Hybrid Energy Generation by Solar and Piezoelectric Sensors with Smart IoT Based Monitoring System

By

Tajdar Haider

CUI/FA16-EPE-057/ATD

Salar Iqbal

CUI/FA16-EPE-076/ATD

Abdul Samad

CUI/FA16-EPE-058/ATD

BS Thesis

In

Electrical (Power) Engineering

COMSATS University Islamabad
Abbottabad Campus-Pakistan

Spring, 2020

COMSATS University Islamabad, Abbottabad Campus

Hybrid Energy Generation by Solar and Piezoelectric Sensors with Smart IoT Based Monitoring System

A Thesis Presented to

COMSATS University Islamabad, Abbottabad Campus

In partial fulfillment of

the requirement for the

Degree of

BS Electrical (Power) Engineering

By

Tajdar Haider

CUI/FA16-EPE-057/ATD

Salar Iqbal

CUI/FA16-EPE-076/ATD

Abdul Samad

CUI/FA16-EPE-058/ATD

Spring, 2020

Hybrid Energy Generation by Solar and Piezoelectric Sensors with Smart IoT Based Monitoring System

An Under Graduate Thesis submitted to the Department of Electrical and Computer Engineering as partial fulfillment of the requirement for the award of Degree of Bachelor of Science in Electrical (Power) Engineering.

Name	Registration Number
Tajdar Haider	CUI/FA16-EPE-057/ATD
Salar Iqbal	CUI/FA16-EPE-076/ATD
Abdul Samad	CUI/FA16-EPE-058/ATD

Supervisor

Engr. Jawad Ahmad
Lecturer, Department of Electrical and
Computer Engineering
Abbottabad Campus
COMSATS University Islamabad, Abbottabad Campus

August, 2020

Final Approval

This thesis titled

Hybrid Energy Generation by Solar and Piezoelectric Sensors with Smart IoT Based Monitoring System

By

Tajdar Haider

CUI/FA16-EPE-057/ATD

Salar Iqbal

CUI/FA16-EPE-076/ATD

Abdul Samad

CUI/FA16-EPE-058/ATD

Has been approved

For the COMSATS University Islamabad, Abbottabad Campus

Supervisor: ____

Engr. Jawad Ahmad

Department of Electrical and Computer Engineering/Abbottabad Campus

HoD: ____

Dr. Imdad Khan

Department of Electrical and Computer Engineering/Abbottabad Campus

Declaration

We **Tajdar Haider (CUI/FA16-EPE-057/ATD), Salar Iqbal (CUI/FA16-EPE-076/ATD)** and **Abdul Samad (CUI/FA16-EPE-058/ATD)** hereby declare that we have produced the work presented in this thesis, during the scheduled period of study. We also declare that we have not taken any material from any source except referred to wherever due that amount of plagiarism is within acceptable range. If a violation of HEC rules on research has occurred in this thesis, we shall be liable to punishable action under the plagiarism rules of the HEC.

Date: ____________________

Signature of the Student

____
Tajdar Haider
CUI/FA16-EPE-057/ATD

Signature of the student

____
Salar Iqbal
CUI/FA16-EPE-076/ATD

Signature of the student

____
Abdul Samad
CUI/FA16-EPE-058/ATD

Certificate

It is certified that **Tajdar Haider (CUI/FA16-EPE-057/ATD), Salar Iqbal (CUI/FA16-EPE-076/ATD)** and **Abdul Samad (CUI/FA16-EPE-058/ATD)** have carried out all the work related to this report under my supervision at the Department of Electrical and Computer engineering, COMSATS University Islamabad, Abbottabad Campus and the work fulfills the requirement for award of BS degree.

Date: __________________

Supervisor:

____

Engr. Jawad Ahmad
Lecturer

Head of Department:

____

Dr. Imdad Khan, Associate Professor
Department of Electrical and Computer Engineering

DEDICATION

First and foremost, we dedicate this Thesis to Almighty Allah, without his blessings it would not have been possible for us to complete this project within the given time frame.

To our Supervisor **Jawad Ahmed** for guidance and devotion to the project which kept us zealous in our Pursuit.

To our parents and families who were there to support. They raised and taught us the value of hard work while giving of themselves in countless ways.

We are also thankful to our teachers, friends and colleagues who assisted us in many difficult barriers during this project.

May ALLAH SWT bless us all.

ACKNOWLEGDGEMENTS

In the Name of **Allah Tallah**, the Most Merciful, the Most Compassionate. The highest praise and gratitude are dedicated to Almighty God, Allah SWT who always gives the writer healthy, opportunity and guidance in finishing this undergraduate thesis.

