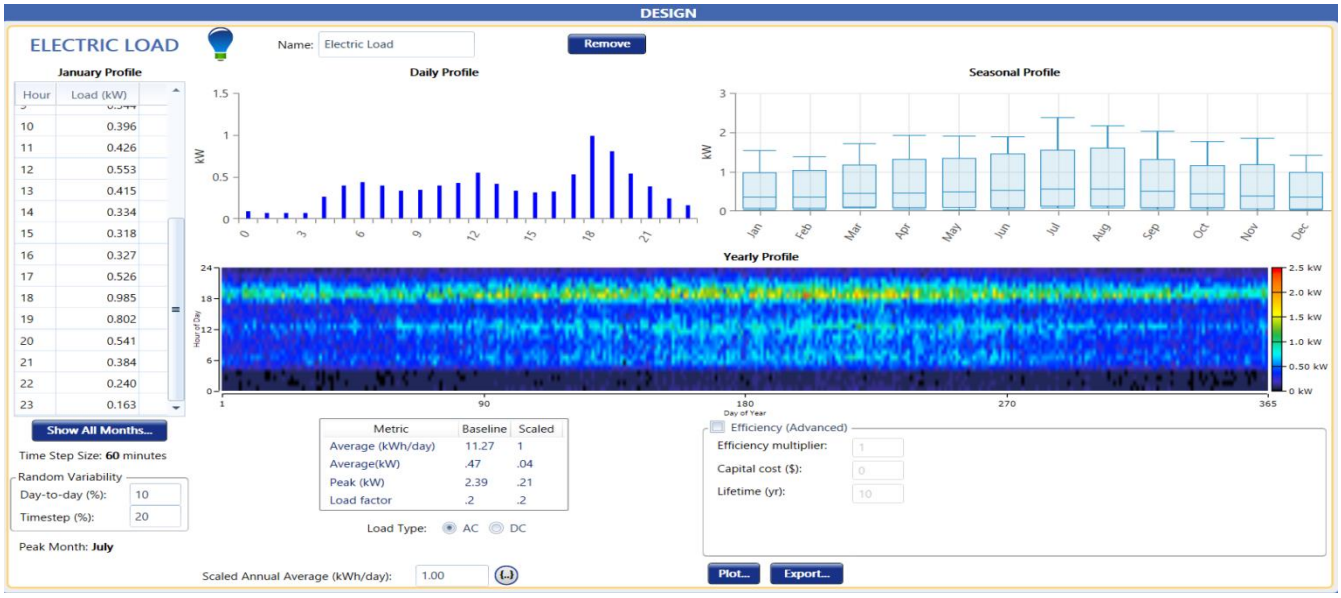
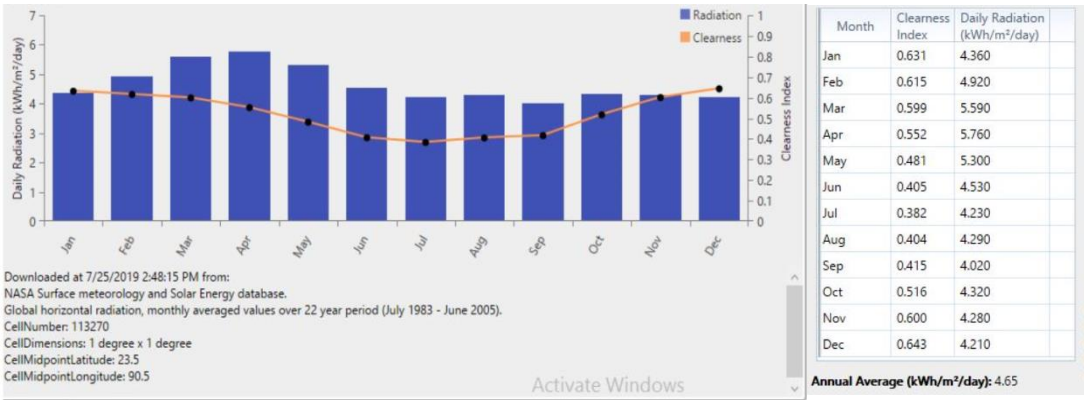


Figure 6.2.4: Electrical Load Profile.

Here, average load is 11.27 kWh per day and the peak is 2.39 kWh at the month of July. From the monthly profile we see that average load per hour is 0.47 kW and from the daily profile we see that the peak load is 1 kWh at 6 PM.

Solar Radiation Index



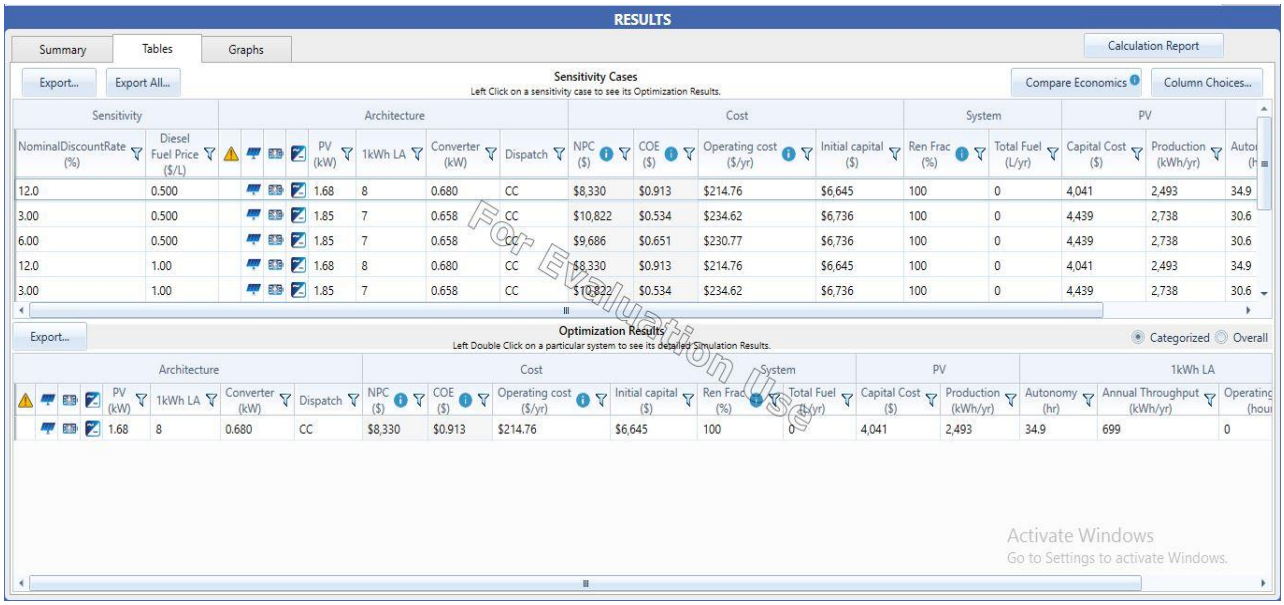
Month	Clearness Index	Daily Radiation (kWh/m²/day)
Jan	0.631	4.360
Feb	0.615	4.920
Mar	0.599	5.590
Apr	0.552	5.760
May	0.481	5.300
Jun	0.405	4.530
Jul	0.382	4.230
Aug	0.404	4.290
Sep	0.415	4.020
Oct	0.516	4.320
Nov	0.600	4.280
Dec	0.643	4.210

