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Applied Smart Grid System Based on Internet of Things - Smart Street

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ABSTRACT- Smart Grid refers to technology which intelligently links electrical elements to electric grid. This provides essential basis of information accessible to both electricity providers and consumers. Smart Grid technology has very good scope in future. This is because it helps to prevent the degradation of environmental quality for human survival. For solution to the problem of greenhouse effect Smart grid helps to reduce CO2 emissions by integrating renewable energy resources to the conventional sources of electricity generation. This system helps to reduce dependency over the conventional energy resources. It provides necessary upgrades to the existing power system and networks to meet the consumer power requirements. Smart Grid helps to regulate and control the Main Grid (Conventional Grid). It provides a reliable infrastructure to the electric grid enabling improving generation, transmission and distribution efficiently. It provides a common platform for energy monitoring data to both utility and consumer with the help of Smart Meters. The energy consumption data is sent wirelessly using microcontrollers and IoT Technologies. This results to both utility and user end satisfaction. Smart grid is committed to improve economy of the nation by decreasing additional power budget for maintenance of existing grid.

KEYWORDS- Smart Grid, Conventional Grid, Main Grid, Microcontroller, Smart Meter, Internet of Things (IoT), Printed Circuit Board (PCB), System on a Chip (SoC), Application Program Interface (API).

I. INTRODUCTION

Smart grid is an integrated network of distributed energy resources. To meet the ever increasing demand of electricity conventional grid have to simultaneously operate with smart grid. Smart grid includes smart communication, power flow, ease of operation and monitoring. Smart grid effectively implements information technology to the Conventional grid. Power cut in present scenario affecting our power availability to the small domestic and industrial consumers connected to the electric grid (Main Grid).Smart grid technology provides control and integration of various small renewable sources ensures power availability up to 24x7. Smart grid system is observable to both utility and end users. With the integration of wireless communication technologies to smart grid utilities enables power monitoring by consumers and power theft also by using Smart Meters. The power usage data is available to consumers for their satisfaction and helps them to do energy audit and energy management. Using Smart Grid technology utilities can make the list of blacklisted consumers to cut off their electricity connection in case of not paying their electricity bills on dated. With the implication of IoT (Internet of Things) in Smart Grid the user is able to control their home appliances by smart phones when they are not in use or become faulty. Smart Grid is combination of digital technology and electricity grid. With the help of islanding technique utilities are able to supply the peak load demand and supply power in power cut durations. In smart grid technology distributed generation emerges called microgrids. They are basically the local grid of renewable energy resources. There are three types of microgrids: AC microgrids, DC microgrids, and Hybrid microgrids. Our proposed system is a hybrid microgrid which includes both ac and dc generation and utilization. Smart Grid also includes protective features by using intelligent electronic devices along with smart relays, circuit breakers, phase measurement units etc. Smart grid includes wide area measurement and control (WAMC) for power management in large geographical area known as Graphical Information System (GIS).

Smart Grid includes following features to the conventional (main) grid:Fast operation, Reliability, Automatic Grid operations, Greater Flexibility, Remotely operable, Higher Load Response, Wide Area Application, Smart Devices (Sensors, Meters, Storage etc.), Less dependency on fossil fuels, Highly Economic, Hybrid Systems (HVDC & HVAC),Eco-friendly and almost no emissions.

II. DEPLOYMENT OF SMART GRID SYSTEM IN CONVENTIONAL SYSTEM

Firstly we have to take an account of System Design considerations. According to various application parameters like area of implication, capacity, and size of the system to be integrated in conventional power distribution systems various designs are possible. But in street type layout houses, buildings, power converting station, power receiving units are properly placed so as to reduce faults and to reduce system implementation cost.In this system 3D design software is used to design all the shape, size, appearance of the system. Each and every block of the systems is designed so as to support Smart Grid infrastructure easily.Typical Project design is as follows:

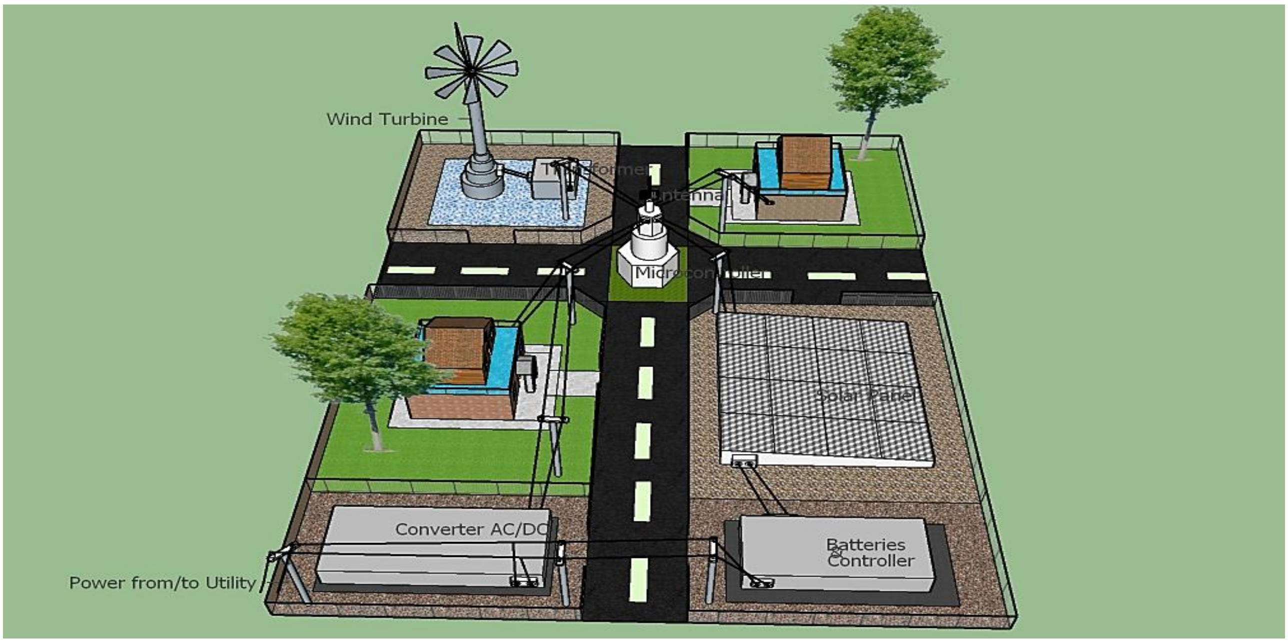

Figure 1: Project design layout

In this project various renewable energy sources such as wind, Solar and load consuming units are at same place. Power Transmission Systems are also indicated above. Power conversion and storing units are allocated in the side of utility power supply. Microcontroller takes the central position in the project system for the system reliability and simplicity. These individual blocks are separated from each other with the help of metallic fencing or some structural block. The whole project is designed in eco-friendly infrastructure and ecological blocks such as trees, bushes, grasses are placed in house blocks.

Project dimensions are as follows:

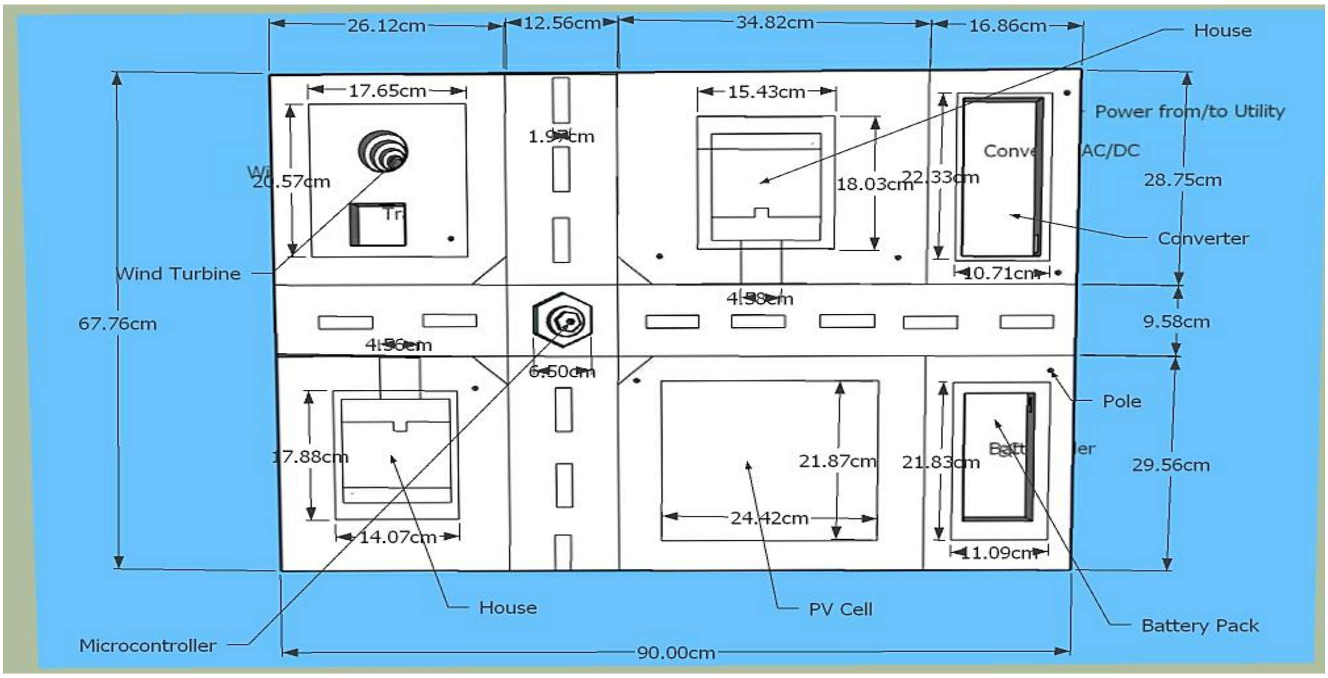

Figure 2: Project dimensions layout

After designing the project various parameters like size and dimensional issues have to simplify with the help of prototype map of each and every block of project. It is done for the ease of implementation of this project. All the dimensional parameters are taken in centimeters in this project because of economic issues for demonstration project. But for the large sized projects we can use multipliers in the dimensions to increase its range in few kilometers and beyond.

In the above figure we can analyze the various design dimensions as well as functional blocks associated with this project. Designing process helps in this project in accuracy, cost estimation, individual block designing, area of span taken by each block and various aspects of coordination with actual implementation.

III. METHODOLOGY

To implement this system on the basis of designed map, project architecture is developed. In which its functional blocks are connected in a systematic way to simplify the implementation process.

Project architecture is sketched below:

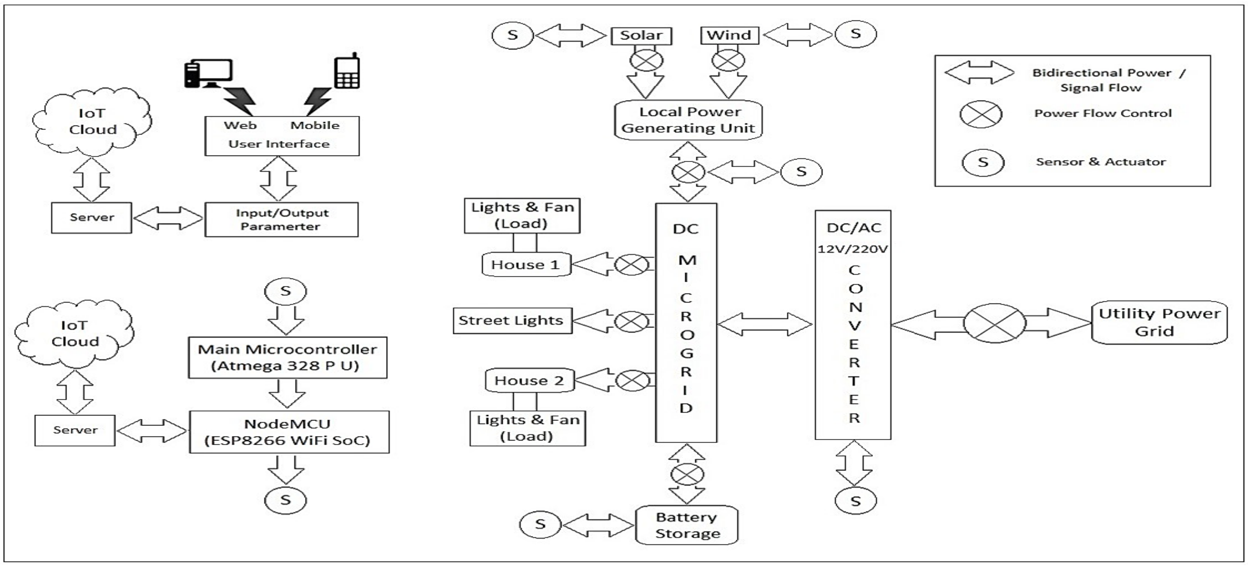

Figure 3: Block diagram of project architecture

In above architecture various project functional block such as Main microcontroller, AC/DC Converter, Local power generating units (renewable e.g. wind and solar), two houses (1 and 2 includes all necessary loads such as Lighting and Fan) are to be used. The analog values like voltage, currents are measured with the help of potential dividers and Hall Effect sensors respectively.

Current sensor and controller schematic is given below:

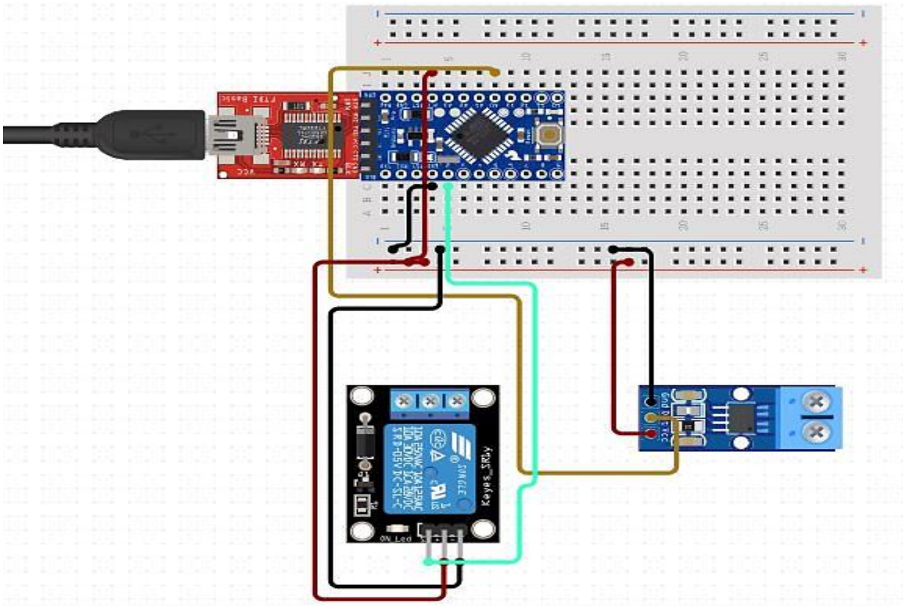

Figure 4: Sensor and controller

These sensors values are used directly as analog or digital as project need. Microcontroller used in this system is Arduino pro mini. Analog values are used to measure and sending various parameters on the internet while digital values are used to send the status of availability of solar power, wind power, utility power, Battery status (charging/discharging).IoT Technology is also used in this project. With the help of IoT all the observational and controlling features to the project. After acquisition of sensor's data by microcontroller (Arduino Uno), it sends this data to NodeMCU (ESP8266). NodeMCU is connected to a Wi-Fi network and also connected to internet. It also sends the control signal to relays for controlling various bidirectional power lines.

Controller with Wi-Fi (ESP8266) and 4-channel relay schematic:

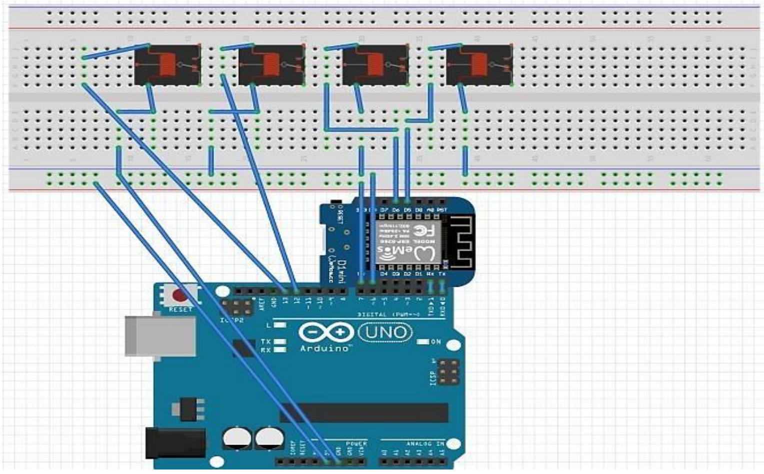

Figure 5: Controller with Wi-Fi

As above microcontroller is interfaced with ESP8266 SoC using Rx and Tx lines connected to Tx and Rx respectively. The above schematic can also be traced on PCB**,** which is important for large scale implementation of project and reduces system complexity.

PCB trace of microcontroller, Wi-Fi module and relays:

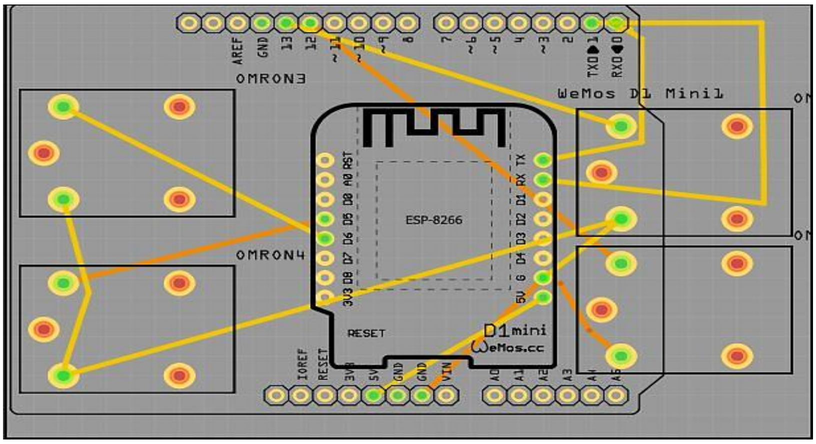

Figure 6: Microcontroller

Above is the dual layer PCB prototype in which top layer is Arduino Uno and bottom layer is of ESP-8266 with relays. For implementation of this project for commercial use many of such PCB can be either ordered or manufactured in a very cheap cost. The main advantage of dual layer PCB is that it saves space for very complex multiplexed network.

IV. HARDWARE USED

DC Motor (Geared), Shaft, Supports, Fan (Aerofoil), Solar Panel, Battery, Wireless Router, NodeMCU ESP 8266, CH340 USB to Serial, Relay Module, Wood & Hardware, Wire, Connectors and Contactors, Arduino Uno (ATmega328 P U DIP), Arduino Pro Mini (Atmega328 TQFP 5V/16Hz), Transformer 5A (12-0-12), LED Strips, PC Fan (Bedini motor), Schottky Diode, Resistors, Boost Converter, Voltage regulator LP2950 33 207 3V, Voltage regulator LM 7805 5V and Hall Effect current Sensor ACS712 are the main components are used in this project.

V. SYSTEM WORKING

The project working may be subdivided into two parts:

A. *Hardware Working*

To start project system's working a storage unit (Battery) or input mains power supply is to be connected. This results in starting of basic systems like microcontrollers, domestic loads like lights and fan, power on of relays. If input is through battery firstly then no power conditioning is required and if from supply mains then it must be stepped down with the help of transformer then with rectifier circuitry proceeded by capacitor filter. If there is absence of AC power from mains this circuitry works as inverter for conversion of DC/AC and feeds the main grid with the help of a battery. This features bidirectional power flow feature to the project which is one of essential features of Smart Grid. For this conversion of AC/DC and vice versa a circuitry must designed to acts as trigger to the inverter operation under absence of mains power and in presence it must be switched off and start working like a battery charger. To make trigger a rectifier of instrument type is used. A small valued capacitor is used to hold the charge temporarily and it energize AC/DC switch relay. Battery storage is of Lead acid type in this project but lithium ion and polymer type of batteries can also be used.