We owe a deep debt of gratitude to our university for giving us an opportunity to complete this work. I am grateful to some people, who worked hard with us from the beginning till the completion of the present project particularly our Supervisor **Jawad Ahmad**, who have been always generous during all phases of the project. His generosity to share his ideas with us was the starting point for this work.

We would take this opportunity to say warm thanks to all of our beloved friends, who have been so supportive along the way of doing this Thesis. We would like to express our wholehearted thanks to our families for their generous support they provided us throughout our entire life and particularly through the process of pursuing the Bachelor’s degree. Because of their unconditional love and prayers, we have the chance to complete this thesis.

Last but not least, deepest thanks go to all people who took part in making this thesis real.

Tajdar Haider (CUI/FA16-EPE-057/ATD)

Salar Iqbal (CUI/FA16-EPE-076/ATD)

Abdul Samad (CUI/FA16-EPE-058/ATD

ABSTRACT

Hybrid Energy Generation by Solar and Piezoelectric Sensors with Smart IoT Based Monitoring System

IoT has turned out to be an emerging field for young researchers. It is a network of objects which are embedded through technology providing bidirectional communication support. It helps to operate and monitor the objects remotely. Hybrid and renewable sources are becoming the near future and embedding them with Iot is revolutionary for mankind. The main project is to generate Electricity from Solar and Piezo Sensors which will be stored and used to operate load. The work is done under real time by monitoring the source and load simultaneously with reasonable control. We will obtain the real time values through Arduino and monitor the load by connecting Arduino to the Android open platform Blynk App through WIFI module. The load shall be further controlled by the mobile app while connected to the Internet. It can also be operated remotely by connecting the Arduino and Mobile App to different Internet Connections. Secondary objective is to provide uninterrupted Power supply in all weather conditions. It can benefit our Environment and Society by providing Clean Energy with Cheap Methods making it Cost Efficient. Using Resources in a more productive way is the new norm of the Developed and progressive Nations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

IoT	Internet of Things
GPS	Global Positioning System
WSN	Wireless Sensor Networks
RFID	Radio Frequency Identification
PZT	Lead Zirconate Titanate
GUI	Graphical User Interface
UART	Universal Asynchronous Receiver Transmitter
ADC	Analog to Digital Converter
PVDF	Polyvinylidene DiFluoride
HRES	Hybrid Renewable Energy Systems
AVR	Audio/Video Receiver
Wi-Fi	Wireless Fidelity
VOIP	Voice Over Internet Protocol
IDE	Integrated Development Environment

Chapter 1

Introduction

1.1 Introduction

Hybrid and Renewable Energy is the main Requirement of the Modern World which is running out of Natural Resources. Hybrid system is a mixture of different renewable energy sources like solar energy, Biomass Power, Piezoelectric transducer etc. It is important to make the Renewable Energy Cost Efficient and up to the standard in order to compensate for the other Natural Resources. It is critical for the advancement of the Daily life Activities which can lead to Smart Homes and even Smart Metropolitans. Instead of relying on conventional sources of energy we need to exploit, utilize and optimize renewable sources of energy. Although, renewable sources have remain undeveloped but now a days scientist are trying to exploit and optimize these sources by inventing new harvesting technologies.

In the recent past, Smart Energy Meters and PV Panel setups have been installed in under developed Countries with low resources. Hybrid Setups are capable of providing Electricity in remote areas as well as urban locations. The initial setup maybe complex but the operational cost and issues are close to none, energy theft is bypassed by Private setups at homes while the real time monitoring and control is available 24 hours, energy saving is also a positive factor making it completely Efficient. Full access to the unlimited star light and pressure sensors is still a challenging task. The setup is intriguing yet complex in addition to the support of multiple software platforms and communication obstacles. Complete surveys and calculations are needed with keeping in mind the reserves for Emergency Loads. Involving such Independent Power Producers with the Smart Grid is complex yet achievable by total Revamp of the Electricity System in the required Areas.

To fulfill our requirements of electrical energy, we are currently dependent hugely on conventional sources. Almost 80% of our energy needs are being fulfilled by consuming such natural resources which are non-renewable like oil, coal, fossils, etc. The known reservoirs of these resources are depleting rapidly. The rate at which these resources are depleting is quite alarming. Today we are heavily dependent on such forms of energy which are derived from these resources. Our dream of being industrialized and technologized is posing threats to these resources. In order to make this world a livable place for our future generations, we really need to figure out alternate sources of energy before we completely run out of energy.

