SOLAR ELECTRIFICATION USING INTELLIGENT ENERGY MANAGEMENT SYSTEM

A Thesis submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

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DEDICATION

This project is sincerely dedicated to

Our prophet
MOHAMMAD [PBUH]
Mercy of all humankind

Our parents

Who have supported and encouraged us throughout the years
&
Our beloved Motherland

DECLARATION

We hereby declare that this thesis is based on our own work and research. To the best of my knowledge and belief, it contains no material previously published or produced by another party in fulfillment, partial or otherwise, of any other degree or diploma at another University or institute of higher learning, except where due acknowledge is made in the text.

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ABSTRACT

Load-shedding is one of the biggest crises in Bangladesh today. Current energy management system calls for reliability and reduction between power supply and demand gaps. Though a huge development is being made in Smart Grid & Smart Metering systems, but with the help of 'Solar Electrification Using Intelligent Energy Management System' we can overcome this power crisis in a smart and efficient way. This System changes the entire traditional power supply system by connecting consumers with each other and giving priority in renewable energy like solar power over national grid. The system is autonomous which is a great update in are of energy management, though it can be manually controlled in case of emergency or special situation. The whole system can by divided into two main parts smart meter and smart server which can automatically measure, calculate, control and distribute electricity according to solar power storage, load requirements, lowering the system loss. As maximum population of our country comes from rural areas, our system has a great future if it can successfully be implemented as designed.

CONTENTS

FIGURES

CHAPTER 1: INTRODUCTION

Solar Electrification Using Intelligent Energy Management System (SEUIEMS) considered by many experts to be the possible panacea to global warming and solution to our future energy problems, consists of a system which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources. Electronic power conditioning and control of the production and distribution of electricity are important aspects of the Intelligent Energy Management System. Using renewable energy for e.g. solar power, the consumer can save a huge amount of money. Therefore, this system is providing an option to the consumer to see the comparison between the electricity expenditure using National Grid only and expenditure using Solar Power along with National Grid. The number of consumers is increasing day by day but the production of electricity is not increasing as expected, as a result load shedding is occurring and in third world country like Bangladesh load shedding is a common incident. In order to prevent load shedding consumers, need to use less electricity and using electricity less than required is quite difficult in this modern era. Hence, it is the undoubtedly the best option to start using renewable energy along with national grid. This system takes the responsibility to control which electric source between national grid and solar power to use according to the demand of the user and energy stored from the solar panel the user possesses. In case of demand being less than the energy stored from solar panel, the user can sell electricity to its neighboring homes. Thus this system is not only giving the user a chance to save money but also an income by selling electricity.

1.1 PROJECT OVERVIEW

The key concept of this project is to build an Intelligent Energy Management System (IEMS) with Solar Electrification, an embedded system which will do the traditional works of Electricity Meters found in households but in addition to this, it will reduce the expense of the consumer by syncing usage of National Grid along with solar power. By doing so the consumer will not only save money but if their solar panels produce more power than their demand then they can even profit from the system financially by selling power to the neighboring homes. This entire process will be controlled by this IEMS. This system will connect a whole city and if possible the whole country can be connected to this system to ensure maximum savings and minimum energy wastage.

This thesis presents a scale model of the IEMS, exhibiting the major functions of it as much as possible, trying to convey an idea about the entire concept of IEMS's functionality.

We are trying to develop a system which requires a manager who will monitor the entire operation of the system. The solar panel that homes possess will produce solar power with the help of the sunlight, converting solar energy into electrical energy, thus, enabling consumers to both buy and sell solar power from/to the homes with similar facilities. This ensures efficient energy management which involves a communication between the buyers and sellers regarding electric power. A consumer can also see his/her energy consumption and usage and also its battery status which contains the amount of solar power produced and ready to be served. In a situation when the consumer is out of solar panel in her home and there are no sellers to sell their extra power, the national grid will come to the rescue which will be connected to every home.

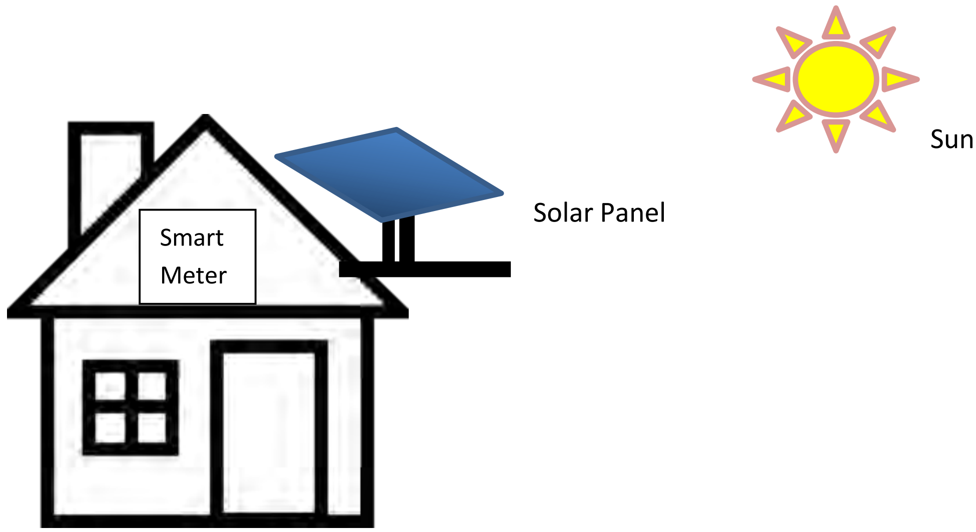


Figure 1: A house connected to Smart Meter and containing Solar panel.

1.2 MOTIVATION

The conventional design of the electrical distribution system in Bangladesh has remained the same in the past many decades. The components of the hierarchical grid have become weary and strained due to increasing electricity demands of the nation [1]. According to the Institute for Energy Economics and Financial Analysis (IEEFA) report, the electricity consumption has risen by an average of 9.7% annually through 11 years to 2015 [2]. Unfortunately, in the midst of increasing dependency on technologies in the modern era, the nation fails to satisfy its people’s growing demands for electricity due to its small, inadequate and not-properly managed energy infrastructure [3]. Electricity is considered to be the major source for most of the economic activities of Bangladesh [3]. According to Ainun Nishat, an educator emeritus at the BRAC University in Dhaka, says for Bangladesh, producing greater power to satisfy the increasing demands of its people should be of paramount issue. "Load shedding is going on even in 2016, which indicates we need to increase production of commercial energy immediately," he emphasized. Monowar Islam, the secretary of the government's power division, calls Bangladesh a "power-hungry country that needs huge amounts of electricity to develop" [4]. However, the problem does not end here. The mismanagement of energy due to using traditional energy infrastructures also leads to emission of greenhouse gases, resulting in the higher rate of global warming, hardware disappointments, frequent blackouts, problems of storing energy, one-sided communication (which reduces energy efficiency), decrease in natural resources such as fossil fuels, and flexibility issues. Intelligent Energy Management System (IEMS) with Solar Electrification seems the most rational and best solution that the nation can implement in order to solve the seemingly 'myriad' of problems relating to energy distribution [1].

1.3 OBJECTIVE

The objective of this project is to build a scale model of Intelligent Energy Management system which is a system that involves exerting a level of control over connected demand and generation in the most efficient and cost effective way. Solar Electrification using Intelligent Energy Management System (IEMS) is a system that involves a better view of the power being supplied and can take care of both the demand and the generation associated with the network along with the network itself. This system conveys power all the more effectively what's more, dependably by, Consequently, re-directing power, moving loads and/or maintaining embedded generation to handle restrains and blackouts on the networking system [5]. Monitoring the condition of network assets and predicting failures, thus reducing maintenance costs [5]. 'Intelligently' dealing with the system to amplify the power disseminated [5]. There are likewise extra advantages this system provides to its buyers. It includes great visibility of the system that permits distributors to identify and handle blackouts all the more rapidly, thereby, diminishing the time buyers are without electricity [5].

1.4 METHODOLOGY

We have divided the whole project in three stages and we will complete each stage respectively.

Stage 1: Smart Server with manual input (keypad representing the Smart Meter)

Stage 2: Smart Server with Smart Meter (or complete System SEUIEMS)

Stage 3: SEUIEMS with Data Logging for a small town

1.4 SCOPE OF WORK

The Solar Electrified Intelligent Energy Management System is mainly proposed for a vast area. But for designing and explaining purpose we assumed only two LED are connected to this system along with two batteries. So the main scope of work with this system is that, we can control the ON OFF of LEDs by this system, we can connect batteries which are representing the solar power storage.

CHAPTER 2: SYSTEM DESCRIPTION

2.1 INTRODUCTION

There are many ways of doing a work and this line applies for this paper too. As technology is growing fast and we have to stay tuned with it we can go for wireless to implement this system. Again there are many people who are not comfortable with using wireless, so we can design the system in traditional wired way too.

2.2 TRADITIONAL WAY

The traditional way of implantation the idea so nothing but designing the system with wires as most of the people are not used to with going wireless especially for this electricity purpose. So in this way we can mainly divide the system in two basic parts SMART Meter and SMART Server. A brief description of these two devices are given below.

2.2.1 SMART METER

SMART Meters are a great replacement of traditional Energy Meters. Traditional Energy Meters were one way communication. Consumers gets electricity from the national grid and pays the bill for their consumption. But by using SMART meters consumers can know how much they are using, how much available and what could be their monthly electricity bill. There are many more applications of SMART Meters which are very interesting and smart too.

2.2.2 SMART SERVER

SMART Server is the brain of this system. It connects all the consumers to itself and controls everything we are going to talk about. We can give the SMART Server any look we desire right now as we are connecting three consumers we are giving some seven segment displays along with switches to control the power on/off.

2.3 CELL AND CLUSTER METHOD

Each home has solar panel installed in it to produce solar power with the help of sunlight. The current, voltage and power factor reading are performed by the smart meter. Moreover, the consumption of power and production of solar power in the battery is also read by the smart meter. The location of that particular home is also provided by the smart meter. The smart meter then provides all this information to the primary server and notifies it to does the computation every time and take decision for the home. The smart meter has a unique name or id for that particular home by which the server identifies it. The solar powered homes are also connected to national grid for crisis or urgent situation.

2.3.1 INSIDE A CELL

In a cell there is a primary server which is connected with the houses inside the cell. The primary server makes decision for the houses located inside the cell. It gets information from the smart server. Primary server also sends information to the main server every time. When a demand for power is created inside the cell between any of the houses but there is no supply of extra battery power from other homes inside the cell, the primary server contacts the main server telling it to fulfill the created demand. The following are the steps a primary server does inside a cell.

1. Enter ID of Home.

2. Read all the information provided by the smart meter of that ID. Example: power consumption, battery status, etc.

3. Calculate Extra Power and hence find out request for selling or request for demand

Extra Power = Battery Status - Power Consumption

4. If there is more power in the battery keep it in Extra Storage and then request for selling is made.

5. If the consumption is more demand exists and request for demand is made.

6. Search for extra storage power from any other home inside the cell and provide it.

7. If there is no available power in any of the home inside the cell to satisfy the existing demand then ask help from the main server.

2.3.2 INSIDE A CLUSTER

The cells are covering the total land area each being in a cluster. Each cluster has a main server. A main server is responsible for taking decision and administering inside a cluster. The cells make communication inside its cluster with the help of main server. A communication is also established between the clusters through the main server. The main server also notifies other clusters about request for selling.

When the main server is unable to fulfill the demand inside its cluster it seeks help from the neighboring main servers of other clusters. The neighboring main servers are connected with one another. By this way the main servers communicate. The following are the steps a main server does.

1. Enter ID of primary server.
2. Take all the information from the primary server.
3. Check if there is any request for demand or any request for selling.
4. If there is request for selling notify the primary servers inside the cluster at first and then to all other neighboring main servers.
5. If there is request for demand search for extra storage in homes in other cells inside the cluster by communicating with the primary servers and provide it.
6. If there is no available power for selling from other cells seek help from the neighboring main servers.
7. If there is no help from the neighboring main servers then provide power from the national grid.

2.4 CONCLUSION

Every time the servers gets notification about request for selling or request for buying if any. The servers also keep all the information required for the whole system to work. The smart meter also notifies the server every time with its ID that it is active and is in use. Moreover, homes can be located as smart meter provides this information as well.

CHAPTER 3: SYSTEM DESIGN

3.1 INTRODUCTION

As we are designing the system for a vast area we have to make sure we keep a space for more consumers to connect with the system otherwise the whole idea of connecting people to use the solar power will be ruined. As we are going with a dual designing approach Traditional and Cell-Cluster method so we have to keep in mind to design openly so that anyone can get connected.

3.2 TRADITIONAL WAY

3.2.1 SMART METER

It is nothing but an upgraded version of traditional electricity meters. This meter has three types of input, three types of output and switching capacity to control the loads connected to the meter. The meter will also have an LCD Display which will show consumption of the consumer and any information the consumer wants to see. The information that the smart meter will collect will also be transferred to Smart Server, as a result the consumer can check those from mobile or PC. This feature makes the meter unique from traditional meters.

Here is the physical outlook of the Smart Meter with Block Diagram which shows the flow of information related to the Smart Meter.

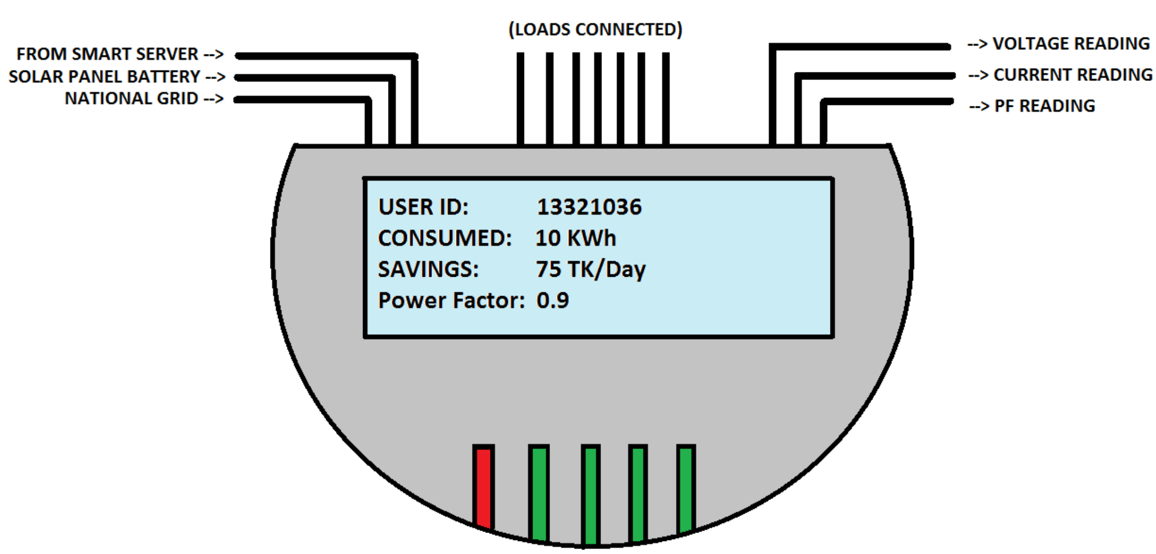


Figure 2: Outlook of the Smart Meter

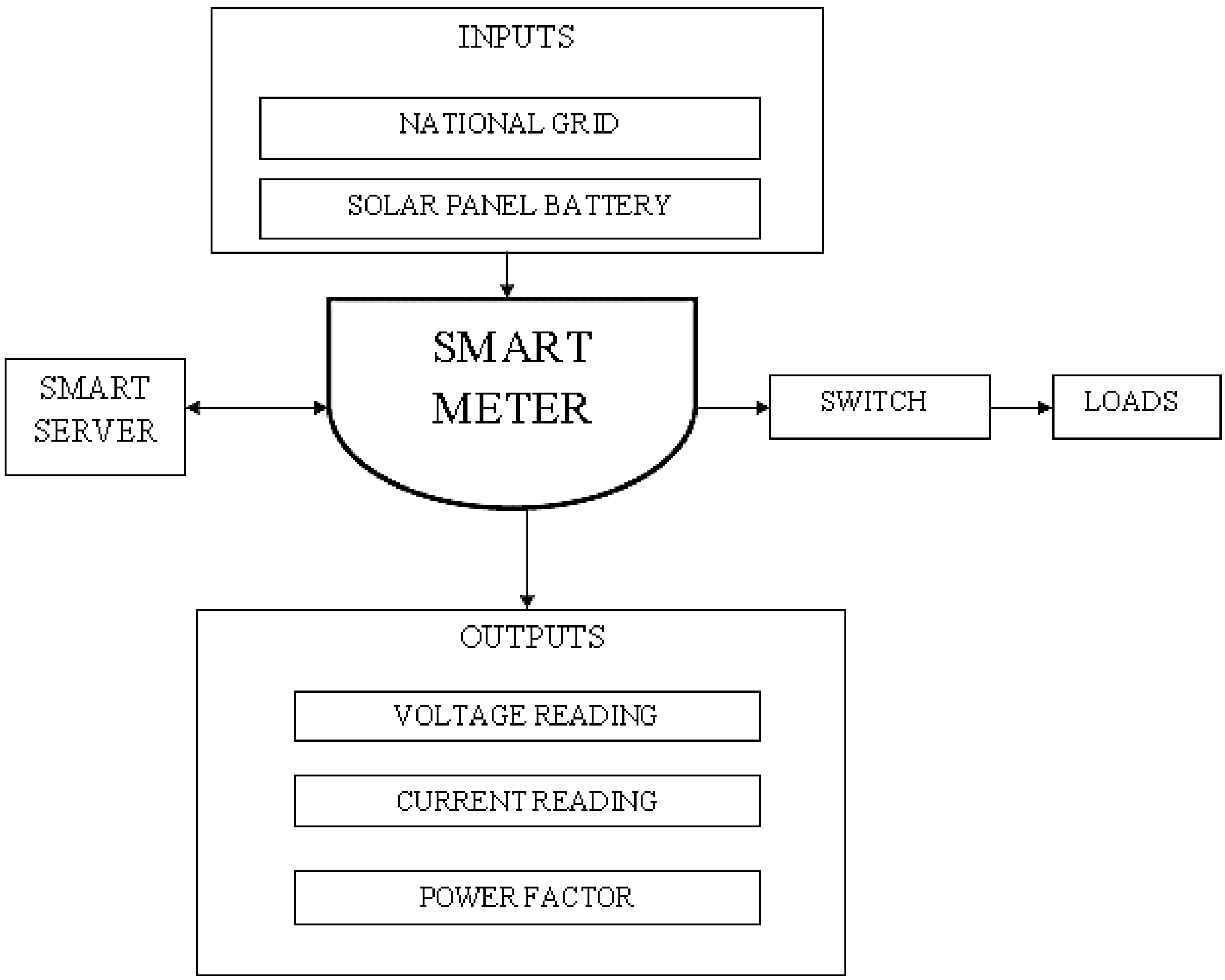


Figure 3: Complete Block diagram of the Smart Meter

3.2.2 SMART SERVER

Smart Server is going to be brain as it got the responsibility to manage the whole network. Every house will have a Smart Meter with unique ID number. For example, there are 4 houses. So the Smart Meters of each house is connected to the server. Each Smart Meter has 2 type of input Solar Power and National Grid and the Meter is connected to relay switch which will control the loads. Between Smart Meter and Smart Server 4 type of data will pass. Demand of the user which will be collected from data log by using the unique ID of Smart Meter, Battery Status of the Solar Power stored, Distance from the power plant these 3 data will pass from Smart Meter to Smart Server. After deciding which line to use the Smart Server will tell the Smart Meter which line to use Solar Power or National Grid. The block diagram of a smart server is shown below:

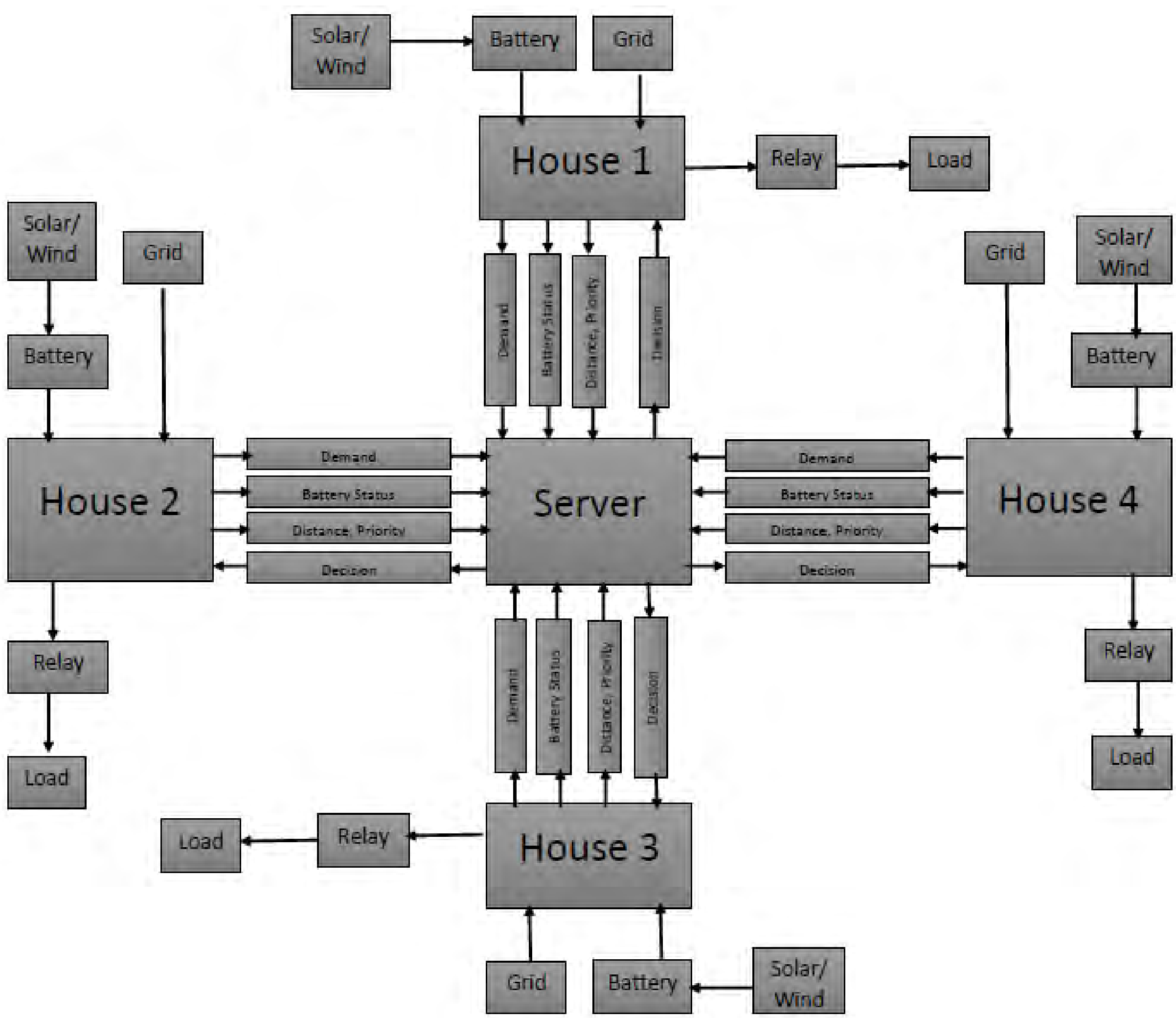


Figure 4: **Block Diagram of Smart Server for 4 Houses**

Now we are going to connect a whole town with the Intelligent Energy Management System (IEMS) to give an idea how the server will act. To do so we will need data logging as Arduino cannot store too many information. Now the decision making will be done by computer and the information sent by Smart Meters will be stored in a Hard Disk Drive (HDD) for further use.

Let's see this table first before any further discussion,

Serial No.	Date	Unique ID	Demand in KWh	Battery Status in KWh	Load from Battery in KWh	Load from Grid in KWh	Total Grid used in KWh	Total expense 3.33 Tk. Per unit	Total savings Tk.
1	17-8-16	13121095	30	25	25	5	5	16.65	83.25
2	17-8-16	13110023	24	20	20	4	4	13.32	66.6
3	17-8-16	12221072	32	20	20	12	12	39.96	66.6
4	17-8-16	13321036	27	25	25	2	2	6.66	83.25
5	18-8-16	13121095	29	22	22	7	7	23.31	73.26
6	18-8-16	13110023	25	18	18	7	7	23.31	59.94
7	18-8-16	12221072	31	19	19	12	12	39.96	63.27
8	18-8-16	13321036	28	24	24	4	4	13.32	79.92
9									
10									

Figure 5: Possible Table for future implementation

We can data stored in the log. In the date 17-8-16 log of four users can be seen. The previous demand of user: 13121095 was 30KWh, the battery status of the user was 25 KWh as result the user had to use only 5 KWh electricity from the National Grid which saved 83.25 Tk for that day. From this data log we can see the savings of each user. Now what happens when the battery status is greater than the Demand of the user? In this case the user can sell electricity to other users. In this case if any user needs to use National Grid the server will supply the extra electricity of the first user to the second user to save National Grid Electricity. In this process the need of Load Shedding will minimize and people will less likely have to depend on national Grid supply. This will also ensure minimum environment pollution as we know Power Stations pollute the environment more than the Solar Panels.

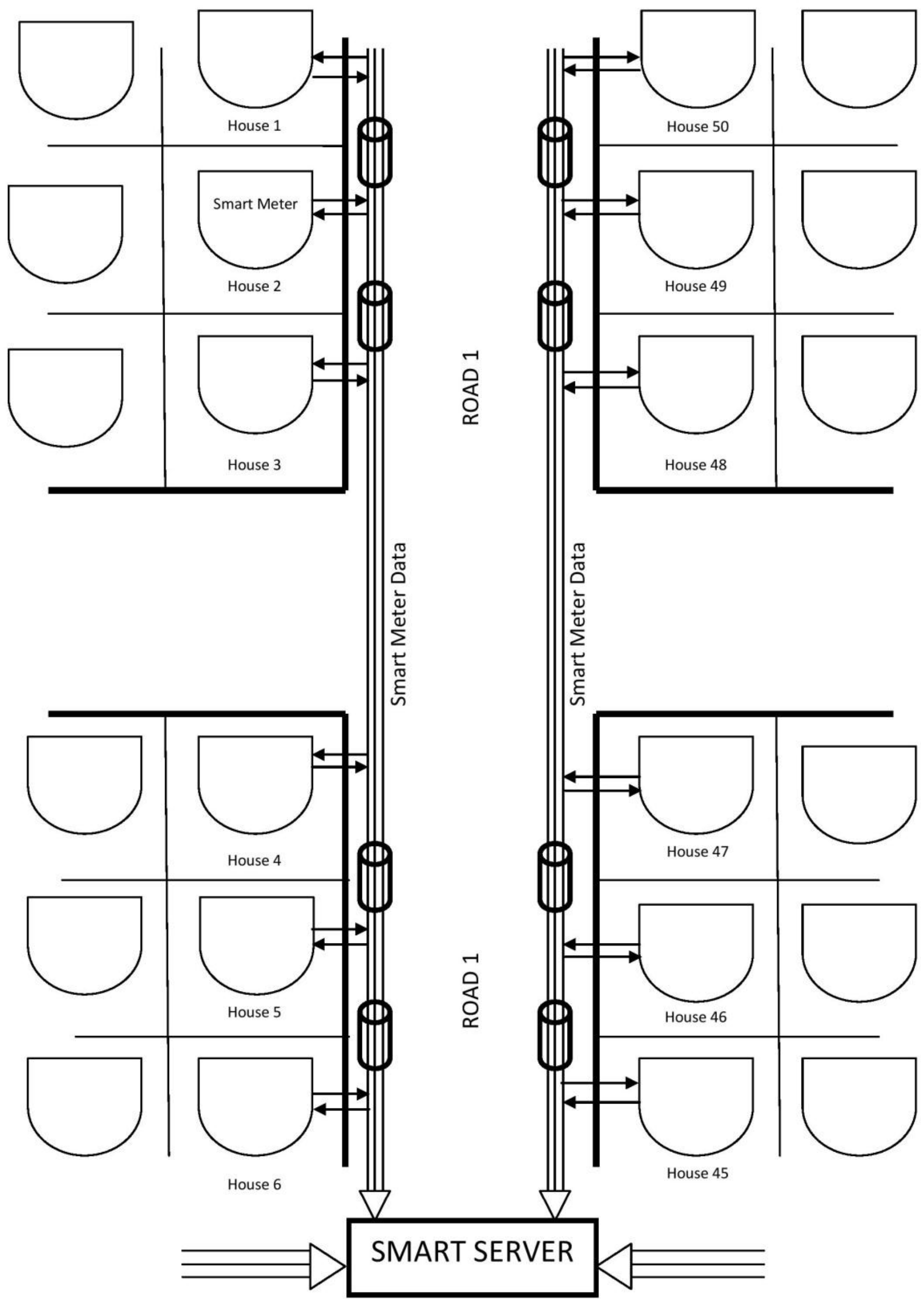


Figure 6: **Block Diagram of Smart Server with a small town**

3.3 CELL AND CLUSTER METHOD

We are to develop a system where the consumer can buy or sell solar power and hence manage the energy system efficiently. Therefore, there must be an establishment of communication between the consumers to buy or sell the solar power. For the management there must be a manager who will be responsible for controlling and administering the whole operation.

If we see in mobile communication people communicate using mobile phones which are connected to a network. Due to limited frequency resource cellular concept is used and same channels are assigned to cells in different clusters. In cellular concept the total land area (per square kilometer) is segmented into small geographical areas called cells. A group of cells make a cluster. Cell may be of any geometric shape but hexagonal shape is taken as an ideal. The whole system is more descriptive.

The system design of this project is influenced by cellular concept from mobile communication so that there is an efficient management of energy system. In this chapter the whole system is illustrated part by part at first and the big picture is shown later.

3.3.1 INSIDE A CELL

The total area is divided into smaller geographic sections called cells. A cell covering a smaller area contain a primary server (or initial server) and the solar powered homes located inside this area. A server is a device that administers or controls the work and provides service by giving decisions. It also transfers and receives information. Solar powered homes are connected with the primary server (or initial server). The primary server (or initial server) is again connected with another server known as the main server. The hexagonal shape is taken as ideal for a cell.

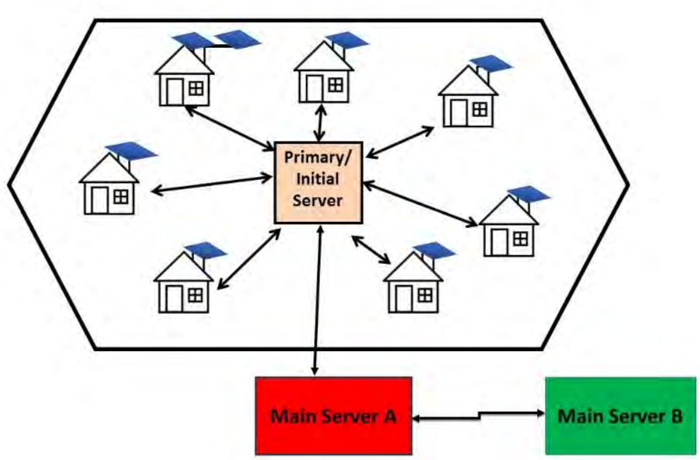


Figure 7: A cell containing primary server

3.3.2 INSIDE A CLUSTER

For simplicity we take N=3 cell system making a cluster, where N=number of cells in a cluster. A cluster contains a main server. The main server is connected to the primary servers (or initial servers) inside a cluster.

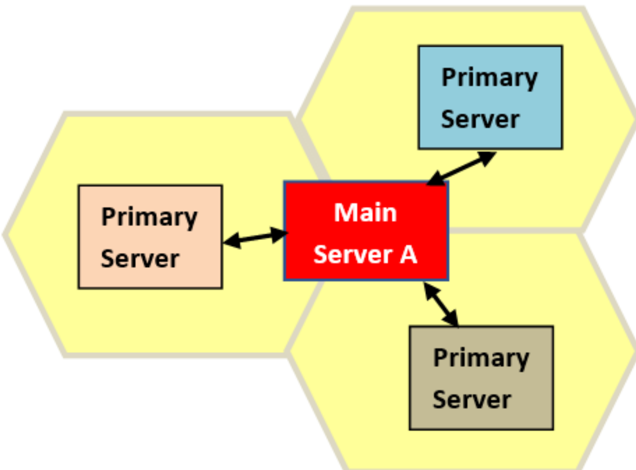


Figure 8: Block diagram of a Cluster where the Main server is connected with the primary servers.

The main server of a cluster is connected with the neighboring main servers of other clusters. This builds a communication system between the main servers through which information can be received or transferred to other clusters.

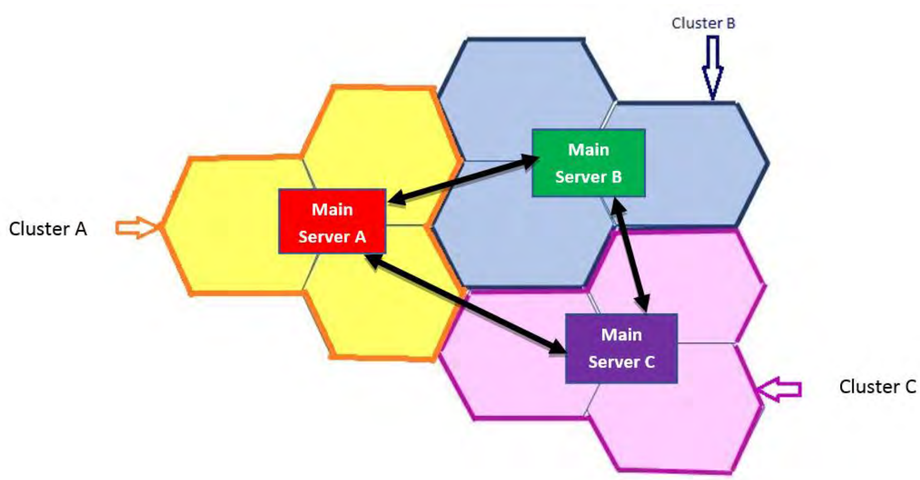


Figure 9: Three Clusters where their respective Main Server is connected with the neighboring ones

3.4 CONCLUSION

The whole system includes all the ingredients homes, cells, clusters and everything inside them. This is how the system will look but now there is a common question about how it will work or operate. The description about the system is discussed in the next chapter.

CHAPTER 4: SYSTEM IMPLEMENTATION

4.1 INTRODUCTION

In this chapter each ingredient in the block diagram is discussed briefly. The procedure on how the system will work has also been discussed here. At first there is a little description about the solar powered homes. Afterword the working procedure or actions inside a cell and inside a cluster is explained.

4.2 INITIAL LEVEL IMPLEMENTATION

At first we are going to consider an Arduino Uno as a decision making device. Now we will develop a whole circuit using the Arduino Uno which will act as our desired Smart Server. We will not use any Smart Meter data for this stage.

Our objective is to make decisions for a home on how to distribute the power source to the loads according to demand. Let's make it easy to understand, say one house with daily demand of 30KWh have Solar Panels which produces 20KWh Energy daily. If there are 5 lights and 5 fans in that house, we have to make sure that maximum number of light and fan are using power from Solar Panels and after that the rest of the light and fan will use National Grid power. As a result, the user need not to worry about when and which line to use the server will do it for him. By doing so, the user can save a lot of money for using the solar power instead of national grid.

So we will need a keypad to entry the demand of user and the energy stored by solar panel in the battery which is battery status and connect the keypad to the Arduino Uno. We will also connect an LCD display to know about our entry and what is the decision of the server. We will connect a light and a fan via relay switch to see if the decision making algorithm is working or not.

For this Thesis we are going to show 4 houses connected to the Smart Server so we are going to connect three more keypads to the Arduino to show how the smart server will act if it gets multiple entry.

So for single home we need an Arduino Uno, a keypad, a 20x4 LCD, 2 Relay, 1 light and 1 fan.