Schematic diagram of converter circuit:

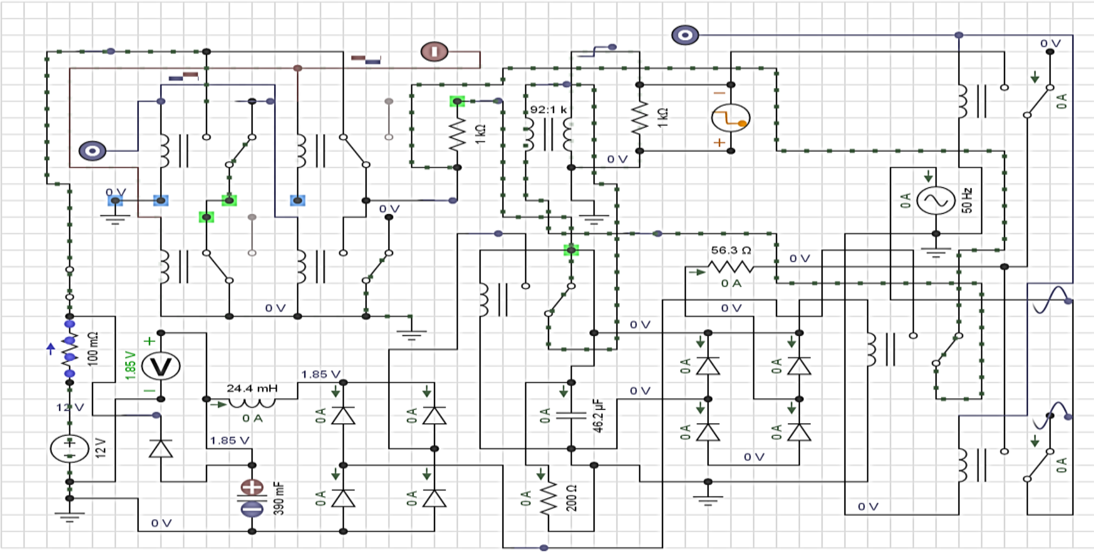

Figure 7: Converter Circuit

The circuit described above is capable of delivering 250 Watts of power output used in the project. For alternating output of current H-bridge MOSFET configuration is used in this project. Other semiconductor or electromechanical devices can also be used for switching operation. Firing circuit for these switching devices is actuated by battery storage or by instrument rectifier. The voltage divider circuit is used to measure voltage of instrument rectifier because microcontroller's analog voltage input range is 0 to 5 Volts. This value of voltage is now sent over the data lines to microcontroller which decides whether the switchover operation is to be occurred automatically or manually by user. There are total 7 voltage dividers are being used among which 2 is for domestic supply status, one for wind power status, one for solar power status, one for Storage battery to sense the overvoltage and undervoltage conditions, one for Utility power status and one for Battery charging/discharging status. There are two renewable energy resources wind and solar panel is used. In wind generator permanent magnet DC motor is used along with boost converters. It is used at wind power generator to maintain constant 12 Volt output irrespective of variable DC output voltage of generator. Solar panel system is rated as 12 Volt 10 watts. There will very uncertain conditions are present in case of solar power so a boost converter of rating 4 to 12 Volts input gives 12 Volt constant DC is used. All these renewable sources integrated to DC local microgrid and charge the storage unit when they produce excess power. In the project the power lines are made up of coated aluminum wire and signal wires are of copper coated with insulation layer of plastic. There are two relays used in house premises due to different logic levels of different microcontroller. NodeMCU have 3.3 Volt and Arduino Uno have 5 Volt logic level. In houses, energy generating units and power supplies manual switches are also introduced. If any automatic system fails then the system can be made shutdown with the help of such switches. This project consists of overcurrent protection too. With the help of ACS712 Hall effect current sensor Arduino pro mini senses the abnormalities and sends a trip command when short circuit condition occurs. After tripping the whole power supply system the microcontroller removes the trip signal at every definite time interval and increasing this time periodically. This feature incorporates the self healing operation of Smart Grid.