In this chapter we will be proposing a Suitable platform for the Data Communication and Operation through Modern Techniques with sole purpose of benefitting the consumer in every possible way. Interfacing of Power sources with this platform will be explained thoroughly.

1.2 Background of IoT

IoT is relatively a new idea of machines communicating with each other and observed through different methods. Machines have provided us with direct connections and communication in remote scenarios or wired connections. It can be dated back to 1830s when Telegraph was invented leading to the wireless Radio technology. It was the basic step of entering into the Domain of Communication advancements with the first Voice Transmission done in the 1900.

The Internet, itself a huge segment of the IoT, began as a component of DARPA (Defense Advanced Research Projects Agency) in 1962, and developed into ARPANET in 1969. During the 1980s, business specialist co-ops started supporting open utilization of ARPANET, permitting it to develop into our cutting edge Internet. Worldwide Positioning Satellites (GPS) turned into a reality in mid-1993, with the Department of Defense giving a stable, exceptionally practical arrangement of 24 satellites. This was immediately trailed by exclusive, business satellites being set in circle. Satellites and landlines give fundamental interchanges to a significant part of the IoT. One extra and significant segment in building up a useful IoT was IPV6's amazingly unique choice to expand address space. Steve Leibson, of the Computer History Museum, states, “The address space expansion means that we could assign an IPV6 address to every atom on the surface of the earth, and still have enough addresses left to do another 100+ earth. Put another way, we are not going to run out of internet addresses anytime soon [1].

We can say “IoT is combining data, cloud, connectivity analytics and technology in a way that enables a smart environment in which everyday objects are embedded with network connectivity in order to improve functionality and interaction” [2]. With the assistance of the relative advances, for example, Wireless Sensor Networks (WSN) and Radio Frequency Identification (RFID), sharing of data happens. So in other words we can say that IoT permits individuals and things to be associated whenever, wherever, with anything and anybody utilizing any system and any assistance as appeared in Figure 1.1.

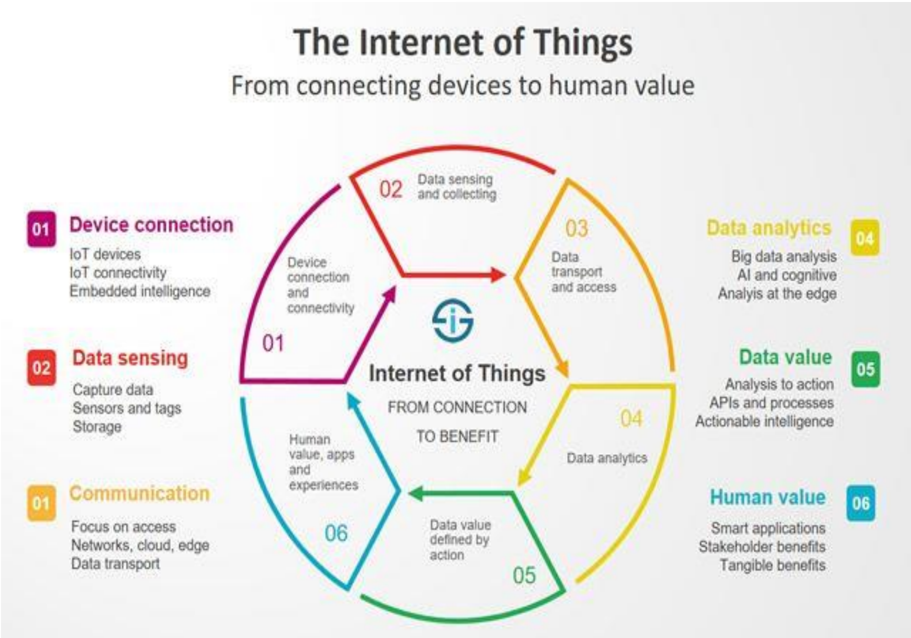

Figure 1.1: Overview of IoT

As indicated by Cisco Internet Business Solutions Group (IBSG) findings in 2003 there were 500 million gadgets associated with the web and around 6.3 billion individuals were living [13]. Vigorous development of advanced cells and tablet PCs brought the quantity of gadgets associated with the web to 12.5 billion out of 2010, while the world's human population expanded to 6.8 billion. It additionally predicts there will be roughly 25 billion gadgets associated with the web by 2015 and 50 billion by 2020 which is shown in Figure 1.2.