Annual Average (kWh/m²/day): 4.65

Figure 6.2.5: Monthly Solar Radiation Index

Homer downloaded solar radiation value from NASA Surface meteorology and solar energy database [16]. It took monthly averaged values of global horizontal radiation over 22 year period (July 1983 – June 2005). And the average daily radiation is 4.65 kWh/m^2/d.

Simulation Results



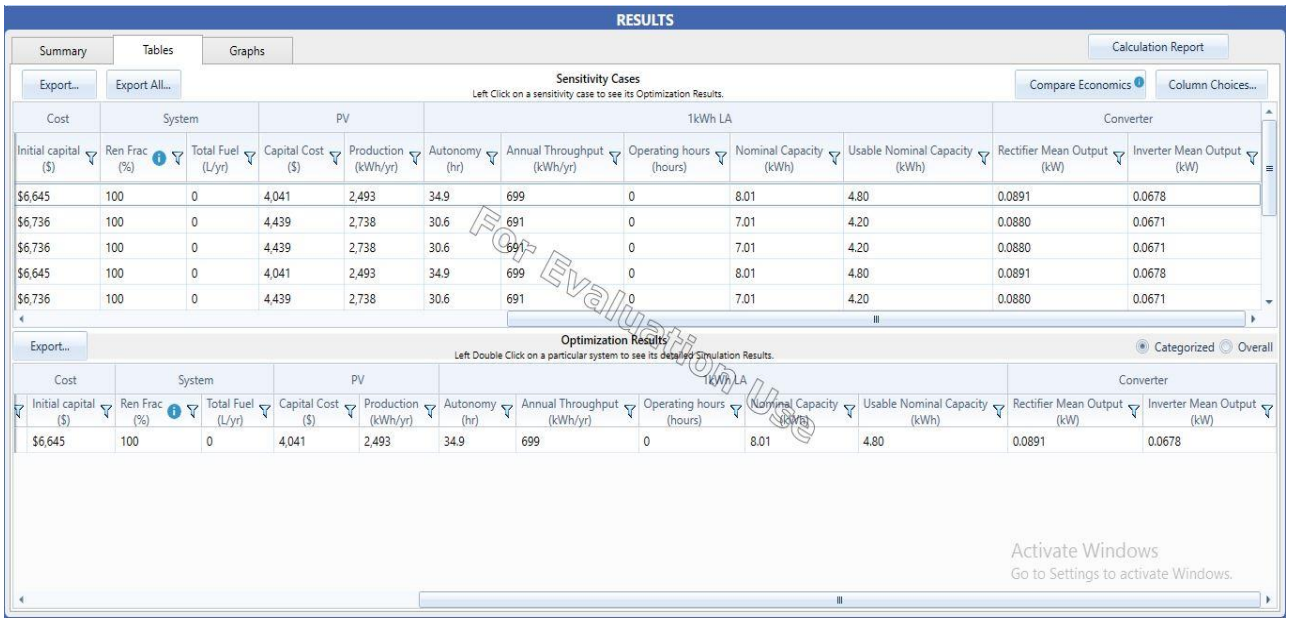


Figure 6.2.6: Sensitivity Cases and only Optimum Results.

From the simulation result we can see that the first one is the lowest cost system with Net Present Cost (NPC) of $8330 and initial capital of $6645 will be needed.

6.3 Graphical Results

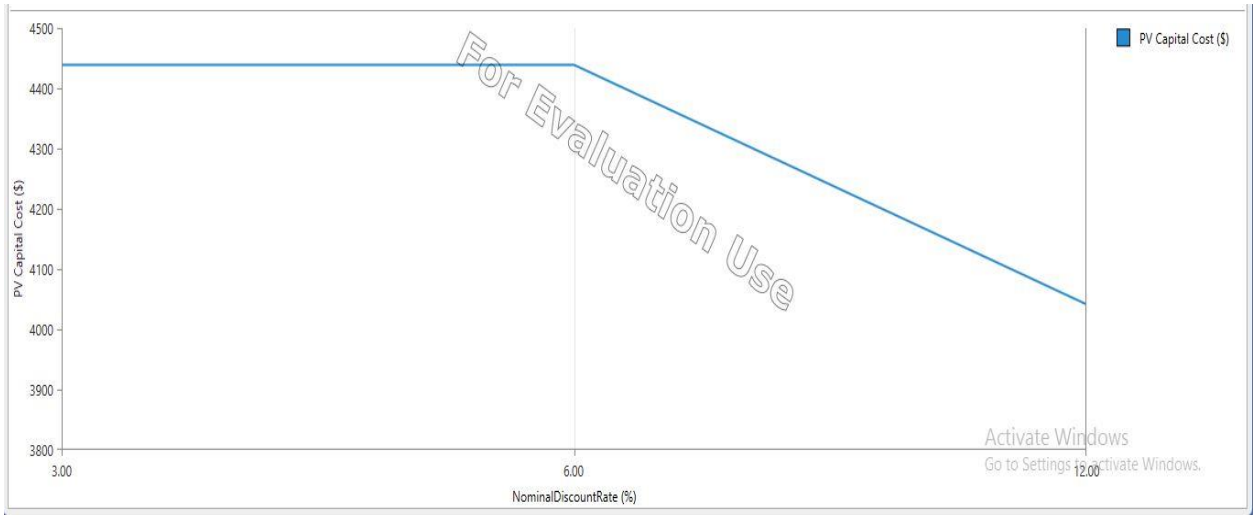


Figure 6.3.1: PV Capital Cost Vs Nominal Discount Rate Plot

From the plot we can see if the nominal discount rate is 6% then the PV capital cost will be $4440. If the nominal discount rate is 12% then the PV capital cost will be around $4000.