4.2.1 THE CIRCUIT

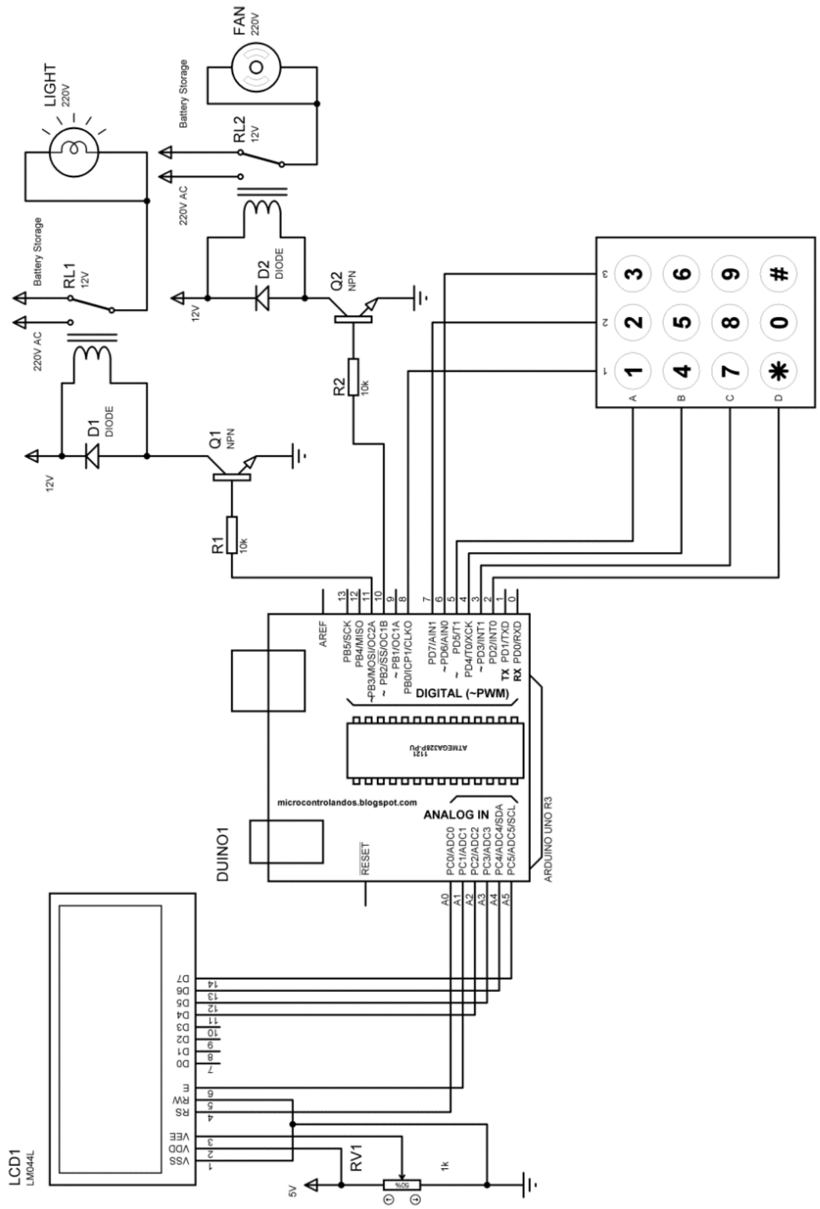


Figure 10: Circuit of initial level implementation

4.2.2 FLOWCHART OF SMART SERVER (FOR SIX LOADS)

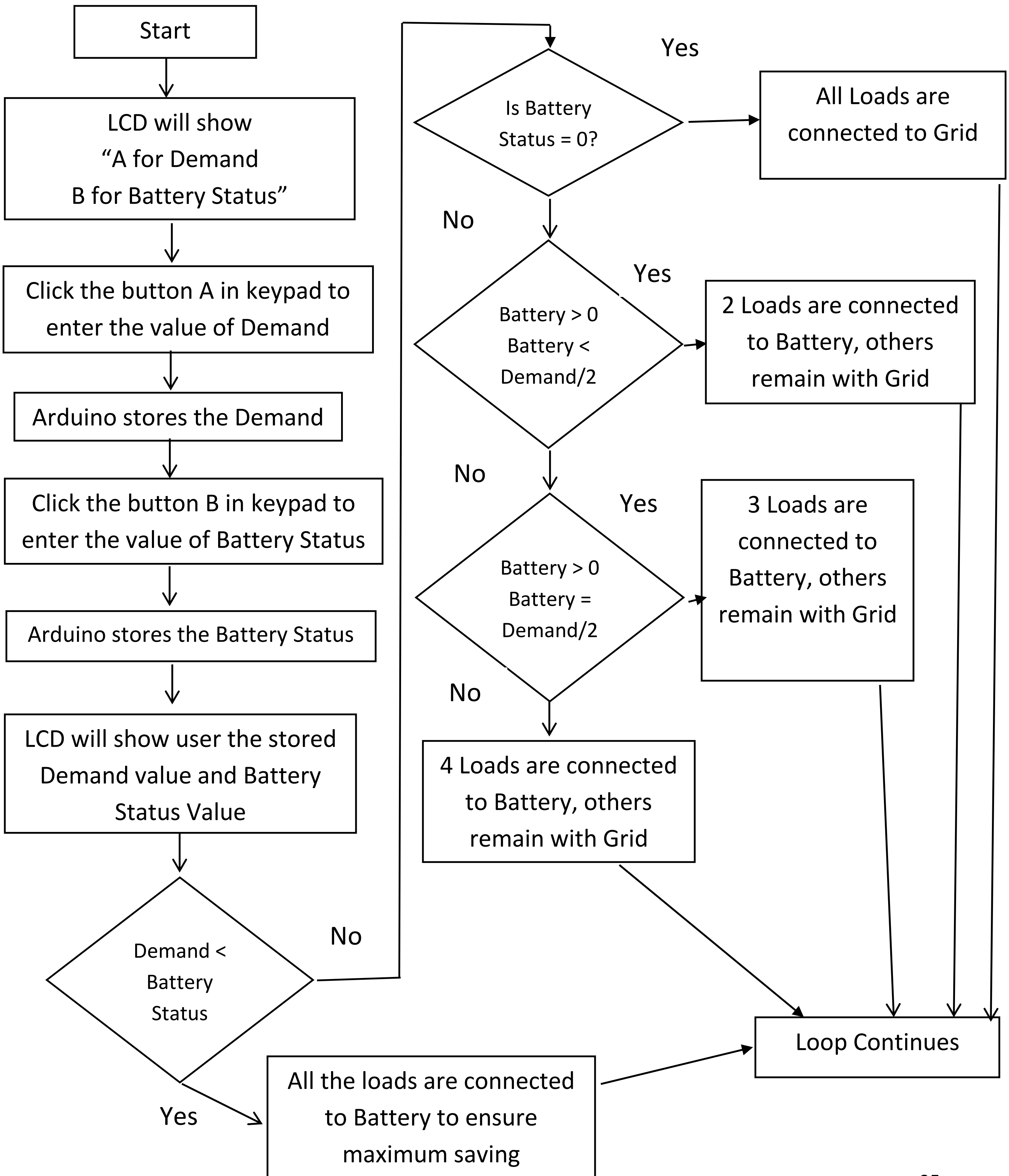


Figure 11: Block Diagram of initial level implementation

4.2.3 COMPONENTS AND EQUIPMENT

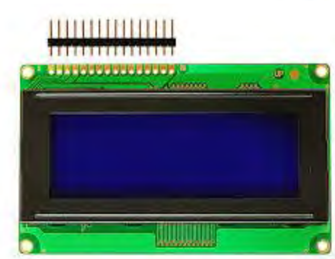
The following components were needed to build the first stage of our thesis:

1. Potentiometer 1K: A potentiometer is basically a variable resistor with 3 terminals. Two terminals are attached to a resistive element's both ends, while the third terminal is attached to a sliding contact, known as a wiper, that is moving over the resistive element. The wiper's location decides the output voltage of the potentiometer. Using pot or potentiometer we provide different voltages to LCD.

2. Arduino Mega: Acting as a smart server that controls the entire mechanism of the smart system of our project. Necessary coding is done on Arduino so that the user can enter his/her required electricity demands for his/her home.

3. Keypad matrix 4x4: Using Keypad we can enter the required demands for electric power of homes.

4. LED 20x4: This is a 20 character by 4-line display which is used to display the values of our demands.



5. 220 ohms for 2 LEDs: Resistors are used for proper electric circuit connection and to ensure that high current does not pass the circuit to burn it.

4.2.4 PROCEDURE

As we are using Arduino Mega as our smart server so each decision is taken by this device. We have used keypad as input device and the output is seen on the LCD screen.

At first, we have tested that all the components are working properly. Then we have completed the circuit by connecting the components according to the following schematic diagram.

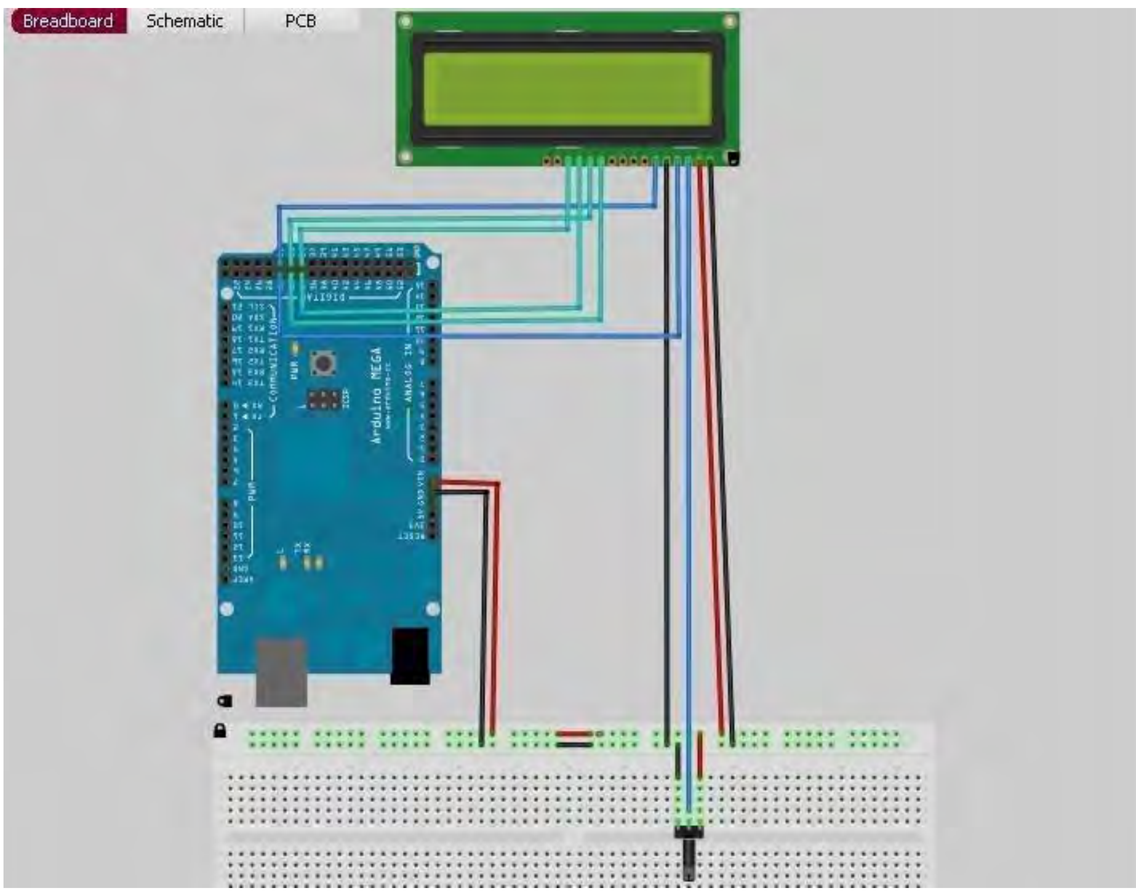


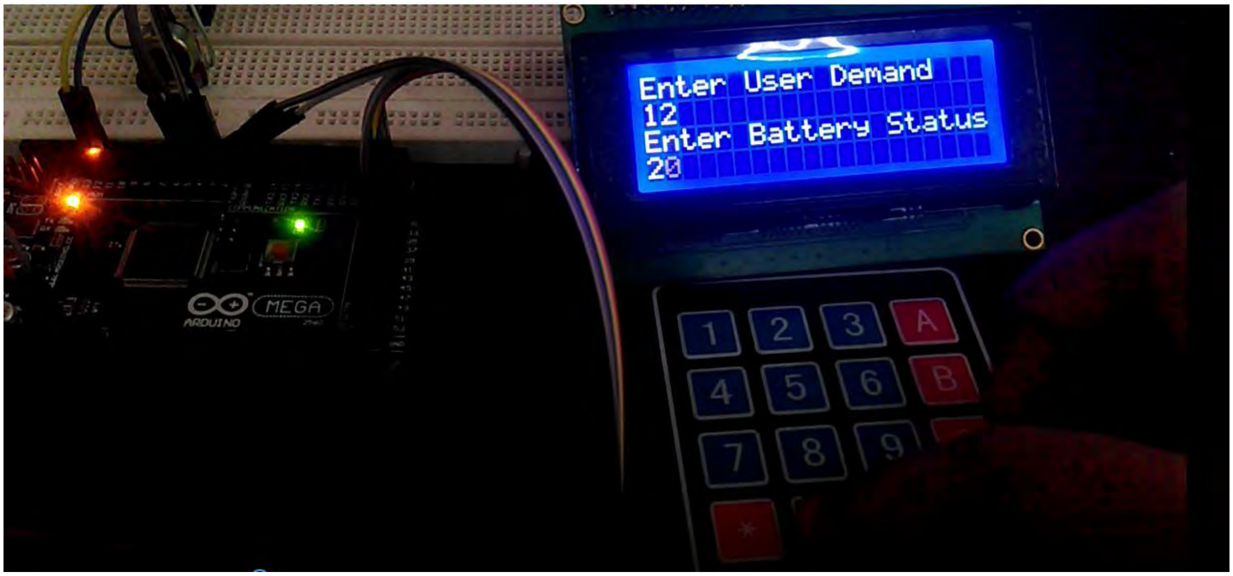
Figure 12: Connection of initial level

4.2.5 RESULTS

After running the code, we see few lines on the LCD display asking about the demand and battery status. For entering the value of demand 'A' has to be pressed and for entering the value of battery status 'B' has to be pressed on the keypad.

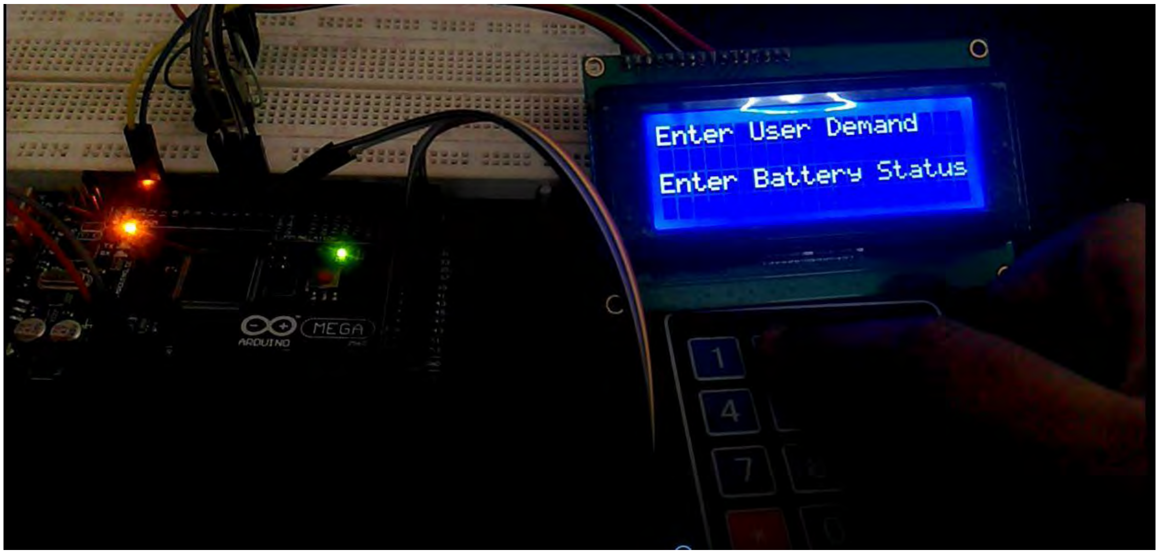
After pressing 'A' the value of demand is inserted in the form of number (0,1, 2,…,n) and after pressing 'B' the value of battery status is also inserted in the same way.

Entering the values.

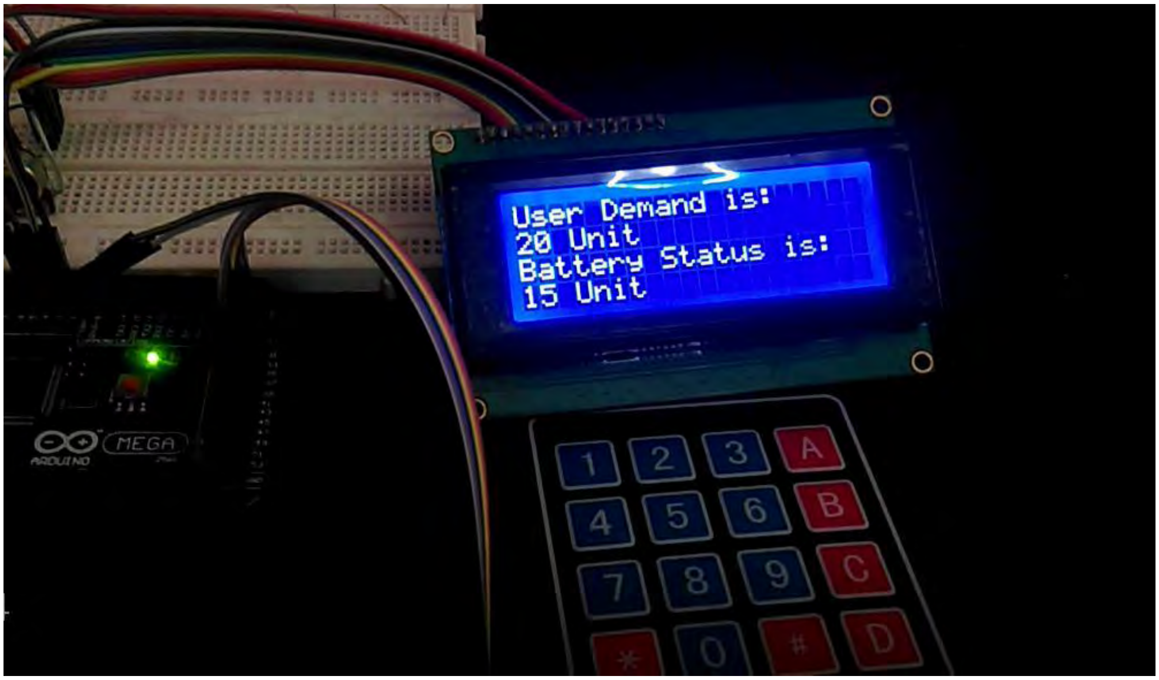


Number sign hash mark '(#)' is used as enter key. So, after inserting the values of demand and battery status hash mark (#) is pressed.