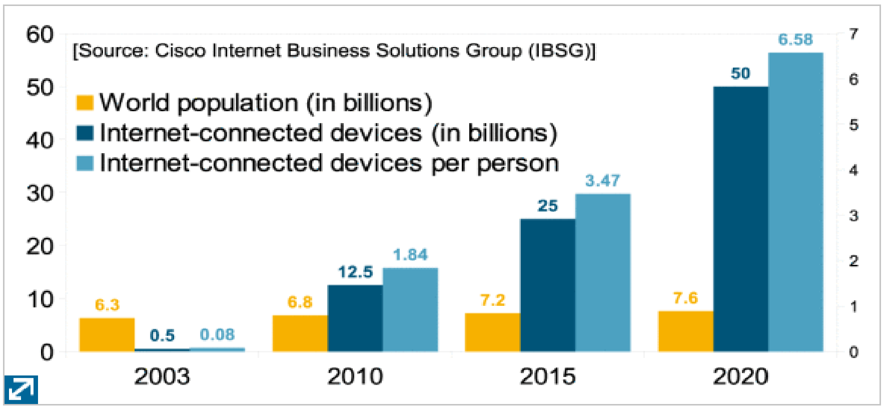

Figure 1.2: Graph of Connected Devices and Population

1.3 IoT Architecture

There is no single accord on engineering for IoT, which is concurred generally. Various Architectures have been proposed by various analysts. The most fundamental design is three-layer engineering. It was presented in the beginning phases of the research process. It has three layers, to be specific, the perception, network, and application layers.

The perception layer is the physical layer, which has sensors for detecting and assembling data about the surroundings. It detects some physical values or distinguishes other smart objects in the surroundings. The system layer is liable for interfacing with other smart things, networking devices. It is used for operating transmit and receive process. The application layer is used for conveying application explicit services to the user. It characterizes different applications in which the Internet of Things can be used, for instance, smart homes, smart urban communities, and smart medical services.

1.4 Piezoelectric Effect

Energy can be converted from one form to another form. There are many natural processes during which energy changes from one form to another. One such process is called piezoelectric effect.

In 1880, two scientists found that some crystals like quartz, Rochelle salt, tourmaline produce voltage on their surfaces when a force is exerted on them. They named this effect as piezoelectric effect. Further experiments showed that when a current is passed through these substances, they bend in a certain direction.

The piezoelectric property of a crystal depends upon the atoms and its arrangement within the crystal lattice. Initially topaz, quartz, tourmaline, and cane sugar were some of the few crystals to exhibit the property of piezoelectricity. Now many crystals are known to us who are piezoelectric in nature, some of them can even be seen in human bones.

“Piezo” is a Greek word which means “to squeeze”. A piezoelectric transducer is a sensor which on pressing generates electricity by using polarization effect. Other than voltage generation Piezoelectric sensors are being used in automotive industries, robots, control systems and in many other areas.

Piezoelectricity is a renewable source of power which does not have any harmful effect on the environment. Since it does not use any fuel to operate so it does not produce any harmful by-product such as CO_2, CO. etc.

Conventional power generating plants are polluting the environment, dangerously. On the other hand like all other renewable power generating techniques piezoelectricity is environmental friendly. Also, piezoelectric technique could be optimized to power the remote off grid areas.

Today, this technology is being vastly used in many areas. Piezoelectric crystals are used in phonographs to produce signals to reflect the stored voices in the grooves. Apart from that it is also used in street lamps.

Apart from this, piezoelectric disc are also used in water heating systems. The pressure of water acting on the disc produces the current which is used to heat up the water. It can also be used in the soles of shoes. This idea may sound silly for daily life application but it can be no less than a blessing for travelers and mountaineers to charge their gadgets. Another prospect of this project is the application of this technology in the tires of cars.

1.5 Thesis Outlines

The remaining thesis is organized in the following order:

Chapter 2-Literature Review: This chapter provides literature review of IoT based load Management systems and the insight of Hybrid Energy methods.

Chapter 3-Hardware Components and Technical Specifications: In this Chapter, the hardware components and their specifications are discussed.

Chapter 4-Project Execution and Results:

This Chapter provides execution and results of Hybrid Energy Generation and its control through IoT based Load Operations.

Chapter 5-Conclusion and Future Work: This Chapter provides the further possible advancements and conclusion of the project.

Chapter 2

Literature Review

2.1 Hybrid Energy Management

This section contains the general management of IoT based Load Management, building blocks of Piezo Electricity and Photovoltaic Generation concepts.