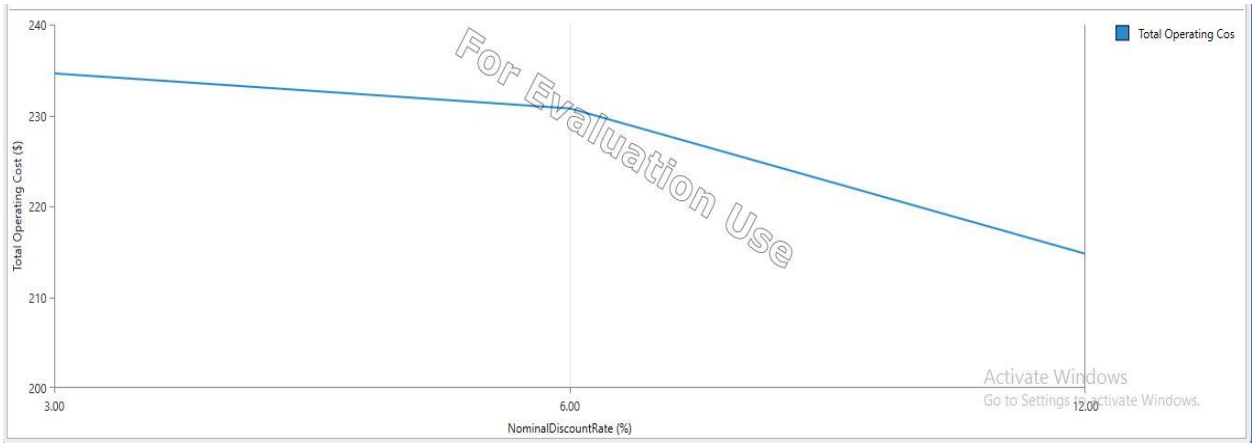


Figure 6.3.2: Total Operating Cost Vs Nominal Discount Rate Plot

If the nominal discount rate is 6% then the total operating cost will be around $235 and if the nominal discount rate is 12% then the total operating cost will be around $215.

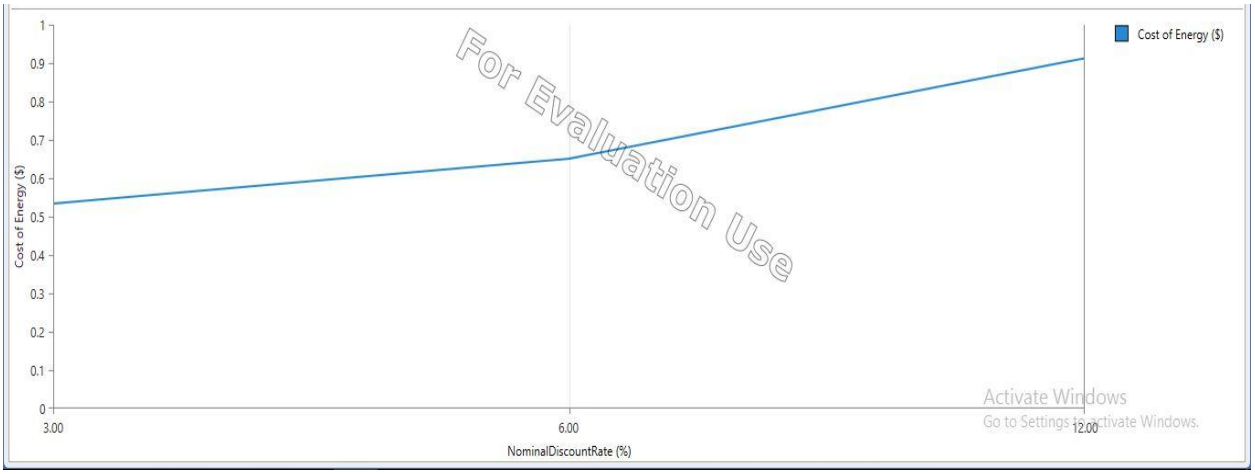


Figure 6.3.3: Cost of Energy Vs Nominal Discount Rate Plot

For nominal discount rate of 6% cost of energy will be around $0.6 and for a nominal discount rate of 12% the cost of energy will be $0.8.

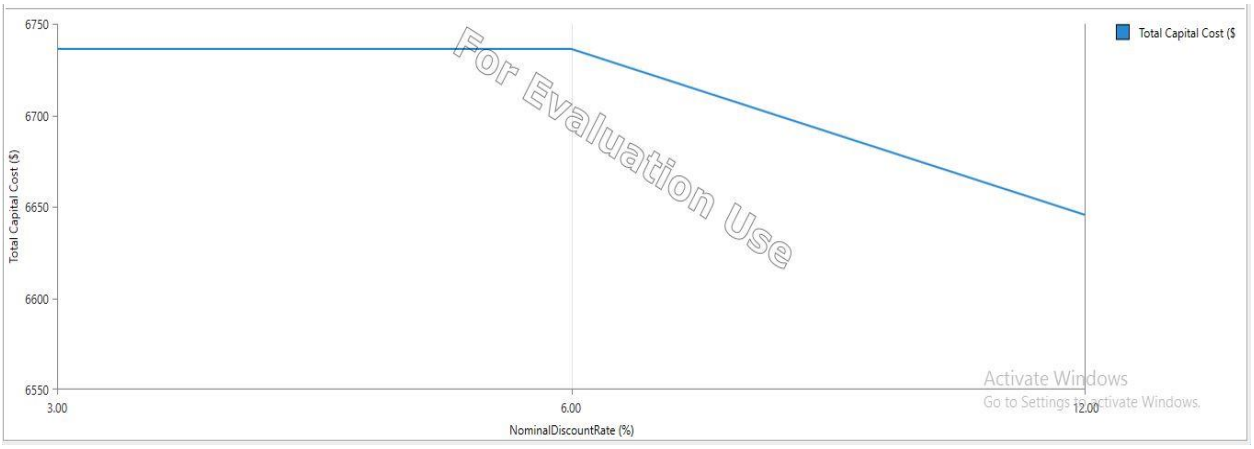


Figure 6.3.4: Total Capital Cost Vs Nominal Discount Rate Plot

Here, for 6% nominal discount rate system's total capital cost will be around $6740 and for 12% nominal discount rate system's total capital cost will be around $6650.