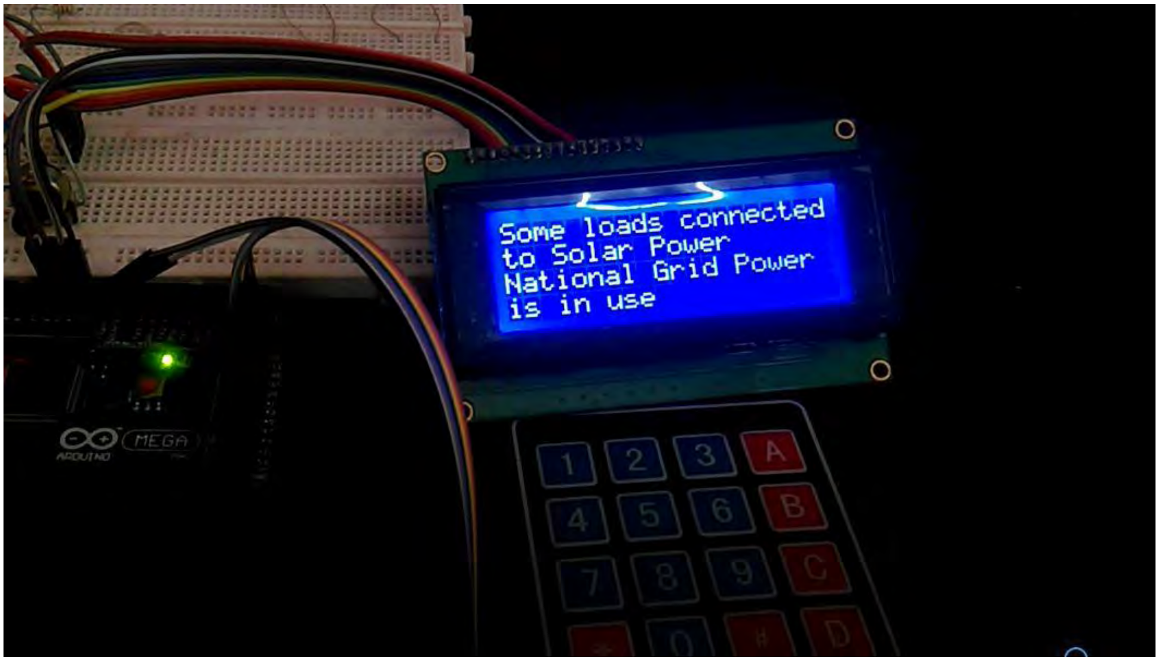
Here it is seen that the demand value is less than that of battery status. Therefore, a message 'All loads connected to Solar Power. National Grid Power is not in use' is displayed.



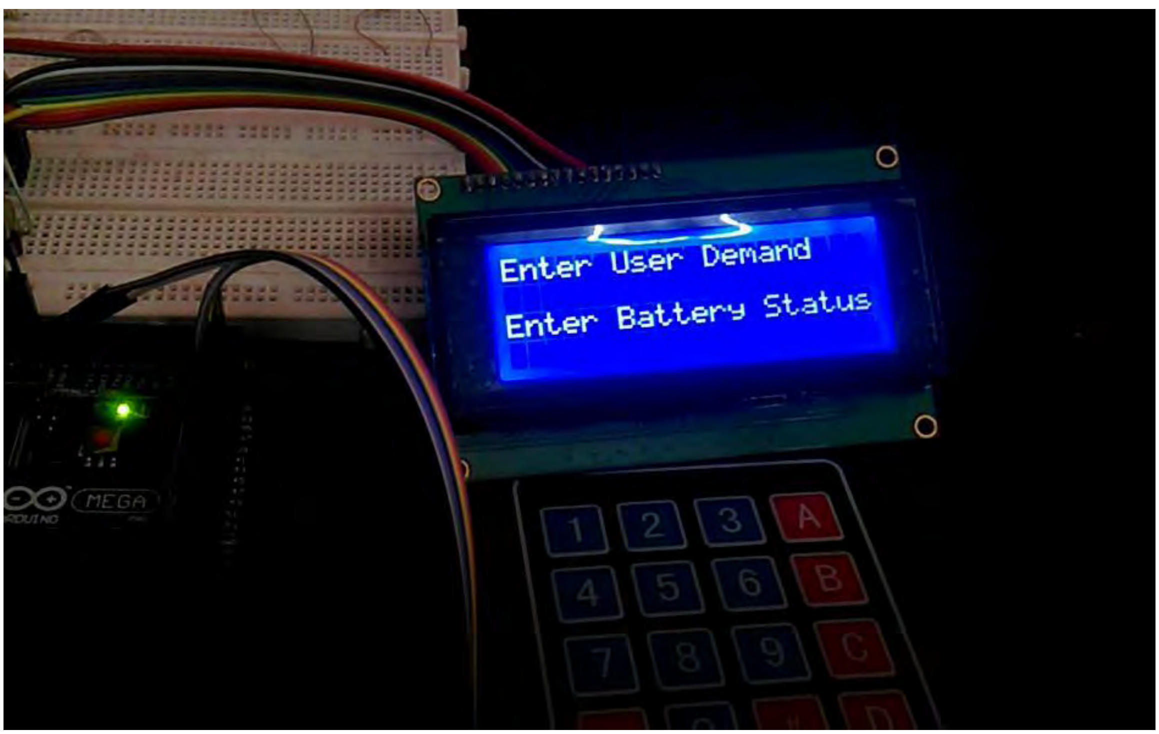
Again the device asks about the value of demand and battery status.



This time the value of demand is more than that of battery status.



Therefore, a message ‘Some loads connected to Solar Power. National Grid Power is in use’ is displayed.



The loop again continues.

4.3 FINAL LEVEL IMPLEMENTATION

The above flowchart shows three users, A, B and C and the interaction these users will have with each other and with the national grid during the process of selling, buying to/from one of the users or from the national grid in the most efficient way.

Every user is asked to give their battery status and consumption as input. We are assuming the values of Battery Status and Consumption. However, in real life the scenario is not exactly similar.' Extra Power' for each user is calculated by subtracting 'Consumption' from 'Battery' status. Suppose Home A has more consumption and less battery status, the first if-else box checks whether A has extra power or not. If extra power>0 then it means its battery status is greater than its consumption and hence it is qualified to sell its extra power to one other users. If extra power =0 then it means both its battery status and consumption are equal and it has no extra power. But if extra power<0 then its consumption is greater than its battery status so 'Demand' exists and it is in need of electric power. The latter decision boxes determine the best option of choosing A's supplier of power. It can be B, C or the national grid if both C and B have no extra power to spare. One by one the decision box will check which user has more extra power with 1 and 0 units where 1 shows the user has extra power and 0 shows the user has no extra power. Then it will check which one has more extra power and that user is finally chosen the one that will sell its extra power to the one in need. In this example A will obviously have 0 in its extra power and so the system checks if C=1 or C=0 and if B=1 or B=0. Suppose both C and B are 1 then it will check if extra power of C is greater than B. If it is greater than B, the server

will tell to buy from C and if it is not greater then C it will be tell to buy from B. If Both C and B have 0 extra power, then A is told to fulfill its demand using national grid. Here we used A as an example but the same process will be repeated for other users as well ensuring all the consumers using this system get fair and equal share of electric power.