2.1.1 Smart Systems

With the shortcoming of electricity, it is eminent to step up towards smart and efficient energy generation through clean and effective techniques. Moreover, observing and controlling the loads on instantaneous levels makes it the ultimate successor of the conventional power systems. Since electricity consumption is growing drastically, energy monitoring and control is very fundamental. This is achieved through interfacing of smart sensors and IoT platform. The Smart Hybrid Systems consist of Hybrid Generation Sources which are connected to the open source electronic platform such as Arduino and further connected to Communication devices with the help of IoT.

Measuring the real time values of Current and voltage is done through transducers. These values are processed, conditioned and digitized through the ADC of Arduino. The internal design of the Arduino consists of MCU, digital and analog I/O pins and communication interfaces. MCU is used for generating energy measurement computation from the acquired and processed voltage and current signals. A communication interface is used to allow data exchange between the Arduino and Communication device such as Android based Mobile. Dedicated Apps like Blynk is used for providing a functional GUI.

2.1.2 Internet of Things

IoT technology empowers a lot of physical devices, sensors, and actuators to be associated through a typical system. In the couple of past years, IoT has developed immediately in research and particularly in spaces identified with smart conditions that incorporate brilliant structures, smart urban communities, and smart grids. In this specific circumstance, IoT is utilized to combine smart transducers and sensors through the Internet given that every gadget possesses an Internet Protocol (IP) address as an exceptional identifier [3].

Smart buildings are equipped with distributed IoT sensing networks that are continuously monitoring energy consumption details and keep storing this data on a server. Moreover, the energy consumption data can be visualized and analyzed to help the users to minimize the building's energy consumption. This could be achieved by following different schemes like scheduling the use of home appliances based on the peak times of energy consumption. Consequently, residents will be able to have control and management over their electricity consumption that will reduce the cost of bills and minimize the carbon footprint of the building.

2.1.3 Theory of Piezo Electricity

Piezoelectricity is emerging as a potential source of electricity. Scientists and researchers are working on this to develop an efficient piezoelectric technology. In the last two decades or so, piezoelectricity has captured a huge amount of attention from researchers all across the globe. The reason behind this interest in piezoelectricity is because of its properties like high power density, scalability and architectural simplicity. As a matter of fact, in the last 5 years, more number of publications has been published on piezoelectric energy harvesting alone than twice the number of research papers published on electromagnetic and electrostatic properties of these crystals.

When a force is applied on a piezoelectric crystal it generates an electrical potential difference. There are two types of piezoelectric effect.

- **Direct Effect**

When a piezoelectric material is subjected to mechanical forces the charges within the crystal lattice lose their symmetry. Due to this an electrical potential difference occurs on its surface. This effect is known as direct piezoelectric effect.

- **Indirect Piezoelectric Effect**

Conversely, when a potential difference is applied on piezoelectric crystal it deforms this phenomena is called indirect piezoelectric effect.

Some of the materials which exhibit the property of piezoelectricity are PbZrO3, PLZT, Quartz, Sugar, PZT, PVDF, BaTiO3, etc.

There are many Piezo and Piezoceramic materials which possess the property of piezoelectricity. Among them PZT and PVDF are being used extensively now a days because of their high power density and generating capacity. V-I characteristic of these two ceramics, when subject to different magnitude of forces, is shown in the graph below.