Table 8: PV Cell Generated Power Consumption Utilities

Appliance type	**Capacity in watt**	**Daily Consumption**	**Monthly Consumption**	
			Summer	**Winter**
Light (9)	20 W	1.08 kWh	43.2 kWh	43.2 kWh
Fan (3)	40 W	1.68 kWh	50.4 kWh	4.8 kWh
Blender	200 W	0.35 kWh	1.06 kWh	1.06 kWh
Iron	100 W	0.26 kWh	27 kWh	27 kWh
Rice cooker	200 W	0.53 kWh	1.6 kWh	1.6 kWh
Laptop	50 W	0.4 kWh	12 kWh	12 kWh
	Total =	**3.28 kWh**	**135.26 kWh**	**89.66 kWh**

As, the approximate desired power is 3.28 kWh in a day of summer, we have simulated a system that can provide 3.3 kWh per day. In a day of winter, the approximate desired power will be less than 3.3 kWh. So, the system power 3.3 kWh per day in winter will be enough. With this system installed in one-month total supplied power will be around 103 kWh.

Chapter 07

Management and Scheduling

7.1 Energy Management

The system of home energy management (HEMS) framework is an innovation stage involved both equipment and programming that enables user to look after power use and generation and to physically control and additionally computerize the utilization of electricity inside a homey [18]. HEMS the board frameworks are touted as the astute approach to comprehend and control the power expenses and outflows. Electricity management in effective homes is instrumental in sparing nature. They likewise help the owner set aside critical measures of cash by diminishing power use and giving various different advantages. By keeping register and trace of the progressions of power in the home utilizing equipment introduced in the property and programming associated through the web. Operator associate and communicate with it by means of an online interface or through an application.

The genuine investment funds are with the enormous high electric load burdens like cooling, high temp water warming and pumping water and this is the thing that the framework can screen precisely. The measurement of heavy use stuff enables to improve when utilizing it, timing the utilization of the electricity to get the best rates. HEMS can assist families with sun-oriented PV frameworks set aside extra cash by programming their framework to run certain apparatuses when the sun is sparkling. Families with enormous burdens and sunlight-based PV have more open doors for controlling their energy use.

7.2 Power Behavior Counselor

Deciding how much power apparatuses and home gadgets use can enable to see how a lot of cash are spending to utilize them. Utilize the data beneath to evaluate how much power a machine is utilizing and how much the power costs so that anyone can choose whether to put resources into a more energy effective apparatus. The amount utilizes a machine each day; anyone can generally gauge the quantity of hours it runs. It might be down to earth for anyone to keep a use log for certain machines. These helps you get where and when utilize the most electricity, enabling anyone to create procedures to lessen electricity use and expenses [19]. Intelligent apparatuses don't simply mood killer during times of pinnacle power request - rather, they utilize unobtrusive approaches to move energy use. Anybody won’t notice about it. For instance, forced air conditioning system may run somewhat less frequently. On the other hand, cooler may defer its defrosted cycle until the middle of the night. On the off chance that your utility charges lower rates for power during the evening, likewise called time sensitive rates, could save money on service bill.

Such changes might be unnoticeable to you, however could signify critical reserve funds for utility; investment funds that can be imparted. Utility supplier can disclose about to increasingly the accessibility of savvy matrix advances and time sensitive power rates in general vicinity and how it can be profited. Anybody can set aside cash and energy at home by picking energy proficient apparatuses and gadgets and diminishing the sum to use them. Investigate the accompanying themes to lessen the electricity use and bills. To help decrease the pinnacle influence requests and set aside cash, numerous utilities are presenting programs that urge the user to utilize power during off-top hours. The projects pass on the reserve funds to the user through refunds or decreased power rates. Such project may charge the genuine expense of intensity at any one time, extending from high costs during times of apex request to low costs during off-top hours. The influence use to off-top occasions these projects can set aside cash while helping the utility.

7.2.1 Energy Efficient Home Automation Advantages

- Focus on improving implementation, no additional structured wiring required.
- Consider the replacement, system scale and simple expansion
- Look for the device that are energy effective
- Don’t over the use of equipment
- Consider taking solar panel energy
- Timeframe energy efficient assessment
- Shady conservation of plants
- Minimize consumption of energy
- The artistic advantages attributable to big areas
- Web server integration based on the automation scheme is feasible anywhere and at any moment [20].

To consume electrical power efficiently we must choose when to consume from the solar power and when to consume from national grid. First the system will check whether there is solar power available or not. If it is available then the controller will switch the entire low load’s connection to the solar power. If solar power is not available then the controller will check whether it is peak hour or not. If it is not peak hour then the controller will switch the entire low load’s connection to the national grid. But if it is peak hour then the controller will switch off the direct national grid supply line from the low loads and shift to another relay which is connected to the low loads but not directly. That means there will be manual switches in between the relay and the low loads. In this peak hour’s user will manually switch on or off the low loads by pressing the manual switches according to their own needs.

Algorithm 1 Power source selection

Require: incoming voltage signal from voltmeter and real time from DS-3231

```
Battery voltage = incoming voltage value from voltmeter
time = incoming DS-3231 value
if (Battery voltage ≤ 120V) then
    return 5V to the relay of national grid to low loads
else
    if (18.00 ≤ time ≤ 23.59) then
        return 5V to the relay of solar power to low loads
    else
        return 5V to the relay of national grid
    end if
end if
```

7.3 Calculation of Power Outlay and Cost

The estimate of HEM is determined based on their ability and the length or recurrence of utilization.