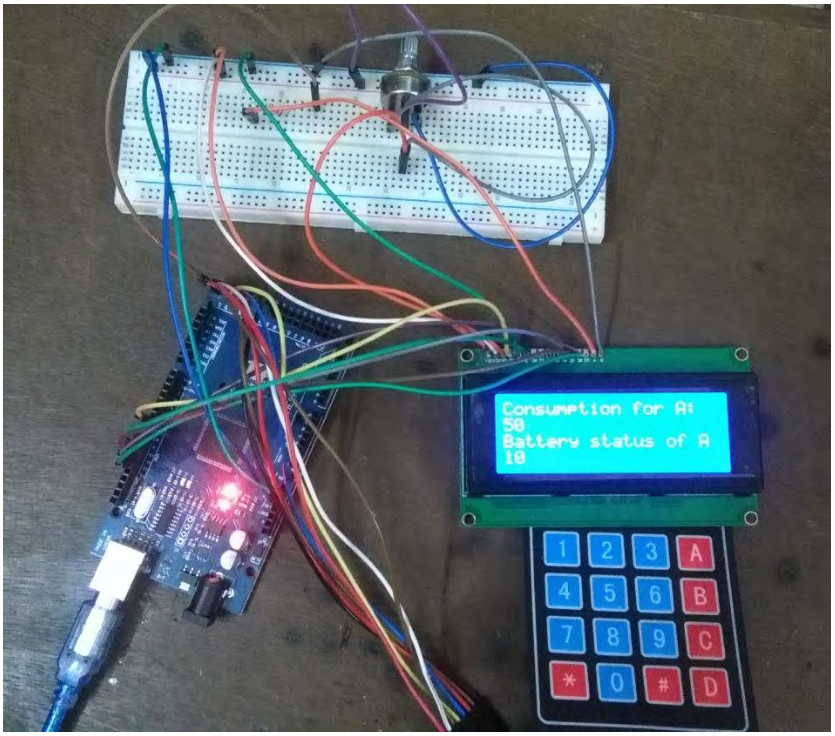


Fig 1: Entering values for A

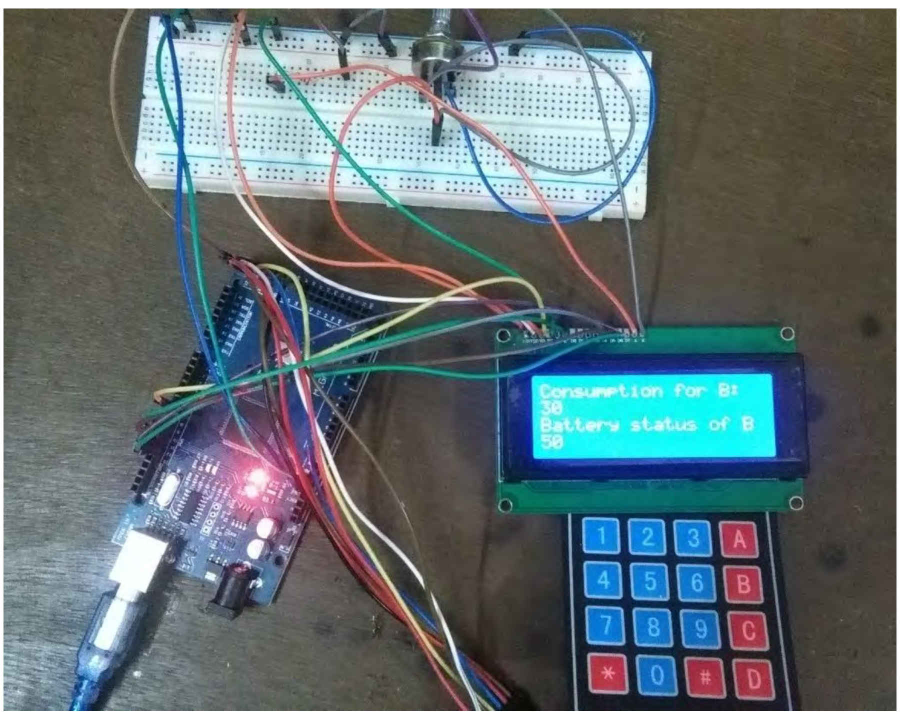


Fig 2: Entering values for B

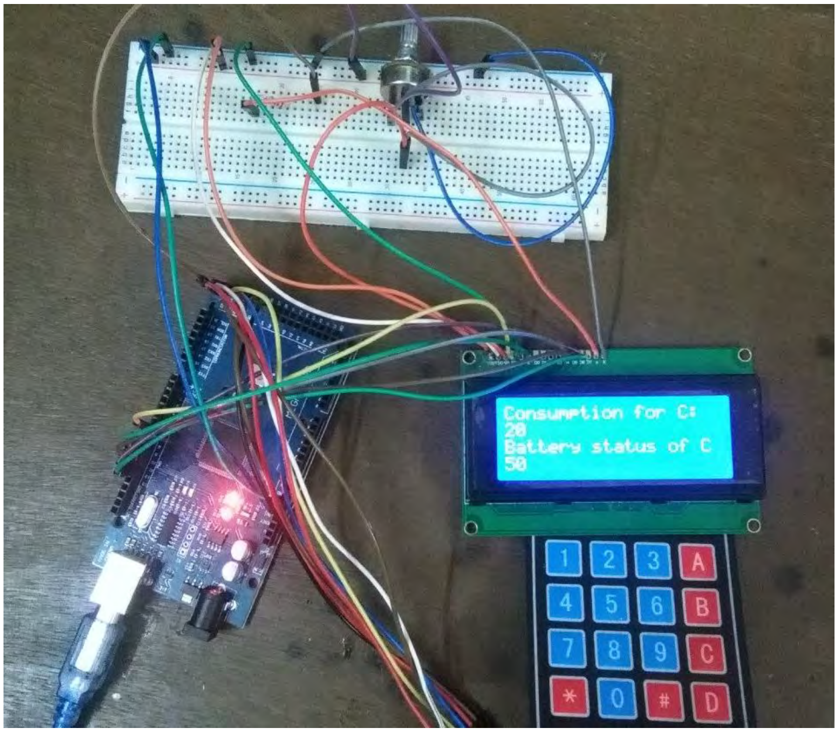


Fig 3: Entering values for C

Fig 4: Smart grid's decision

Scenario 2: Taking from National Grid

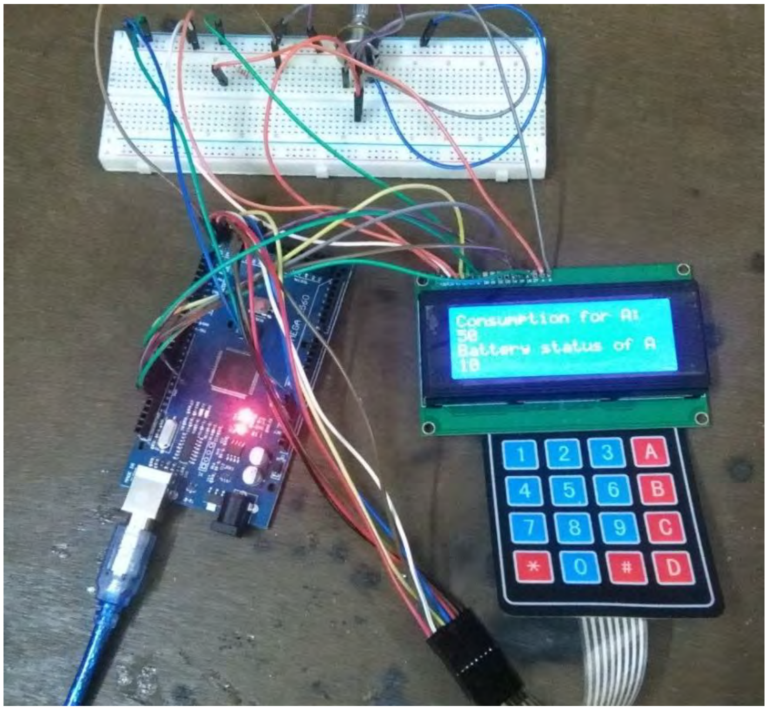


Fig 1: Entering values for A

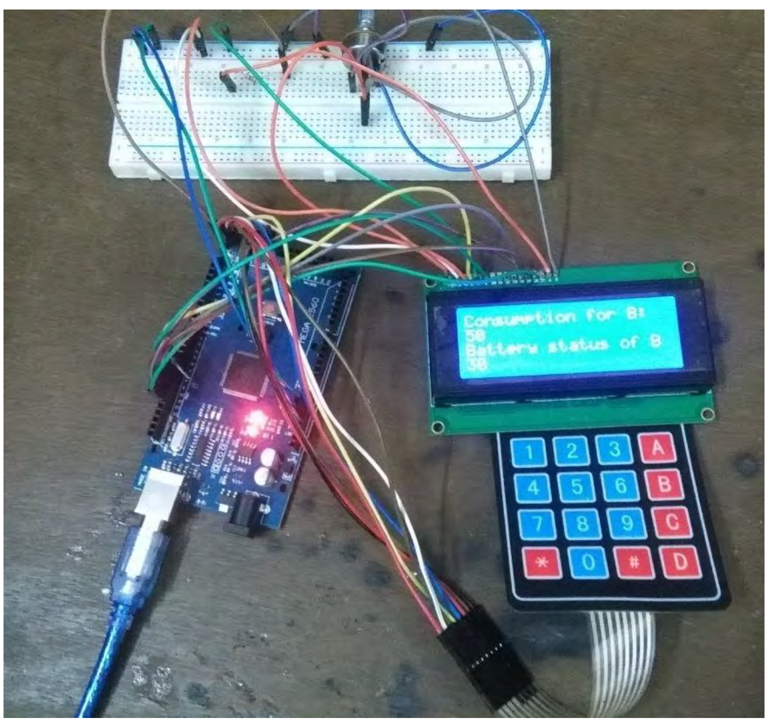


Fig 2: Entering values for B

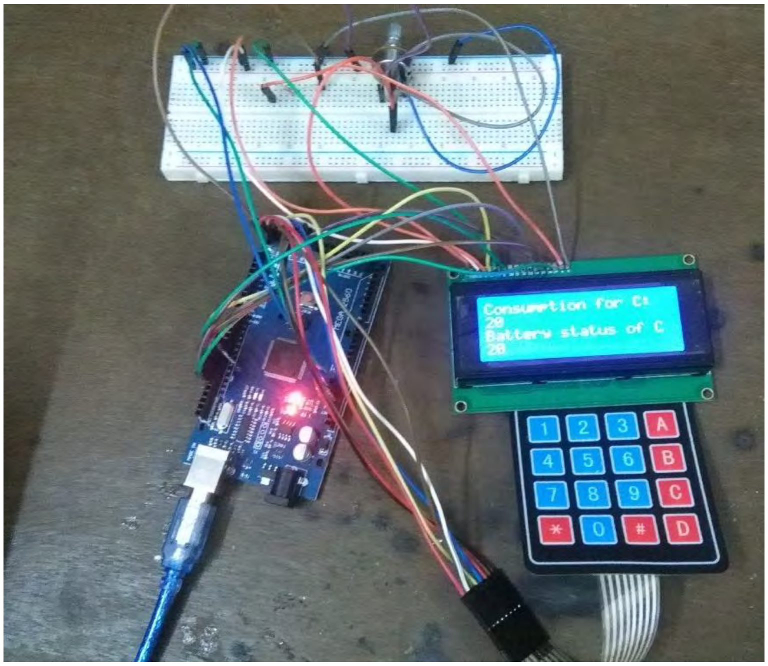


Fig 3: Entering values for C

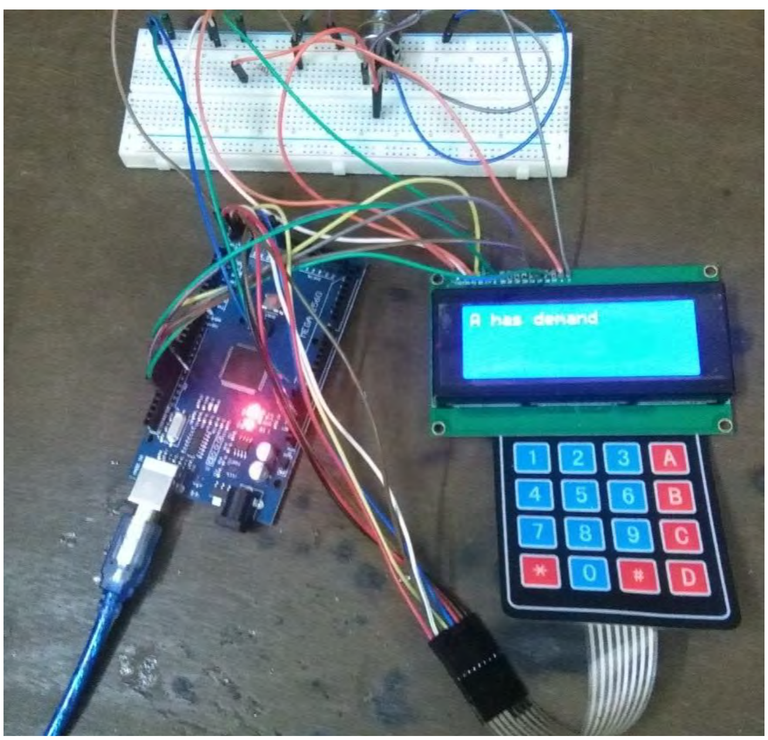


Fig 4: A has demand

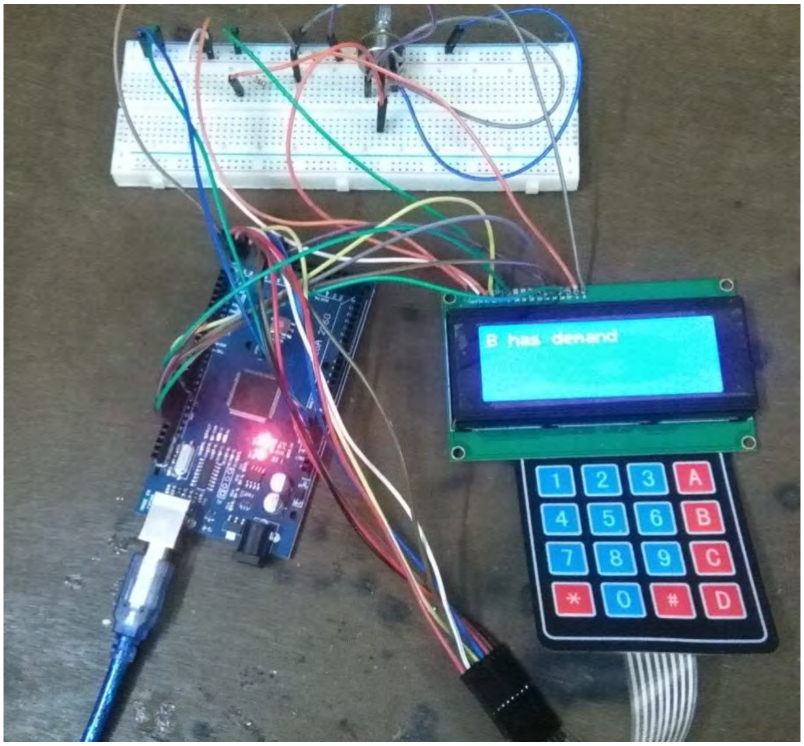


Fig 5: B has demand

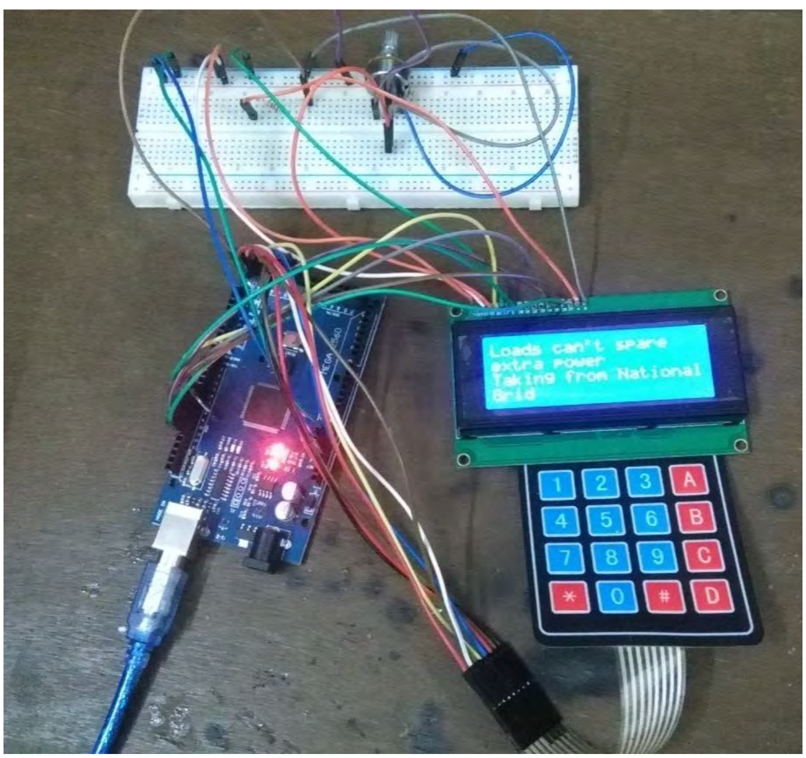


Fig 6: Smart Grid's decision

Scenario 1: A taking power from C's extra storage

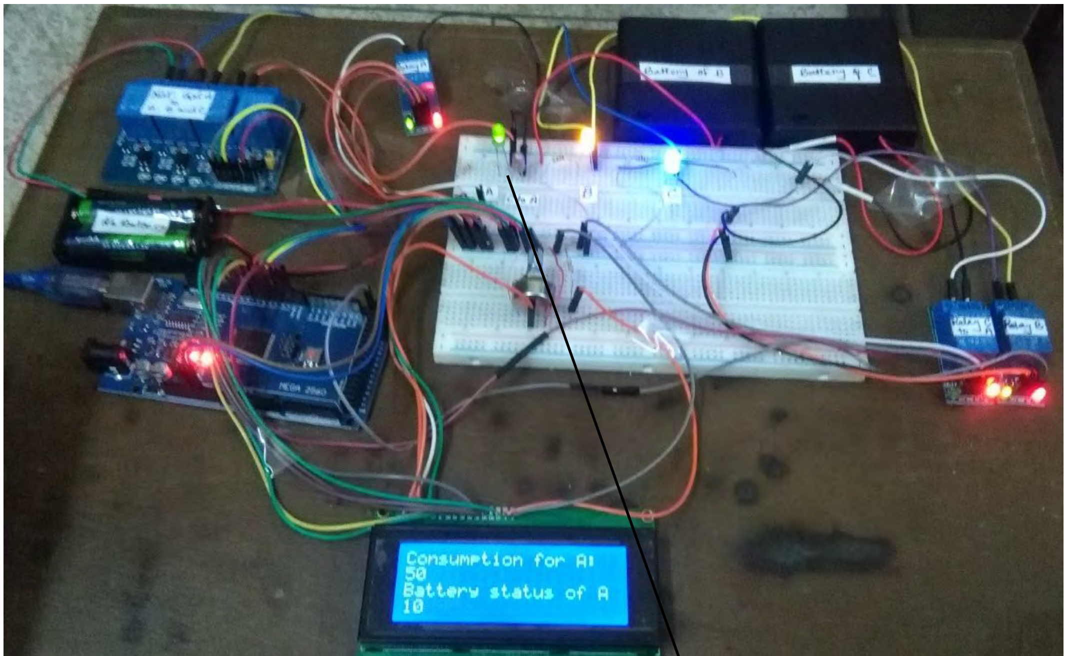


Fig 1: A's battery can't keep up with its consumption

A is glowing dimly

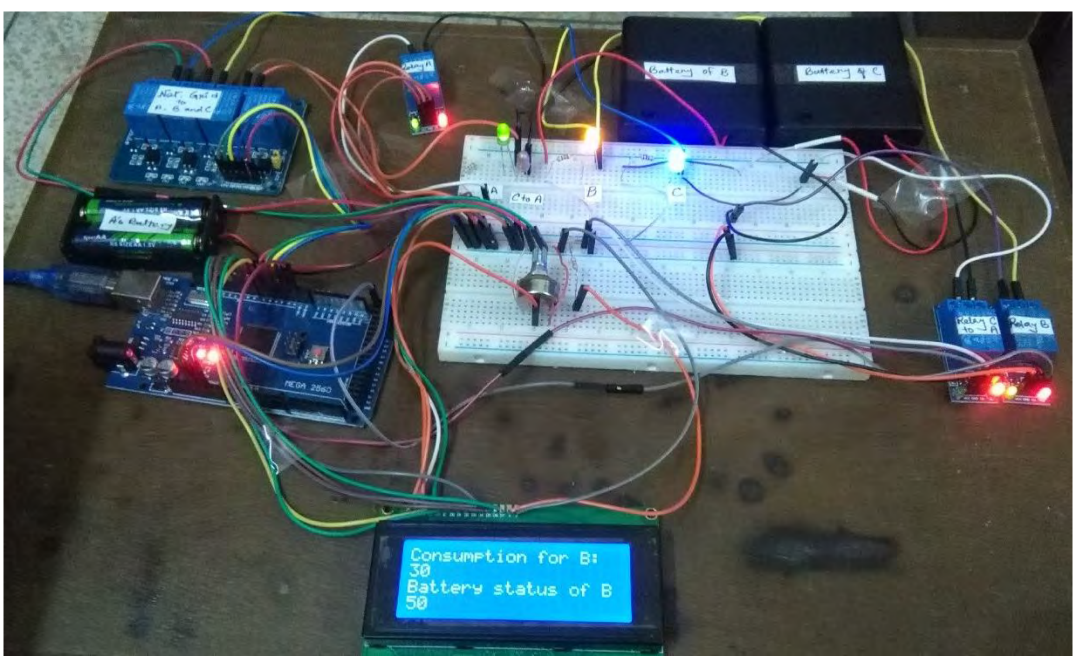


Fig 2: B's battery has sufficient storage for its consumption

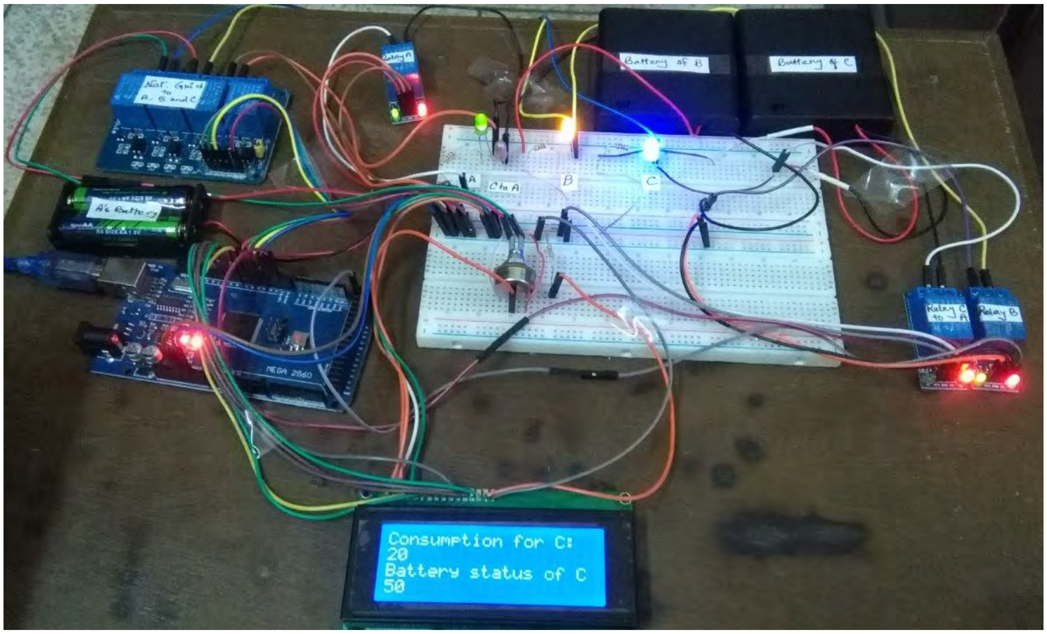


Fig 3: C's battery also has sufficient storage for is consumption

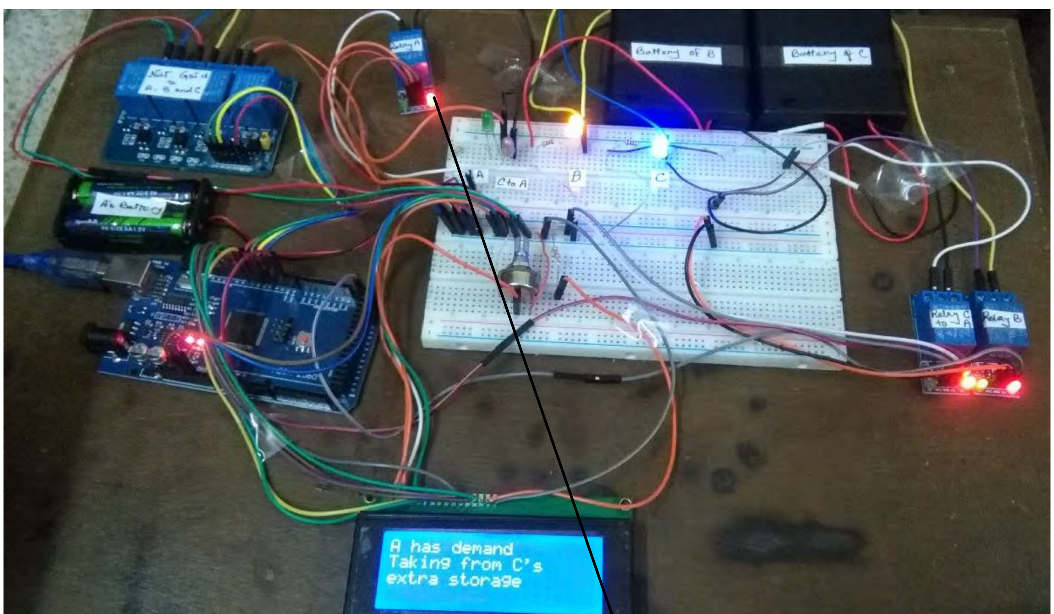
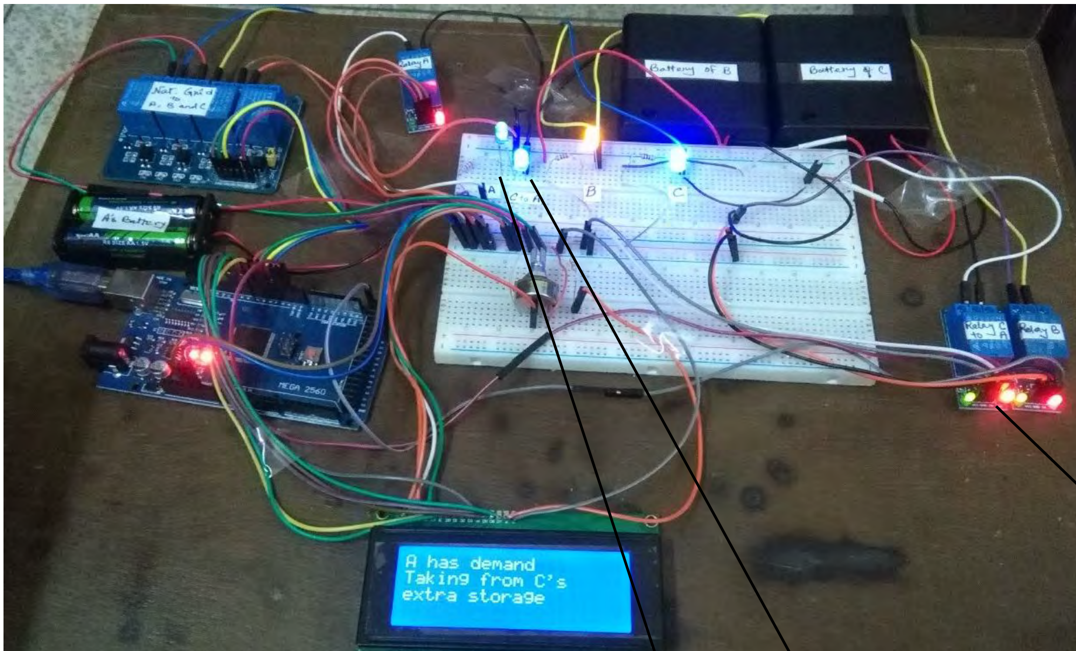


Fig 4: C has more storage than B to spare for A.

The relay turns off to disconnect
A from its battery



Relay connecting A to C’s battery turns on

Fig 5: A connects to C’s battery line and takes its spare power.