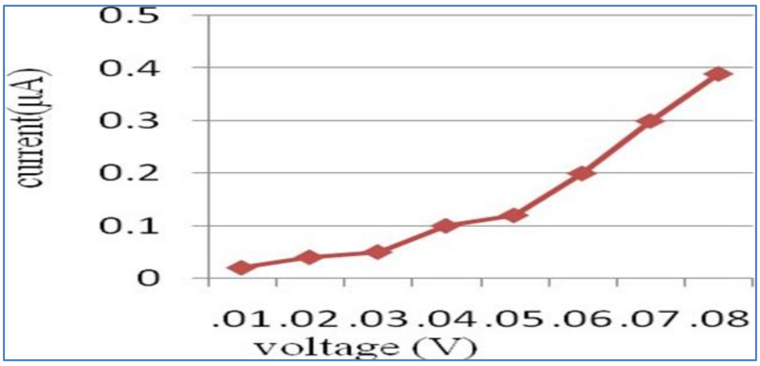

Figure 2.1: V-I characteristic of PVDF

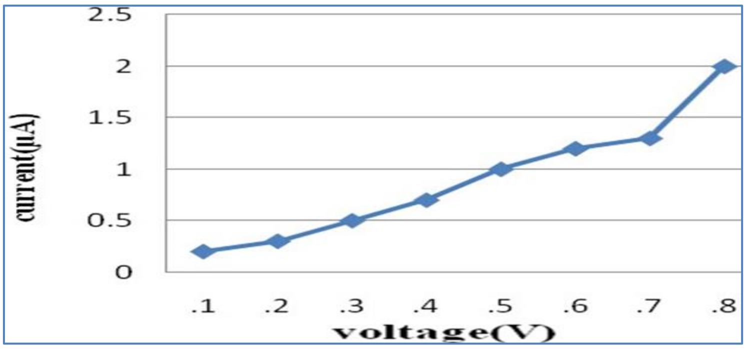

Figure 2.2: V-I characteristic of PZT

PZT or Lead Zirconate Titanate is one of the most extensively used ceramic material in the world. It is made up of Lead, Zirconium and Titanate. Its chemical formula is (Pb [Zr(x) Ti (1-x)] O3). This electrode is made up of plastic. On the outer layer of this plastic, a layer of ceramic (Sio2) is deposited. When a force is exerted on the ceramic, it converts this energy into electrical energy. The outer layer of ceramic acts as negative terminal while the metal behaves as positive terminal.

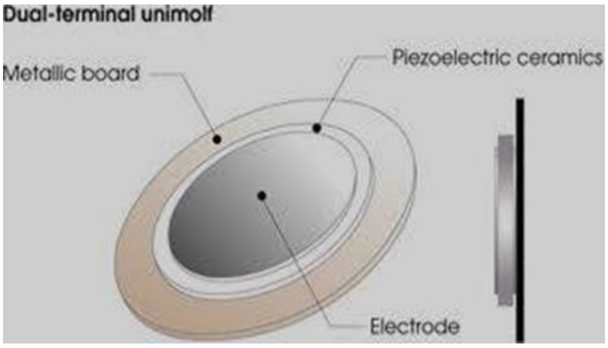

Figure 2.3: Main components on the disc

The interaction between the negative terminal and the positive terminal takes place in two different ways. If we supply current through a source to the terminals of the disc, then it will produce vibrations. This property is utilized in buzzers and speakers to produce sound. However, if no external source of current is connected to the terminal of the disc and instead the disc is compressed by applying force (such as by the vibrations of guitar strings), then electrical current is produced.

The Piezoelectric effect shown by these crystals are due to mechanical & electrical energies.

$$S = s^e T + dE$$

$$D = dT + \varepsilon^T E$$

Where “S” is the strain, “T” is the stress, “s” the strain, “d” is the piezoelectric strain “E” is the field strength, “D” is the dielectric displacement and “ε” is the permittivity of the medium.[4]

2.1.4 Photovoltaic generation

A photovoltaic (PV) system is made out of at least one sun powered panel joined with an inverter and other electrical and mechanical equipment that uses energy from the Sun to create power. PV frameworks can fluctuate significantly in size from little housetop or compact frameworks to gigantic utility-scale generation plants.

The light from the Sun, comprised of packets of energy called photons, falls onto a solar panel and makes an electric flow through a procedure called the photovoltaic impact. Each board delivers a moderately limited quantity of energy, however can be connected along with different boards to create higher measures of energy as sunlight based cluster. The power delivered from a solar panel in the form of Direct Current (DC). Albeit numerous electronic gadgets use DC power, including your telephone or PC, they are intended to work utilizing the electrical utility grid which gives (and requires) Alternating Current (AC). Along these lines, all together for the sun oriented power to be helpful it should initially be changed over from DC to AC utilizing an inverter. This AC power from the inverter would then be able to control gadgets locally, or be sent on to the electrical grid for use somewhere else.

2.2 Design Constraints

While designing a hybrid Energy Generation system with load management, one may face many problems of different types. The first and the most challenging constraint is to clearly identify the important and easily accessible features of the IoT interfaced load operation. For instance, the design and setup for simple home automation will be easy and feasible with low setup costs but for an industrial installation, it can be complex and not much feasible due to negligible advancements in the related field. The following sections represent the key points that need to be considered when designing the Hybrid Energy Systems.

2.2.1 IoT Related Constraints

Any technology accessible today has not reached to its 100 % capacity. It generally has a constraint to go. Along these lines, we can say that Internet of Things has a critical innovation in a world that can assist different advancements with reaching its exact and complete 100 % capacity too. [5]

As the Internet of things encourages a lot of advantages, it additionally makes a critical arrangement of difficulties. A portion of the IoT challenges are given beneath:

- **Security**: As the IoT frameworks are interconnected and connect over systems. The framework offers little control regardless of any security measures, and it very well may lead to different sorts of system assaults.
- **Privacy:** Even without the dynamic support on the client, the IoT framework gives significant individual information in most extreme detail.
- **Complexity:** The designing, creating, and keeping up and empowering the enormous technology to IoT framework is very complicated.