Everyday consumption calculation process:

$$\frac{\text{power rating in watt} \times \text{daily use hour per day}}{1000} = \text{Daily Consumption in kilowatt-hour (kWh)}$$

Everyday consumption cost calculation process:

Daily Consumption (kWh) × utility rate = Daily consumption cost

Monthly consumption calculation process:

Daily Consumption (kWh) × no of day use per month = Monthly Consumption in kilowatt-hour (kWh)

Monthly consumption cost calculation process:

Monthly Consumption in kilowatt-hour × utility rate = Monthly consumption cost

Yearly consumption calculation process:

$\frac{number\ of\ used\ hours \times \text{no of days used per year} \times \text{power rating}}{100}$ = Yearlong consumption in kilowatt-hour (kWh)

Yearly consumption calculation process:

Annual Consumption (kWh) × utility rate = Yearly consumption cost

Table 9: Home Appliances Monthly Consumption Rate (Summer)

Appliance Type	Capacity in watt	Duration Of use	Consumption	
			Daily	Monthly
Water pump	360 W	20 min/day	108W	3.24 kWh
Refrigerator	150 W	24 hours/day	3600W	108 kWh
Oven	2150 W	20 min/day	645W	19.35 kWh
Air Condition	1000 W	8 hours/day	8000W	240 kWh
Light (12)	20 W	6 hours/day	1440W	43.2 kWh
Fans (3)	40 W	14 hours/day	1680W	50.4 kWh
Washing Machine	500 W	4.5 hours/week	-	9 kWh
Blender	200 W	1.2 hours/week	-	1.06 kWh
Iron	100 W	2 hours/week	-	0.8 kWh
Rice Cooker	200 W	2 hours/week	-	1.6 kWh
Television	150 W	6 hours/day	900W	27 kWh
Laptop	50 W	8 hours/day	400W	12 kWh
				Total = 515.65 kWh

Monthly Power Expenditure Cost:

Total monthly Power consumption = 515.65 kWh

In a residential purpose according to DESCO for 401 to 600 units of electricity cost is 9.30 taka/ unit [21].

So, per month current consumption = 516 kWh × 9.30 taka/unit = 4798 Tk.

Table 10: Home Appliances Monthly Consumption Rate (Winter)

Appliance Type	Capacity in watt	Duration Of use	Consumption	
			Daily	Monthly
Water pump	360W	1.5hour/week	108W	3.24 kWh
Refrigerator	150W	24 hours/day	3600W	108 kWh
Oven	2150W	20 min/day	645W	19.35 kWh
Air Condition	1000W	-	-	-
Light (12)	20W	6 hours/day	1440W	43.2 kWh
Fans (3)	40W	4 hours/day	160W	4.8 kWh
Washing Machine	500W	4.5 hours/week	-	9 kWh
Blender	200W	1.2 hours/week	-	1.06 kWh
Iron	100W	2 hours/week	-	0.8 kWh
Rice Cooker	200W	2 hours/week	-	1.6 kWh
Television	150 W	6 hours/day	900W	27 kWh
Laptop	50 W	8 hours/day	400W	12 kWh
				Total = 230.05 kWh

Monthly Power Expenditure Cost:

Total monthly Power consumption = 230.05 kWh

In residential purpose, according to DESCO for 201 to 300 units of electricity cost is 5.70 taka/ unit [21]. So, per month current consumption = 230 kWh × 5.70 taka/unit = 1311 Tk.