A now glows brightly

This LED between A and C’s battery connection indicates that A is drawing power from C’s battery

Scenario 2 :A and B taking power from National Grid

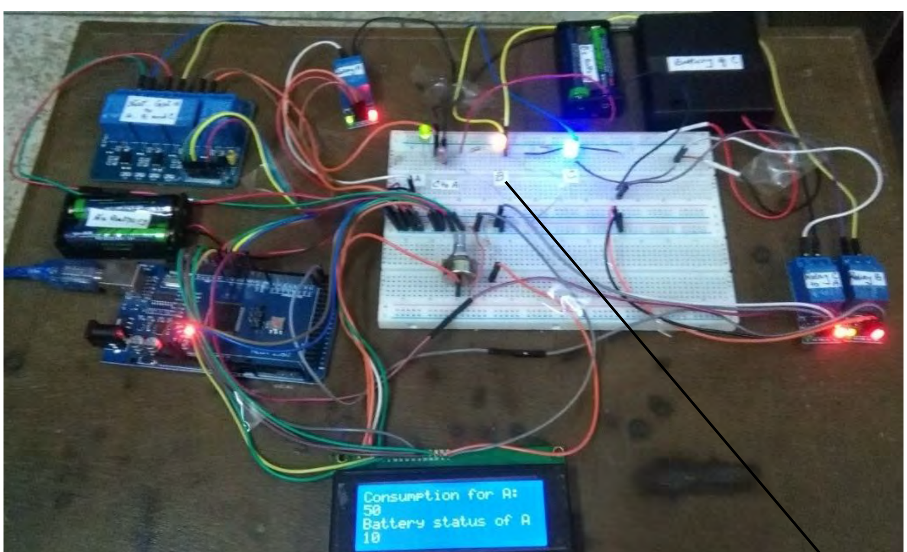


Fig 1: A’s battery storage cannot keep up with its consumption

A is glowing dimly

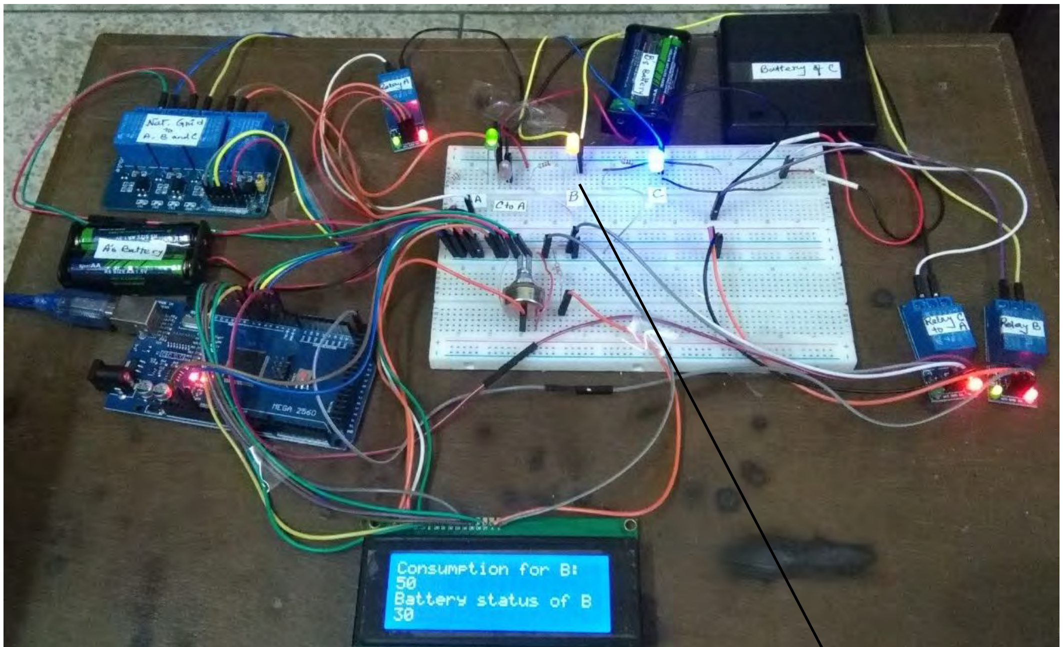


Fig 2: B's battery storage cannot keep up with its consumption

B is also glowing dimly

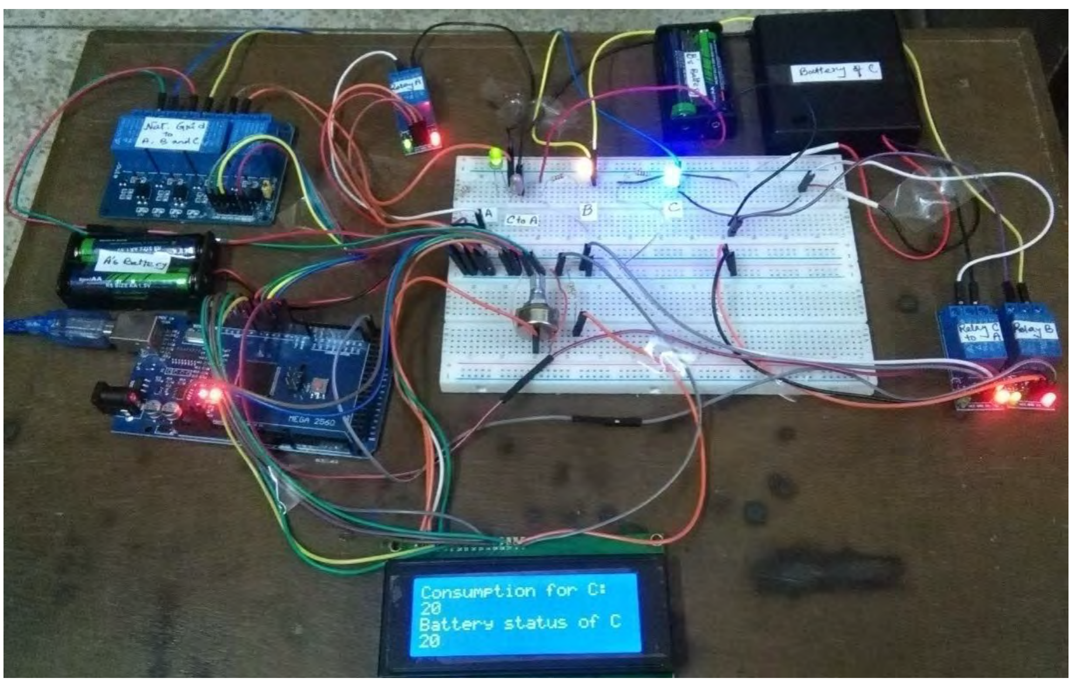


Fig 3: C's battery has enough for its consumption but cannot spare more for other loads

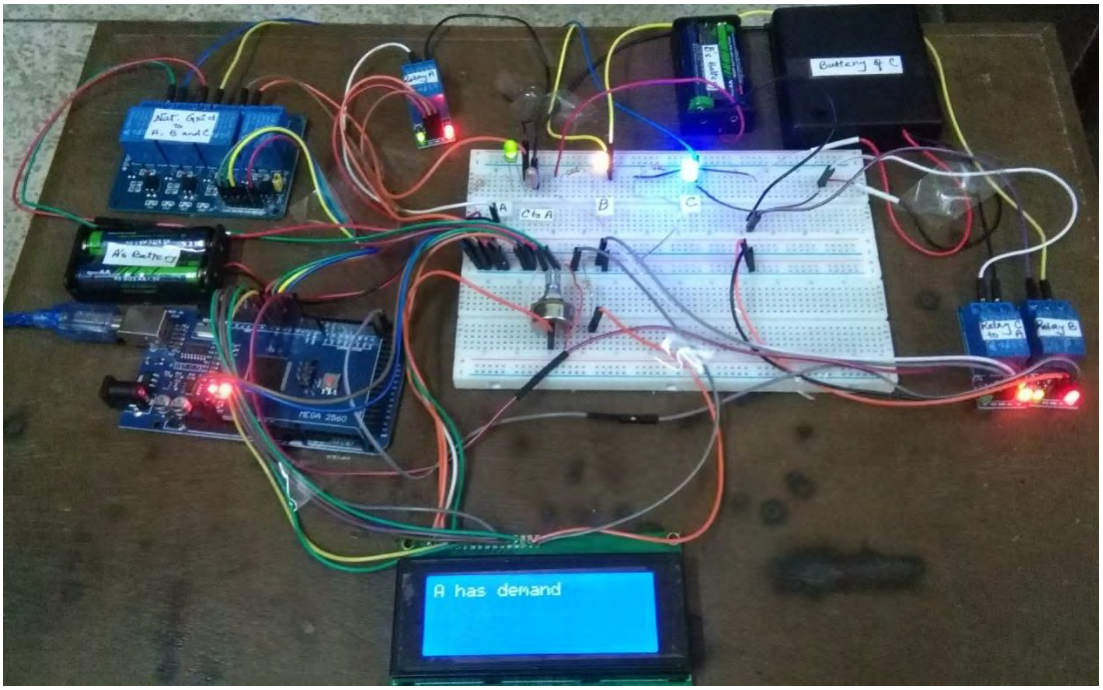


Fig 4: A is need of more power

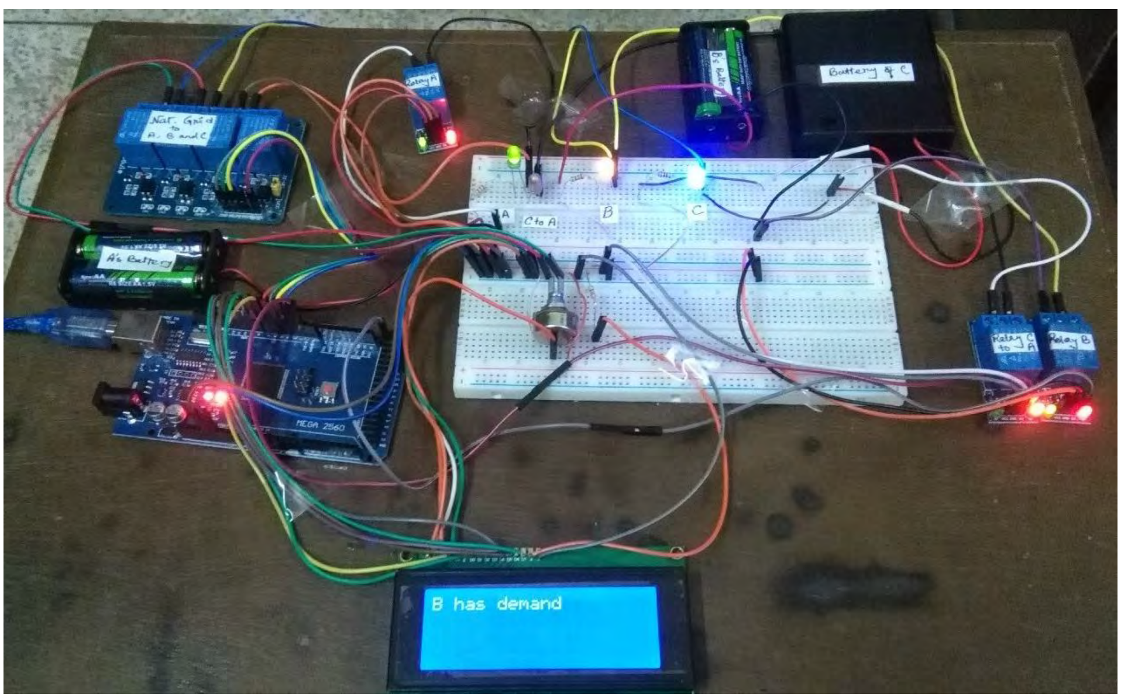


Fig 5: B is also in need of more power

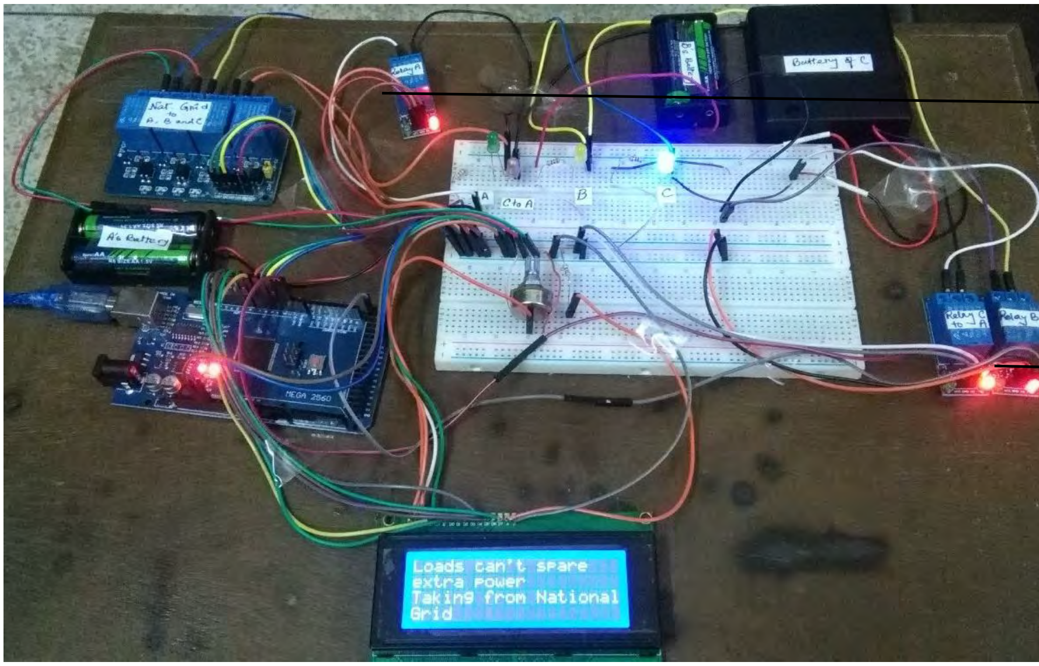


Fig 6: C cannot spare extra power so A and B seeking to connect to the National Grid

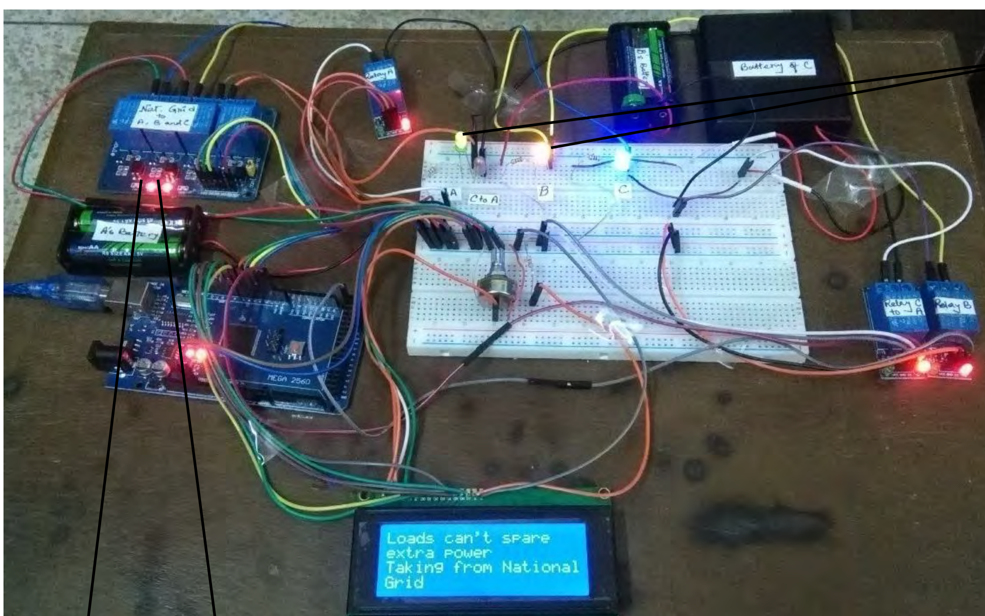


Fig 7: A and B is consuming power from National Grid

4.4 FUTURE IMPLEMENTATION IDEA

The system is mainly divided into two parts, Control Server Box and Consumer Blocks. For the simplification purpose we have designed the server for three consumers which means there are total three consumer boxes. Each consumer box consists of one battery and three loads each of different consumption level which are 25 Watt bulb, 60 Watt bulb and 100 Watt bulb. Consumers can control each bulb manually with traditional wall mounted switches. Again the bulbs can be controlled wirelessly by any mobile device or directly by the Control Server Box when needed. The control server box has manual switches to control the supply of each consumer. It also has a LCD that displays Total Available Solar Power, Solar Power Production of each consumer, Average Consumption of each consumer. An outlook of the whole system is given below:

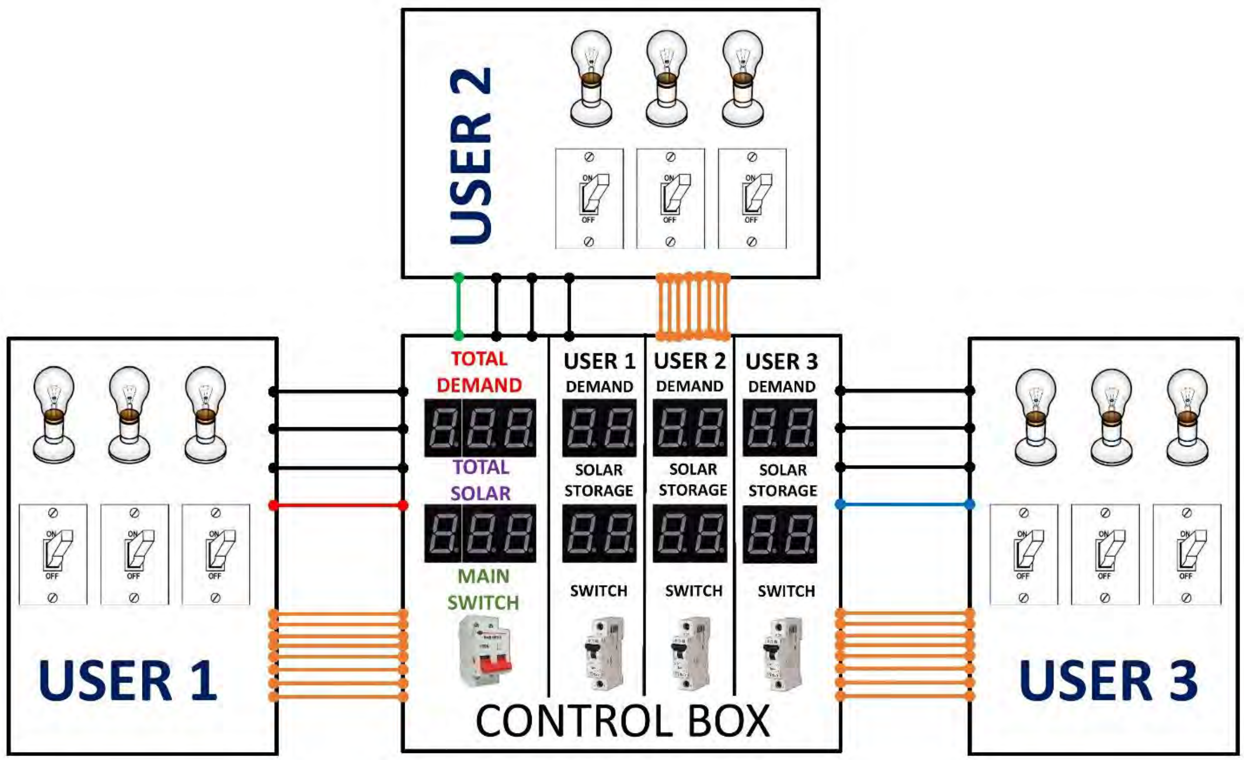


Figure 13: Top View of the System

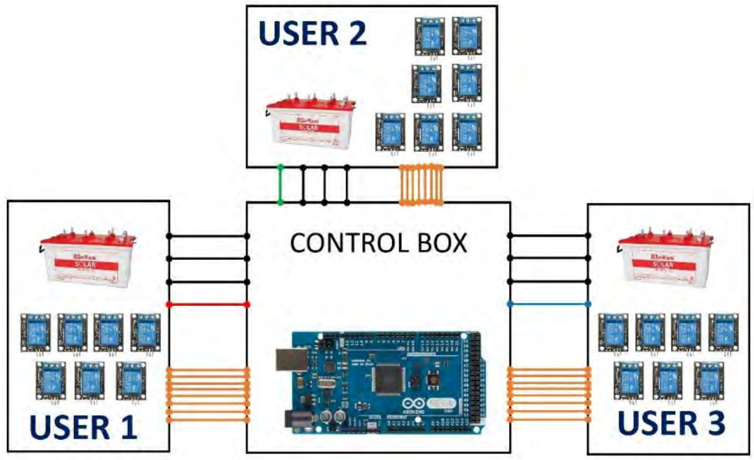


Figure 14: Internal Components of the System

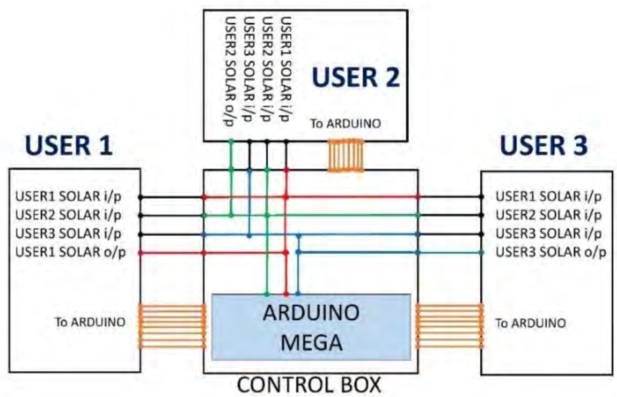


Figure 15: Internal connection of the Batteries of Users

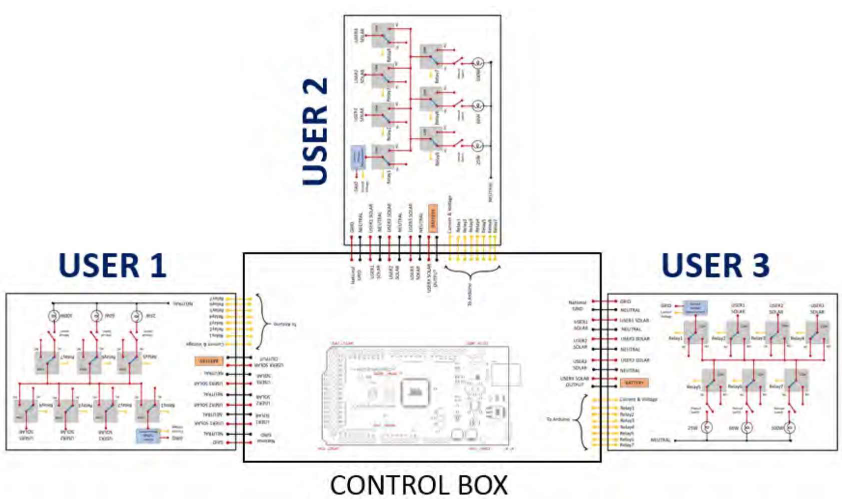


Figure 16: Simplified Internal Connection of the system

4.4.1 CONSUMER BLOCKS

Now we are going to describe the system elaborately. First comes the Consumer Blocks. These blocks are identical for each consumer. The battery represents the total solar power stored by the consumer which will be used when needed.

Each bulb is first connected to a Manual switch with wire and then to a Relay which is connected to an Arduino or Microcontroller. As the bulbs need to be turned on when National Grid Supply is off, we have to connect the Solar power of the three user with each other so that the control box can connect the Light Bulbs with any of the Battery. Here is a simplified connection diagram from the inside of a Consumer Box:

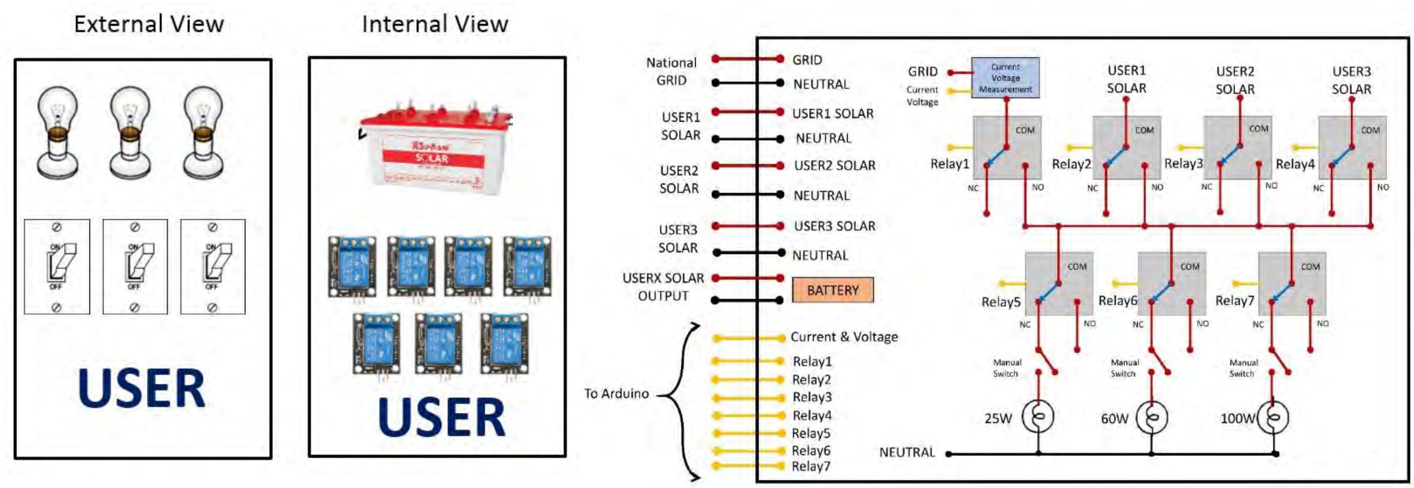
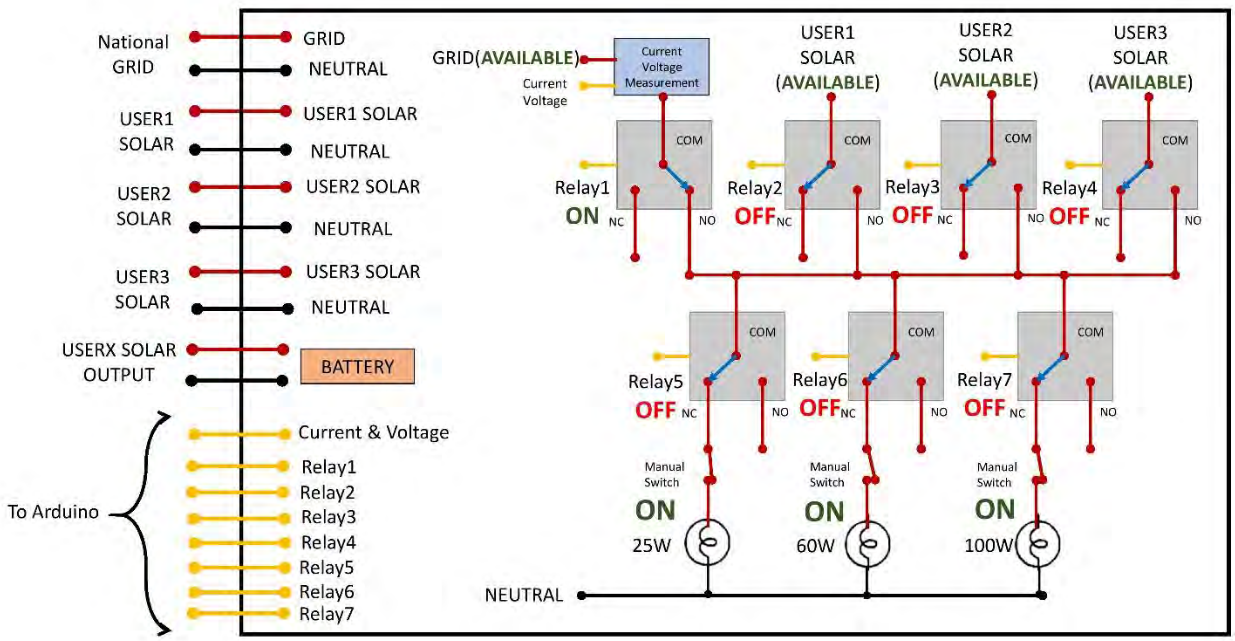


Figure 17: Externa & Inter nal View, Simplified internal connection of a Consumer Box

There are total 7 Relay swithces used in this configuration. The top 4 Relay switches are used to select a suitable Power Source to turn on the Lights. As we are showing this system for 3 consumers, so there will be 3 Solar power storage or battery and national grid connection to light up the Bulbs.

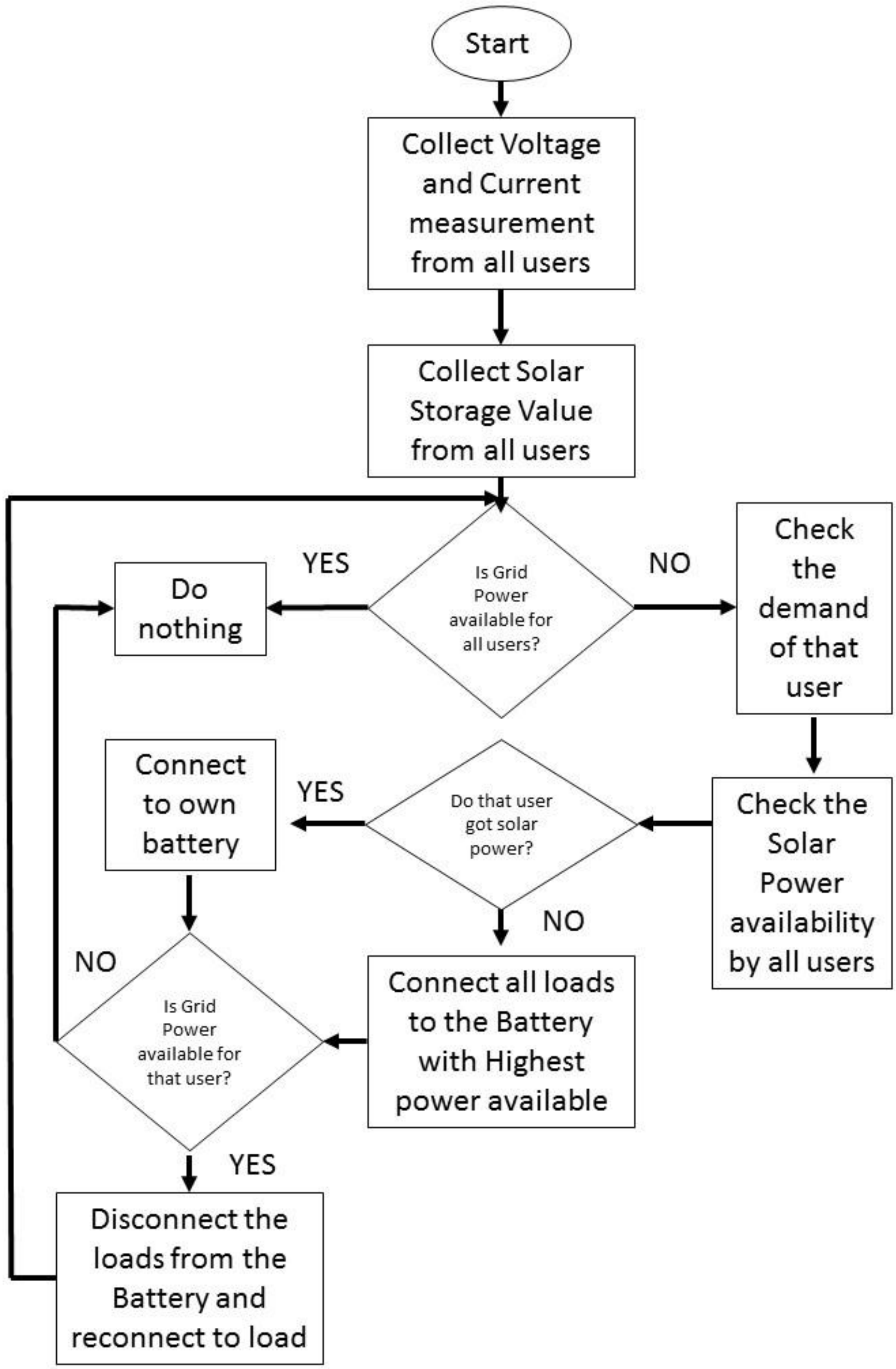
So we can divide the power distribution process in four stages.

National Grid Available:

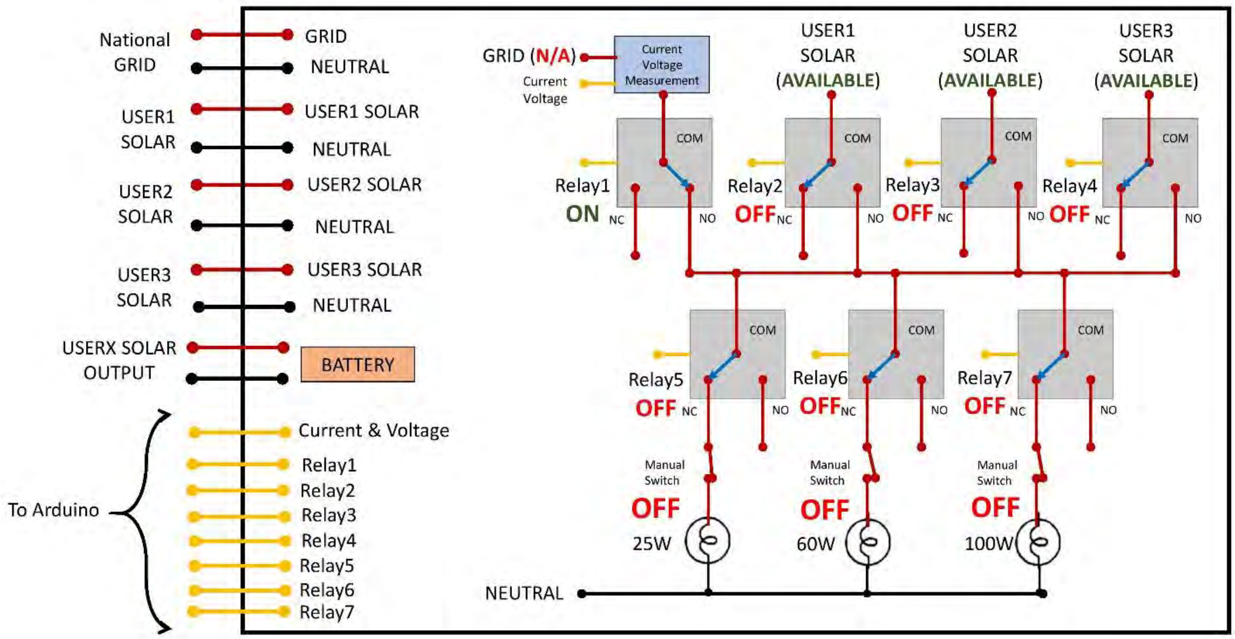


When National Grid supply is available only the Relay1 will be ON and rest of the Relays will remain off. At this moment we can control the on/off of the lights by switching the manual switch. As there are 3 more relays for each Light Bulb we can control the lights through automation. There will be a Current and voltage sensor added with the GRID LINE to send consumption data to the Control Box.

4.4.2 BLOCK DIAGRAM

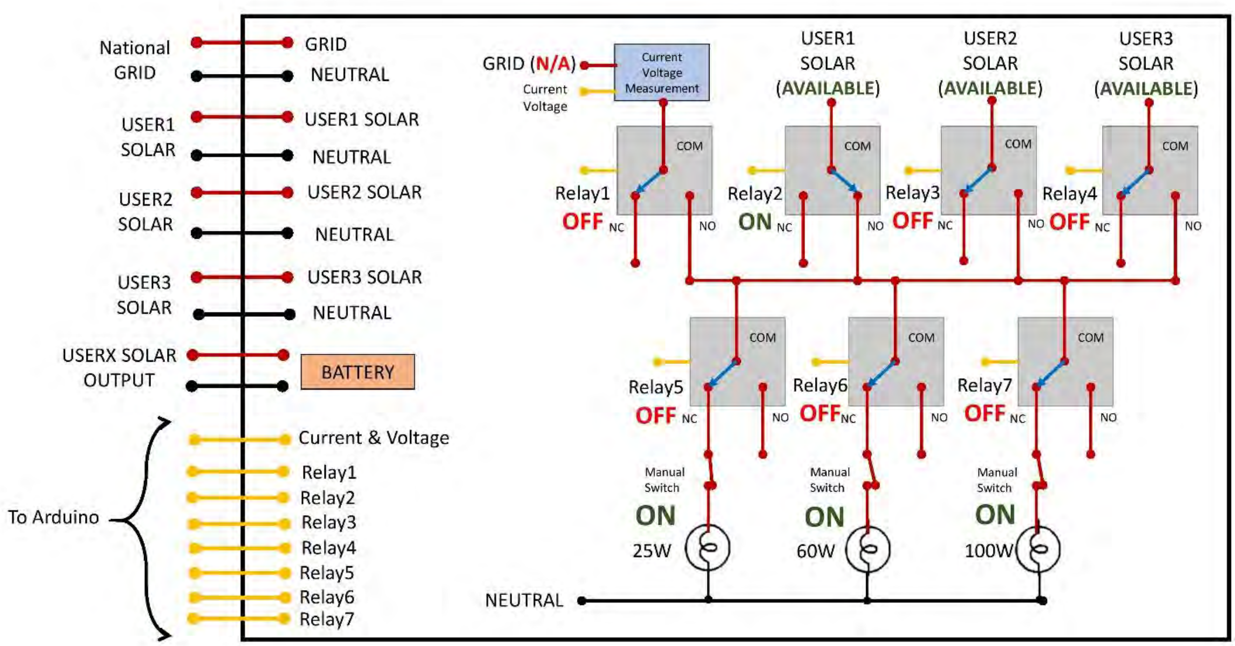


Situation 1: National Grid Available



Situation 2: National Grid Unavailable and User1 Battery Active

.