2.2.2 Instrument Characteristics and Specifications

When selecting electrical equipment, commercial comparison of available instruments in the market and instrument evaluation is done and quantitative criteria for the performance of instruments are required. The most important technical characteristics of instruments for performance evaluation can include accuracy, operating range, response time, sensitivity, resolution, and linearity. In particular, this applies to the selection of the voltage and current transducers for the signal acquisition stage of the Arduino.

Additional parameters to be considered during the selection of the transducers could be electrical constraints, mechanical constraints, thermal constraints, and environmental conditions. Although there are many types of transducers that can be used to measure basic electrical parameters, the selection of the most suitable transducer for any measurement depends on the fulfillment of some criteria to the design requirements. The common voltage measurement methods are voltage divider, voltage transformer, opto coupler, sigma-delta, and Hall Effect voltage transducers, while the common current transducers are shunt resistor, current transformer, Hall Effect, Rogowski coil, opto coupler, and sigma-delta current transducers. The selection of transducers can be done based on their applications.

2.2.3 Power Extracting units

The voltage generated by these piezoelectric discs is fairly good, however due to the poor source characteristic of these crystals; the current drawn from them is quite small. In order to extract more current from these crystals, experiments are being done on their source characteristics. Also, researches are being made to design more efficient power extracting circuits which could enable us to draw more power from these discs. Temporarily, we can overcome this problem up to some extent by using a boost converter which can boost the low voltage level.

Charge controller circuits are better when connected to the output of PV Panels in order to minimize the chances of overcharging the battery source. Better source of light energy and exposure can also result in efficient generation.

2.2.4 The d33 Coefficient

Application of External electric field deforms the crystals. Under stress free condition, the change in dimension takes place along all 3 axis. By literature study, “d” gives the amount of charge developed when a force is exerted along a certain axis.

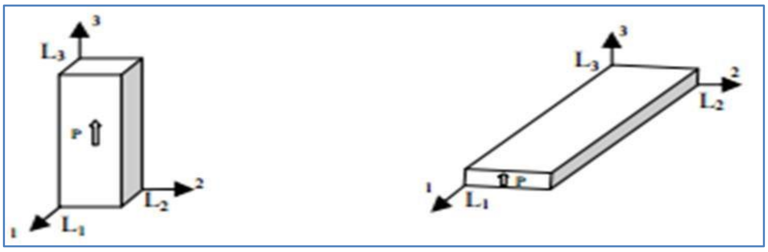

Figure 2.4: d33 and the d31 mode of a piezoelectric crystal

Serial No.	Piezoelectric Material	d33 (10^{-12} C/N)
1.	Quartz	2.3
2.	$BaTiO_3$	90
3.	$PbTiO_3$	120
4.	PZT	560
5.	PZN-9PT	2500

Table 2.1: d33 coefficient of various piezoelectric materials

The d33 coefficient shows 560×10^{-12} Coulombs of charge is produced when 1 newton of stress is exerted on the crystal. According to the literature survey, the magnitude of the stress or pressure exerted on the crystal is directly related to the amount of charge produced. Greater the magnitude of force, greater will be the amount of current produced. This means that the rate of vibration is the key factor in determining the amount of electricity produced [6].

Serial No.	Factors	Values
1.	Power	1 µW
2.	Frequency	13.9K Hz
3.	Power Density Estimated	37,037 µW/cm3
4	Acceleration	10.8

Table 2.2: d33 Characteristics of the Piezo-ceramic PZT

However, the advancement in these sensors is a non-ending process for the researchers. In Japan, piezoelectric discs are installed in some of their streets. According to a report, they are able to produce an electricity of 0.1W/sec from the footsteps of an average 60kg weighed individual.

According to some reports a company named Digital Safari Greenbiz Company has designed a 3* 5 feet panel which can produce around 17.5 Watts of energy per step.

2.2.5 Optimized HRE Systems

With the quick movement of renewable energy market, the significance of combining more sources into a Hybrid renewable energy system (HRES) has obtained more admiration. These hybrid Technologies can conquer limitations of the individual generating innovations as far as their eco-friendliness, financial aspects, unwavering quality and adaptability. One of the fundamental concerns is the speculative idea of photovoltaic (PV) and Piezo Electric sources.