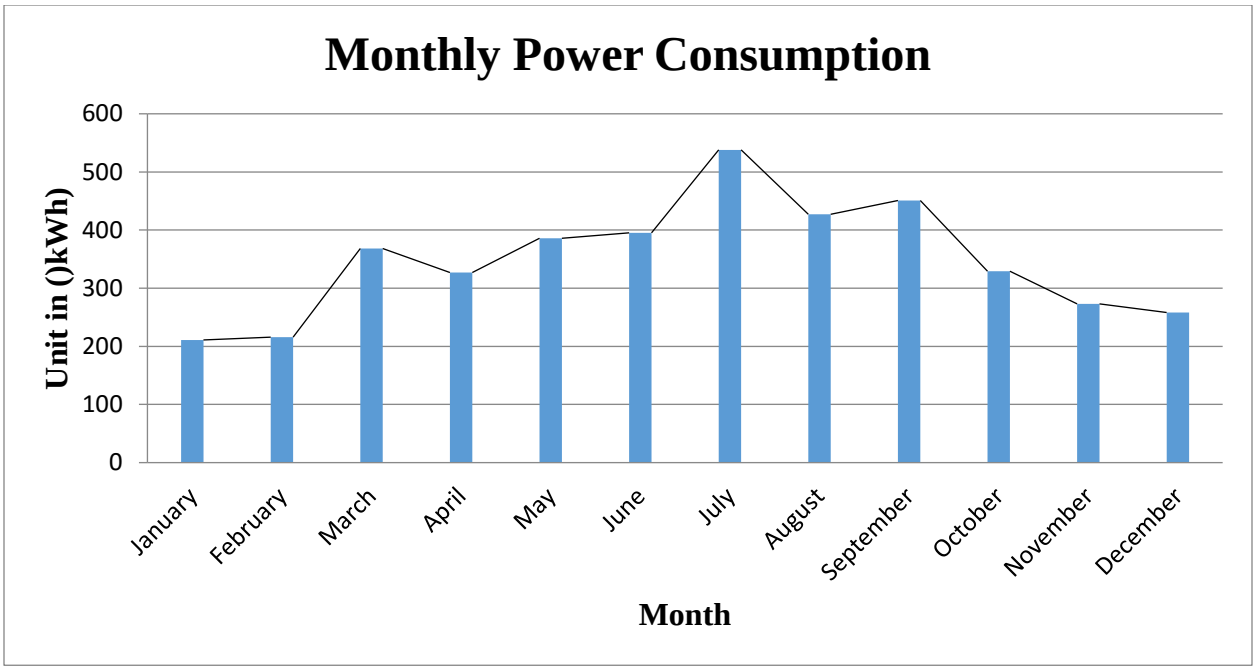


Figure 7.3.1: Monthly Power Consumption

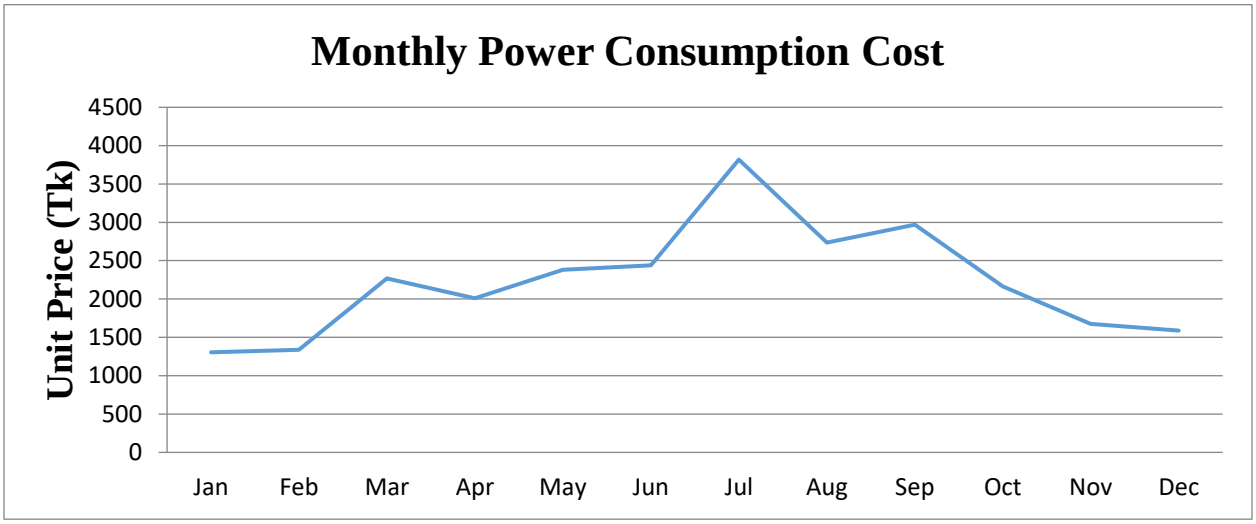


Figure 7.3.2: Monthly Power Consumption Cost

Table 11: Saving Based on Scheduling and Automation

Appliance Type	Schedule based on	Duration use	Consumption	
			Daily	Monthly
Water pump	Peak-off peak price& automation	10 min/ Day	72 W	2.16 kWh
Air Condition	Temperature	4 hour/Day	4000 W	8 kWh
Light (3)	Presence of human & intensity	1 hour/Day	60 W	1.8 kWh
Washing Machine	Peak-off peak price	1 hour/3 Days	170 W	1.7 kWh
Iron	Peak-off peak price	30 min/3 Days	400 W	4 kWh
				Total = 17.66 kWh

7.4 PV Cell Solar Energy

With the assistance of charging batteries, the solar panels are used in our project to provide renewable energy. Now that we have seen how beautifully solar energy solves human energy requirements, let us know what alternatives for home automation can be based on solar energy. Solar automation technologies are smarter than ever before! Consider this situation, for instance. Daytime you want to operate your laundry machine. But when the solar energy per unit would be lower, the smart washing machine will advise you and suggest that you load the dishwasher at that time.

Not only these, you also have an extensive list of home alternatives that can be fully automated with solar power. So what else would be more likeable than solar energy if you were looking for an energy resource to power your home automation? Solar power therefore becomes a sustainable source of energy to meet people's energy requirements. This is what forms the key idea in home automation of solar energy.

Table 12: Power Consumption Comparison & Financial Saving

Type	Summer	Winter
Normal grid	516 kWh	230 kWh
With Automation	498 kWh	212 kWh
With PV Cell	380 kWh	140 kWh
With PV Cell + Automation	363 kWh	123 kWh

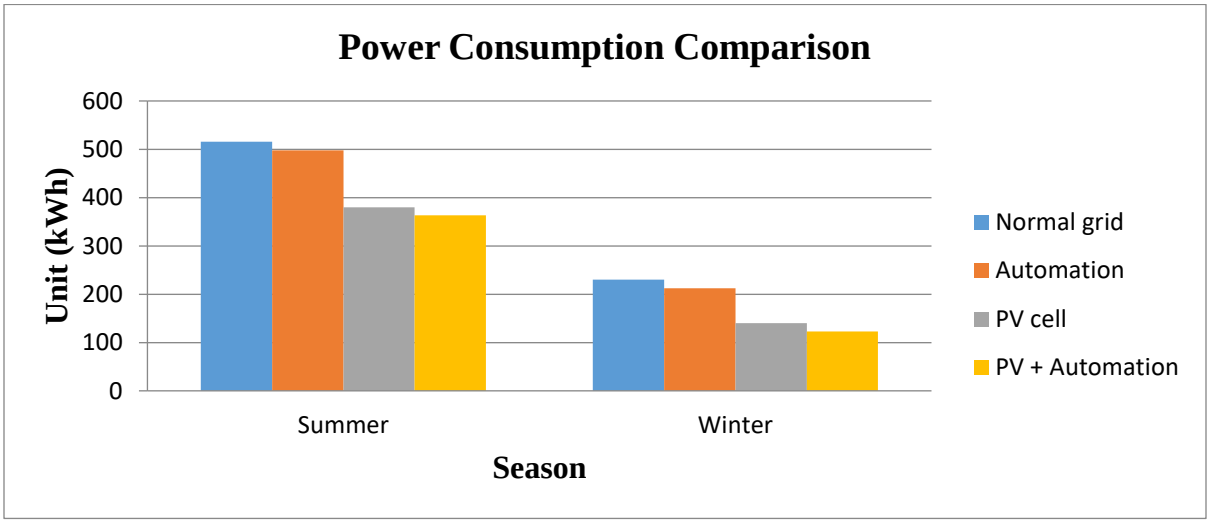


Figure 7.4.1: Power Consumption Comparison

From the above data, it can be seen easily that we can reduce the power consumption of the national grid by using PV Cell+ Automation. In summer, the power consumption reduces around (516-363) = 153 kWh when in winter, it reduces almost (230-123) = 107 kWh. So by this observation, it is not only visible that our power consumption is getting lower or we can get financial benefit, but also, there is another benefit we can get.