Hardware appearance of the project:

Figure 8: Complete hardware project

In the above hardware model Microcontrollers are placed below the National Flag. Arduino Uno and NodeMCU are stacked in the central position of the four main blocks (two Houses, Wind and Solar).For the reverse polarity protection in storage and charging system Schottky diodes are placed. In microcontroller data lines these diodes are also placed to protect the sensitive device damage. This project consumes 0.6 Ampere at no load and up to 2.5 Amperes at normal operation. Greater part of no load current is due to transformer losses. In the output side of transformer i.e. Utility Grid analog voltmeter is used to measure inverted output voltage due to presence of ripples and harmonics.

B. Software Working

This project is mainly based on internet of things. Firstly when power supply connects the system NodeMCU connects to a Wi-Fi network with the help of network id and password which is programmed in the controller. It takes 2 to 5 seconds for connecting up. After connecting with the internet NodeMCU starts reading its serial communication pins for the data coming from Arduino Uno. After each different type of data Arduino sends serially with having parity or some character of English alphabets, NodeMCU reads all data and with the help of characters it stores them in different string variables. Then these data were sent over the thingspeak channels via API keys. Channel data in thingspeak is graphical formats so it is user friendly also. This process is useful in monitoring purposes by the end user and utility. For control application Talkback function is used which is integrated feature in thingspeak. In distinct channel id different control string is to be executed on user's demand. Cyber security of smart grid system is very crucial part. To accomplish this aim a login system is to be made for authentication of users who wish to visit control page of the website. Many other pages are designed on project website to convey the essential project information, signup, login, about us and feedback page. These pages are user friendly and very responsive so that it can be loaded on any device browser.

Network infrastructure of the project:

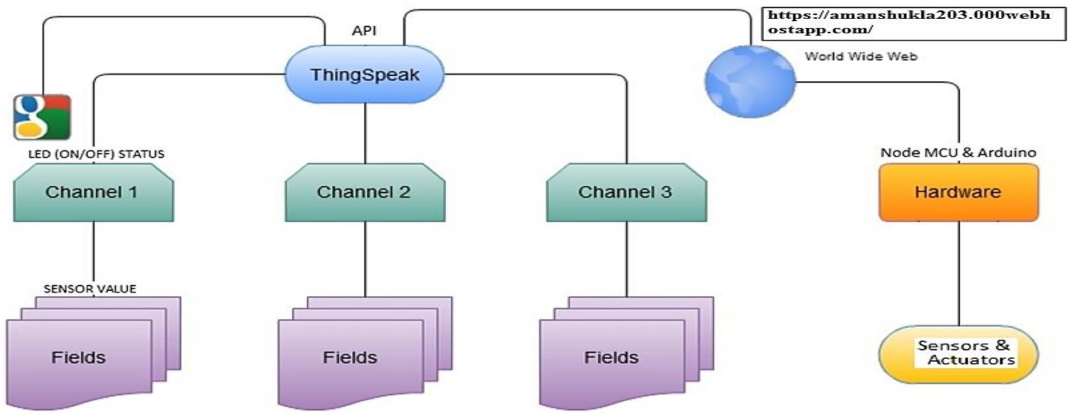

Figure 9: Network infrastructure

In above diagram all sensors' data are posted on thingspeak IOT cloud through Web Server. After reading all sensor's data user either manually decides which part of the Grid is to be under control. Protection from over current i.e. Short circuit, under voltage of the DC Microgrid and Reverse Power flow from Local Grid to Utility grid are operated automatically after reading and comparing data to pre-set values . Control Parameters like Utility Power flow, Overall DC control and Power Supply control of both two houses named 1 and 2. Data like DC grid Voltage, Current drawn from the storage and Power flow in watts are displayed on user interfaces like web and mobile. The Status tags like connection status, utility incoming status, and Wind and Solar power, Battery Status i.e. Charging / Discharging are also displayed on User Interface.With the use of HTML5 and CSS four control buttons are designed, all are checkbox type. Header and footer are designed with this feature. Various other features like iframe and better integration of JavaScript, page features not only descent looking graphs of monitoring parameters but it also features dynamic page contents to load varying parameters without refreshing the page.