Situation 3: National Grid Unavailable and User2 Battery Active

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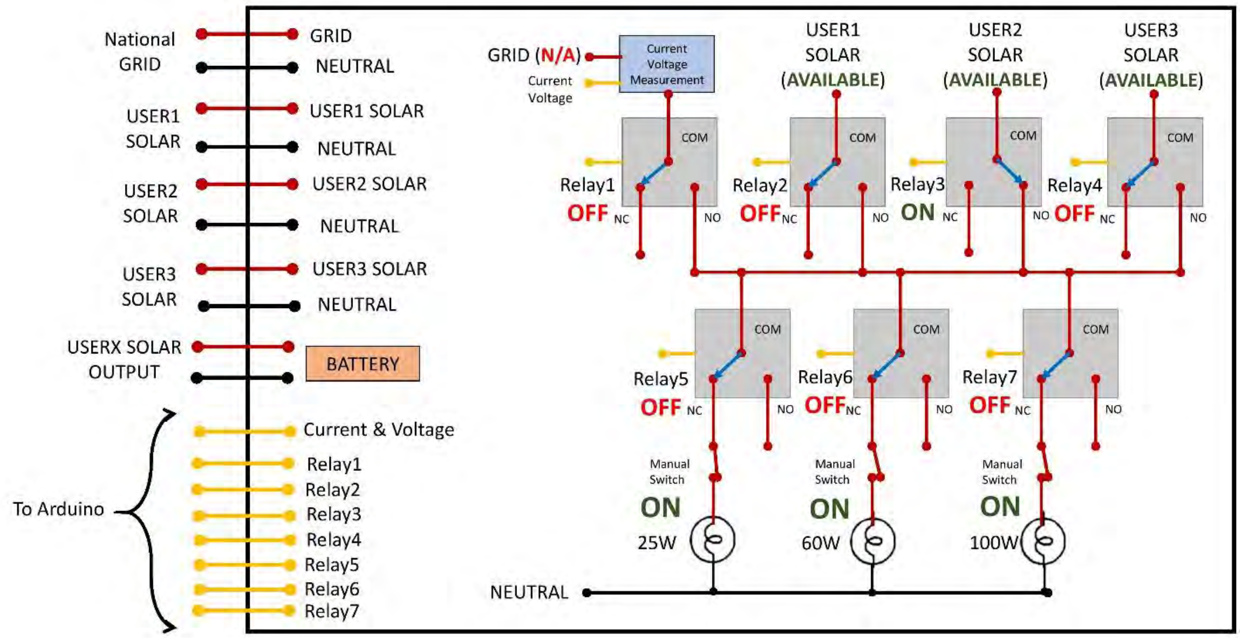

Situation 4: National Grid Unavailable and User2 Battery Active

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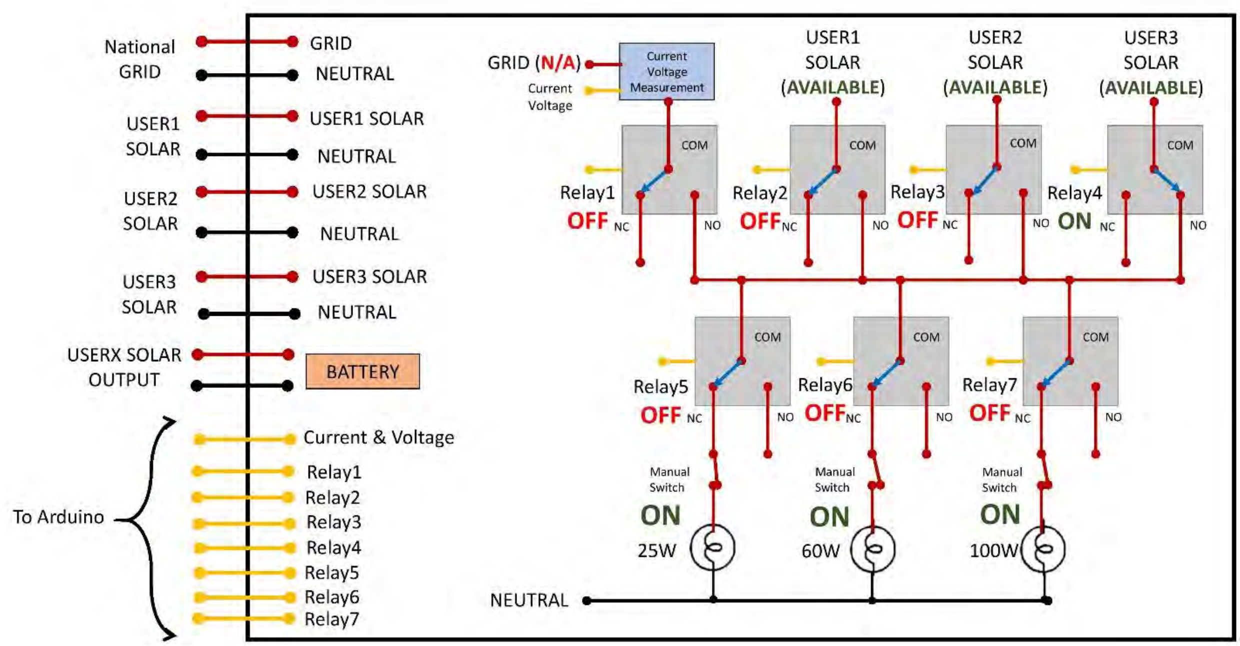

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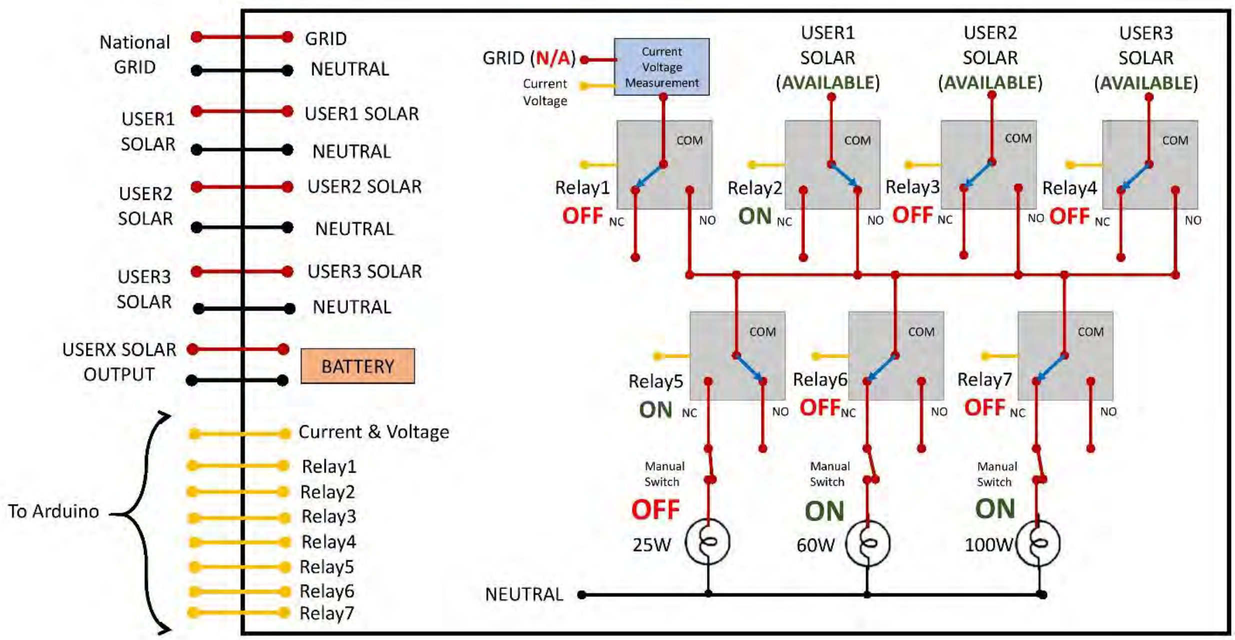

The components we are using in this circuit are:

1. Arduino: This is the brain of the smart meter by which give demand and consumption information to the smart server. In this section we are showing the consumer side connection with the Arduino. The Arduino is taking two inputs in pin D9, D3 and three outputs in pin D10, D7, D4. The inputs are mainly current measurement and voltage measurement of three bulbs. The outputs are mainly Relay Switch Command giver.
2. Relay: This is an electromagnetic switch which controls a magnetic switch depending on voltage available or not. If Arduino sends LIGHT ON command or give voltage to the relay through NPN BJT, the switch of relay will shift from NC (Normally Connected) to NO (Normally Open), which will actually turn on the light.
3. BJT: Relays need a high voltage normally from 5V-12V where Arduino's maximum voltage is only 5V. By controlling the BJT on/off with Arduino we actually control the Relay.
4. Diode: A diode is parallel connected with every Relay to make sure current is flowing through only one direction.

5. Current Measurement Device: We are using ACS712 Current sensor to measure the AC current passing through the whole circuit. The output of this device is DC, so we can connect it directly to the Arduino.
6. Voltage Measurement Device: We are using a step down transformer and rectifier to convert the AC voltage value to DC value so that we can give the voltage measurement value to the Arduino.

4.4.3 Control Server Box

The Control Box has mainly three inputs which consists the information of three consumers and three outputs which controls the Lights of each consumer.

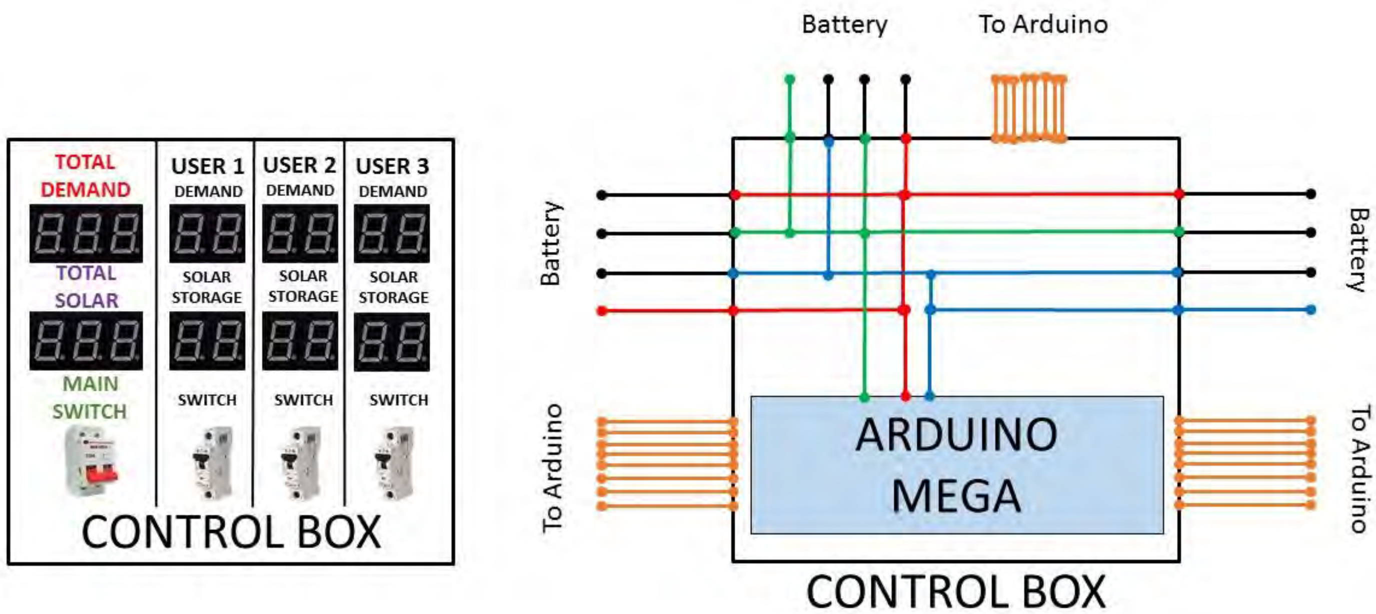

Figure 18: Control Box Top View, internal view

The control Box is mainly an Arduino which controls and interconnects the whole system. The orange colored wires directly connected to the Arduino Mega. The Battery marked wires are interconnected. Red wire represents the User1 Solar Storage, Green wire represents the User2 Solar Storage and Blue wire represents the User3 Solar Storage. The Black wires which actually comes from the red, green and blue wires are equally distributed to each of the users which we discussed earlier. A reading of each Battery Storage enters the Arduino Mega also which is shown in the picture. There are some Manual Switches in case of emergency. The main switch turns off the whole system and other switches are for individual users.

CHAPTER 5: DISCUSSIONS

5.1 LIMITATIONS

As this is an academic project we are ignoring some real life situations. We are also assuming some values like demand of each user, solar storage of each user etc. A short list of some limitations of this project is given below:

1. **Assuming demand:** As this is an academic project we cannot have the real time demand chart to implement in the system. So we are assuming some predetermined demand values so that we can find out if our system is working fine or not.
2. **Assuming solar storage:** Every user will have some renewable energy storage like battery. For this academic project using big solar storage batteries is very costly. So we are also assuming some predetermined values.
3. **Algorithm:** The algorithm we designed for this project is only applicable for three houses connected to the system. This is not going to work for four or more houses. If we want to connect more houses to the system, we need to upgrade the algorithm.
4. **Light Bulbs as Load:** In our home we have different types of loads like light, fan, television, fridge, computer etc. For this project we are only considering Light Bulbs as load. We are using three types of light bulbs depending on how much energy they consume.
5. **Using Arduino:** We are using Arduino which is controlling the whole system. If we replace the Arduino with microcontroller the price of the system will be low.

5.2 ADVANTAGES

This is a very use friendly project which will not only make our life easy but also helps us financially. The main advantages of this system is given below:

1. **Reducing Bill:** One of the main purpose of this project is to reduce the electricity bill of the user by giving renewable energy more priority over national grid. As renewable energy is free we can reduce the bill by using it as much as we can.
2. **Using Renewable Energy:** As there is a huge shortage of gas and coal, so researchers are telling us to use renewable energy as much as possible. This is going to help us financially and make our environment safe.
3. **Connecting Peoples:** In this system if user does not have any solar energy of his own, the system will automatically connect the users load with nearest user's solar storage. So it means the system is going to connect people in a whole new way. People are going to know each other by checking from whom they are now getting power.
4. **Smart Gadgets:** As this a part of Smart Grid Environment people are going to use Smart Phones to know more about their power consumption and electricity bills. So the use of smart gadgets will be influenced more by this system.

5. **Overhauls aging equipment:** In our country the electricity supply system is decades old and there is no chance of updating those until they are usable. By connecting with this system we can update this infrastructure.
6. **Decreases Load shedding:** Load shedding is a most common problem of our country. Due to this sudden cut out of power it can damage TV, Computer and other electronic system in home. By connecting with this system we can reduce the load shedding problem.

5.3 DISADVANTAGES

Like any other digital systems this system has few disadvantages too. Some of them are:

1. **System Down:** Using electronic circuits to control power is a very risky thing. Again if any part of the circuit gets damaged the whole system will fall. As a result, every single houses connected to the circuit will not get any solar power.
2. **Natural Disaster:** During natural disasters there may not be any solar power, as a result the users have to totally depend on National Grid power.
3. **No Extra Power Available:** There may be a chance that every user is using their own solar power. At this moment if any user needs to connect to others solar power than the system can't provide it any power.

5.4 FUTURE WORK

The Solar Electrified Intelligent Energy Management System is mainly proposed for a vast area. But for designing and explaining purpose we assumed only three users are connected to this system. The main purpose of this system is to make the users less depended on National Grid Power as demand is increasing day by day. As majority of the population of Bangladesh lives in villages, our first goal is to implement this system in village areas. By connecting a whole village with this system we can make the villagers totally dependent on solar and other renewable energy.

So the main possible upgrade of this work is in village areas. There are several reasons behind choosing the village areas as scope of work. Some are:

1. Village areas has huge open area or open fields in which we can easily install the Solar Panels or other resources for storing the renewable energy. On the other hand, in urban areas there are no free spaces. The only space we get to install the Solar Panels are the Rooftops which are not enough for a building full of 10-12 families.
2. Village areas has less demand than urban areas. In urban areas most people uses different type of high power consuming machines like Air-conditioner, Fridge, Washing Machine, Micro-Wave Oven etc. Where most the village peoples don't own all of these machines, as a result they have a minimum amount of demand in comparison to urban areas.

3. Village areas are suitable for the simple algorithm of the device. Urban areas are so densely populated that if we connect this device we have to design a very complex algorithm to make the system work.
4. Most of the low-earning peoples live in village areas. By implementing this device in village areas we can give them a helping hand of not paying any electricity bill, even they can get a chance of earning money by selling electricity to others.

5.5 CONCLUSION

Load shedding is such a problem that people of Bangladesh started to accept it as a daily routine rather than trying to find smart ways to solve it. In our paper we have generated a smart idea to get rid of this problem. We have designed this system for the rural areas keeping in mind that the urban areas are overpopulated and there are less space to install solar panels. Specialty of the system is that we can expand the number of users as much as we can by simply updating the code and following the load connections. The consumers will be willing to be a part of this system as, if you can sell your solar power to other consumers and get paid in return.

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APPENDIX