According to DESCO of Bangladesh, there are different payment rates for per unit electricity. For example if a user uses more than 100 kWh per month, then the electricity bill of that user will come according to 5.45 taka/per kWh. Like that, there are different rates for more than 200, 300 unit consumption. For more than 500 units in household or apartments, the rate is 9.30 taka per unit [22]. So, if the total consumption reduces after automation and PV Cell using, then the rate of per unit also decreases.

Table 13: Energy and Expense Comparison for Summer

Criteria	Unit (kWh)	Per unit cost (Tk)	Cost (Tk)
Normal	516	9.30	4798
Automation + PV	363	6.02	2186
Save	153		2612

In this above case for summer season, per unit for per kWh price decreases to 6.02 taka from 9.30 taka because of reduction of total power consumption usage. That's why the total cost we can reduce is around 2612 taka by taking all the consumption as an average use.

Table 14: Energy and Expense Comparison for Winter

Criteria	Unit (kWh)	Per unit cost (Tk)	Cost (Tk)
Normal	230	5.70	1311
Automation + PV	123	5.45	671
Save	107		640

Again for winter, per unit rate decreases to 5.45 taka from 5.70 taka as total consumption reduces to 123 kWh from 230 kWh. So, for 107 kWh savings for automation and PV Cell, the cost reduces around 640 taka.

So, this implies that when user chooses solar-powered home automation alternatives, every time he/she uses it, gets benefit right from the start. Besides, user will get benefit in so many distinct ways if he/she opts for such solar powered home automation alternatives.

Chapter 08

Goal & Uniqueness

8.1 Goal

The basic most vital goal of home automation is to ensure amenity of user time and making life simpler even if guided us to frugal of electricity. The importance here is on objectives; for each smart thing automation project, they are distinct. However, epiphany during the construction that home mechanization without sensationalizing it can stabilize our daily lives. There was a lengthy method of gradual reasoning, where in hypothesis it was checked whether all that does something in house cloud or should be automated. Architecture is coming up the first step before jumping into intervention. During the real execution of any scheme a lot of rework needed such as a home mechanization system. We inaugurated the system by keeping some questions in mind which are -

- Which type of appliance should I want to govern
- Is this governance should have specific access use only or not
- Is the cost being a solicitude
- Is the vigilance important
- Can it be possible for installing for myself?

8.1.1 Established Goals

First, we assembled a system consisting of controlling-unit, web server and internet connection. Then, we will create a webpage and upload it to the web server. Uploaded web page will be the user interface for the following's goals.

1. Controlling all loads
2. Monitoring all load’s power consumption
3. Calculating total power consumption
4. Providing time varying electricity price and suggestion regarding the price
5. Scheduling some loads when total power consumption excides peak value

8.1.2 How any Client gets benefited from our Established Goal

The client’s automation purpose is to reset their demands as to how they spend their time. This can be accomplished by:

a. Faster response time when there is a haul
b. The sense of personalization
c. Timely monitoring
d. Future demands and investigation

How automated home is, it doesn't count, unless it offers a valuable experience to them.

8.2 Uniqueness

8.2.1 Simplicity and Ingenuousness

Simplicity is a significant consideration, although it is difficult to accomplish. However, it is enormously complex quite convoluted to be resolute interfaces. Automation is the main focus, along with generating green energy through PV sell this implies the automation system does what is desired or needed effectively and efficiently, only initiating human influence messages.

8.2.2 Usability

Anyone can use this system such as a nonprofessional individual can be capable to use it in a definite broaden and also arrange the system without console screen. In addition, because of having ingenuousness of the system can only see a indisputable form an functional prospect else from a structural prospect. The access of web page and operating appliances for any task is suitable. There is no complex situation programmed to work the system functionally.

8.2.3 Affordability or Economical

If not hundreds of thousands of bucks, a domestic home automation will cost huge. Household automation with only a very few appliances controlled, a single-family home management scheme will readily surpass 850,000 Tk. Nobody wants to spend such much cash on sensors, actuators or parts of home automation in particular. The home improvement path was completely viable based on electronics and engineering hence the path short listed.

8.2.4 Efficiency

Though energy consumption is a significant factor in the functioning of a home automation scheme, some preconditions are almost compulsory. As we are constructing a fresh home, by constructing the residence from the beginning, we have left no question unanswered to discover efficiency improvements. Most of our lighting is LED-based and energy-efficient after automation. Timer, incident, intensity as well as transient triggers will continue to use these lights. After automation we be focusing on generate green energy to save energy consumption

from main grid and as well as nature. The generating green energy power will work on the basic components. In such manner we save extra energy consumption cost and nature.

8.2.5 Undo Ability

Because of having it undo ability feature user can easily change or add any home appliance to be monitored. This system will allow or install appliances by themselves easily with all the apparatus connected directly through electricity. As this system automated lights, hardly any people have seen such home without having light switches. The system should be exchangeable with a conventional electrical installation without changing the cabling.

Chapter 09

Conclusion

9.1 Summary

This project depicts the home energy management by using systematic usages of home appliances in a smart home. It is a novel proposed model which we implemented at minimum cost system to determine an authentic smart home by using its intelligent management of home appliances in efficient manner. Home mechanization framework includes a lot of system and diverse technology.

Home customization innovation looks to decrease your worry by guaranteeing your house is secure notwithstanding when you are far away. It is additionally intended to lessen the measure of exertion you put each day into running your family so you can concentrate more on yourself and the general within it. Envision if your home could naturally set aside save you cash, time and exertion. With a large number of these effectively settled and effectively improving frameworks, these aspirations are conceivable.

We accomplished this project into two steps through the utilization solar power beside grid line in skillful way and a user friendly dedicated authentic webpage to monitor and operate the apparatus that will make busy life more pleasant and hassle free.