Control Page of the project with URL "https://amanshukla203.000webhostapp.com/indexadmin.php":

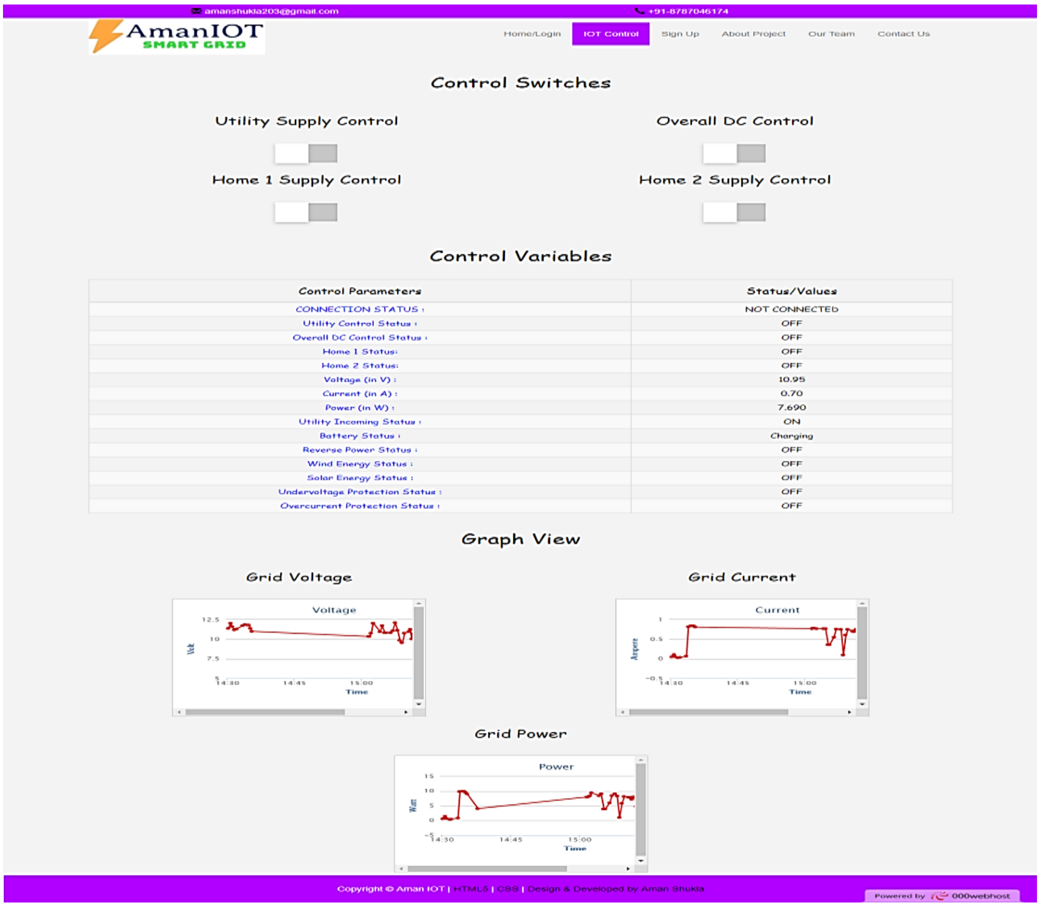

Figure 10: Control page with URL

In above control page Control variables changes their values dynamically in respective to the change in parameter changes in the hardware.

VI. CONCLUSION

This paper concludes that with the involvement of end user in power storage, production and utilization can effectively reduce the power outage durations. By using the features Smart Grid Technology such as GIS, communication, smart measurement, smart sensors, controllers and bi-directional grid capacities India can boost their economic growth as well as GDP. Phase synchronization is the technology that can meet the increasing power demand and supply surplus power with the integration of distributed renewable resources without Load Shedding. End power consumers earn profit with it, in the manner that if they deliver the electric power to grid they starts earning money or can reduce their electricity bills. Hence resulted grid system is very efficient and reliable.With the implication of IOT (Internet of Things) in Smart Grid the user is able to control their home appliances by smart phones when they are not in use or become faulty. Smart Grid is combination of digital technology and electricity grid. With the help of islanding technique utilities are able to supply the peak load demand and supply power in power cut durations.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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