The leading goal of this project is to use home energy in efficient form by abating unnecessary energy waste, money and improve a user-friendly home appliance management. The efficiency of cost management system in this project inferior enough compared to any other automatic method available in market. Additionally, we also implement a different type of appliances in this circuit. It will help to operate household smoothly.

They need a framework that is strong and keeps running as one unit that issues directions that are astute and appropriate for the home owner a way of life without them saying it. Regardless of whether through one-time programming or by figuring out how to examine movement and follow up on its own, these projects are worked in light of the client. Keen home frameworks will just proceed to develop and turn out to be further developed. Numerous devices and frameworks are intended to either mix in with the environment or even stand out as an announcement piece. So, while shrewd home frameworks may set aside some effort to comprehend and ace, they will, and as of now are, making life simpler.

9.2 Future Research

As the innovation for savvy homes keeps on advancing, the scope of capacities is just going to grow. Right now, home customization is proceeding to evolve. In future things have taken ordinary assets and transformed them into computerized gadgets, to catch data about your own utilization propensities and adjust to them. Homes of things to come might just accompany shrewd home highlights worked in, considering the rate at which these advances are being formed and incorporated into our regular day to day existences. However, a few people might need to establish and further redo home mechanization gadgets by themselves.

Bibliography

[1]. Evans, D. (2011). The internet of things: How the next evolution of the internet is changing everything. *CISCO white paper*, *1*(2011), 1-11.

[2]. Buyya, R., Broberg, J., & Goscinski, A. M. (Eds.). (2010). *Cloud computing: Principles and paradigms* (Vol. 87). John Wiley & Sons.

[3]. Xiong, G., Chen, C., Kishore, S., & Yener, A. (2011, January). Smart (in-home) power

scheduling for demand response on the smart grid. In *ISGT 2011* (pp. 1-7). IEEE.

[4]. Bharath,S., Pasha, M.Y., & Deepth, J.(2017, April). IoT-Home Automation. *International Journal of Computer Technology and Research*, *5*, 4-6.

[5]. Li, B., & Yu, J. (2011). Research and application on the smart home based on component technologies and Internet of Things. *Procedia Engineering*, *15*, 2087-2092.

[6]. Kim, J. (2016). HEMS (home energy management system) base on the IoT smart home. *Contemporary Engineering Sciences*, *9*(1), 21-28.

[7]. Kodali, R. K., Jain, V., Bose, S., & Boppana, L. (2016, April). IoT based smart security and home automation system. In *2016 international conference on computing, communication and automation (ICCCA)* (pp. 1286-1289). IEEE.

[8]. Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A., & Sha, M. (2015). An internet of things framework for smart energy in buildings: designs, prototype, and experiments. *IEEE Internet of Things Journal*, *2*(6), 527-537.

[9]. Jain, S., Kumar, V., Paventhan, A., Chinnaiyan, V. K., Arnachalam, V., & Pradish, M. (2014, March). Survey on smart grid technologies-smart metering, IoT and EMS. In *2014 IEEE Students' Conference on Electrical, Electronics and Computer science* (pp. 1-6). IEEE.

[10]. Zhao, Z., Lee, W. C., Shin, Y., & Song, K. B. (2013). An optimal power scheduling method applied in home energy management system based on demand response. *Etri Journal*, *35*(4), 677-686.

[11]. Haque, K. F., Saqib, N., & Rahman, M. S. (2019, March). An Optimized Stand-alone Green Hybrid Grid System for an Offshore Island, Saint Martin, Bangladesh. In *2019 International Conference on Energy and Power Engineering (ICEPE)* (pp. 1-5). IEEE.

[12]. Singh, R. S. S., Ibrahim, A. F. T., Salim, S. I. M., & Chiew, W. Y. (2009, November). Door sensors for automatic light switching system. In *2009 Third UKSim European Symposium on Computer Modeling and Simulation* (pp. 574-578). IEEE.

[13]. Vaghela, M., Shah, H., Jayswal, H., & Patel, H. (2017). Arduino based auto street light intensity controller. *Invention Rapid: Embedded Systems*, *2013*(3), 1-4.

[14]. Jewel, M. H., Islam, M. N., & Hasan, M. J. (2017). *Automatic Room Light Control Using Bidirectional Visitor Counter and Gas Detection* (Doctoral dissertation, East West University).

[15]. Pavithra, D., & Balakrishnan, R. (2015, April). IoT based monitoring and control system for home automation. In *2015 global conference on communication technologies (GCCT)*(pp. 169-173). IEEE.

[16]. Khadem, T., Billah, S. B., Barua, S., & Hossain, M. S. (2017, September). Homer based hydrogen fuel cell system design for irrigation in Bangladesh. In *2017 4th International Conference on Advances in Electrical Engineering (ICAEE)*(pp. 445-449). IEEE.

[17]. Adhya, S., Saha, D., Das, A., Jana, J., & Saha, H. (2016, January). An IoT based smart solar photovoltaic remote monitoring and control unit. In *2016 2nd international conference on control, instrumentation, energy & communication (CIEC)* (pp. 432-436). IEEE.

[18]. Khan, M., Silva, B. N., & Han, K. (2016). Internet of things based energy aware smart home control system. *IEEE Access*, *4*, 7556-7566.

[19]. Bedi, G., Venayagamoorthy, G. K., Singh, R., Brooks, R. R., & Wang, K. C. (2018). Review of internet of things (IoT) in electric power and energy systems. *IEEE Internet of Things Journal*, *5*(2), 847-870.

[20]. Adila, A. S., Husam, A., & Husi, G. (2018, April). Towards the self-powered Internet of Things (IoT) by energy harvesting: Trends and technologies for green IoT. In *2018 2nd International Symposium on Small-scale Intelligent Manufacturing Systems (SIMS)* (pp. 1-5). IEEE.

[21]. Desco retail electricity price rate, (2019). DESCO. Retrieved from https://www.desco.org.bd/bangla/tariff_rate_b.php

[22]. Mondal, A. H., & Denich, M. (2010). Hybrid systems for decentralized power generation in Bangladesh. *Energy for Sustainable Development*, *14*(1), 48-55.