Piezo electricity is not often related to the daily load patterns and maybe low in case of no displacements. Also, solar energy is only available at the day time. A hybrid system consisting of storage units with renewable generating units can highlight the issues and problems related to Renewable uncertainty and fluctuation. Huge number of random variables and boundaries in a hybrid energy system requires an advancement that most effectively measures the hybrid system parts to understand the economic, specialized and designing objectives [7].

Chapter 3

Hardware Components and Technical Specifications

3.1 Hardware

There are different components in this project like Current sensor, Voltage Sensor, Arduino Mega, Relay Board, Wi-Fi Module, Boost \converter, charge controller, Inverter, Battery and Load. The main focus will be kept on the Arduino connecting the Load with Source and interfacing sensors with IoT. The Wi-Fi module is really helpful as we can connect our System to the internet and transmit data to cellphone and receive commands from it. The amount of power produced by Piezo Sensors and PV Panels is shown on the Android App while we can control the Load from the App according to the Power Generated. By Operating Loads with such configuration, one can easily minimize the Power usage at home or other places which is vital for the Growing usage of Electricity. We should encourage such setups in order to consume fewer resources and encourage the Stake holders to invest more in the particular field. It would be beneficial for our Society and our Country equally in terms of Economics and Technology.

3.2 Current Sensor

Different amount of current is used by different devices in order to operate at full capacity and efficiency. Most of the devices at small scale are very sensitive and can get damaged when high amounts of current are passed through them. In order to avoid such situations, monitoring and control of such devices is most important. Smart Sensors when used with bidirectional open source platforms are best in such cases. ACS712 current sensor is of such type. Current flowing through the specific conductor causes a drop in voltage which is justified by ohm’s Law. In electronic circuits, the exponential rise in current can lead to overloading and damage to the devices. Measurement of current is important for the device to work properly. Voltage measurement is a passive process and can be measured directly without disturbing the circuit while current measuring is an intrusive task. For measuring current flowing in an electronic circuit, a current sensor is used with the open source platform. ACS712 is perfect for such operations and can work accordingly without any disturbances to the circuit.

ACS712 current Sensor is a completely integrated; Hall-effect based linear IC. This IC has 2.1kV RMS voltage isolated alongside a low obstruction current conductor.

3.2.1 Working Principle

The sensor detects the corresponding digital value of the analog input to the sensor. That value is either stored as digital output. The current is measured in a wire or circuit and then generates the proportional value in digital terms.

Current sensing is carried out by two ways:

- Direct method
- Indirect method

In direct sensing method, the current is measured in a wire and then calculated with Ohm’s law by measuring the voltage drop. Current carrying conductor also produces a magnetic field around it.

In the second method which is Indirect sensing, the magnetic field is measured by either applying Faradays Law or Amperes Law. Hall Effect sensor or Fiber optic sensors are used to measure the magnetic field surrounding the current carrying conductor.

ACS712 uses the indirect method of sensing. A Low offset linear Hall Effect Sensor is mounted on the top of the copper conduction when observed. When the current is passed through this conduction path, the resulting magnetic field is sensed and measured by the Hall Effect Sensor and thus a proportional voltage value is obtained for current measurement.

The availability of the magnetic field to the Hall Sensor is the key to accuracy in this process. Nearer the field, the greater will be the accuracy of the Sensor. These sensors are available in small size with surface mount ability. In this IC, the current flows from Pin1 and Pin2 towards Pin3 and Pin4 forming the conduction path where the value is measured. It is a device of easy handling and operation.

These sensors can be used in circuits with electrical isolation as the terminals are isolated from the IC Leads. No further isolation techniques are required for safety purposes. Supply voltage required for IC is 5V while it can provide AC or DC Current with almost no Hysteresis Losses.

Pin 1 to Pin 4 forms the conduction path, pin 5 is the signal ground Pin and Pin 6 is the filter pin that is used for bandwidth calculation through an external capacitor. Pin 7 is the pin for Analog Output while Pin 8 is used for giving power supply to the IC [8].

3.2.2 Applications of ACS712

This IC has the capability to measure both AC and DC Current which makes it versatile in usage. It is used in Peak detection Circuits, High Gain Circuits, overcurrent circuits and Rectification circuits for Analog to Digital Converters. The filter pin is used to remove the Attenuation in the Resistor Divider Operation. This IC can measure current for high voltage loads operating at 230V AC. ACS712 is shown in Figure 3.1

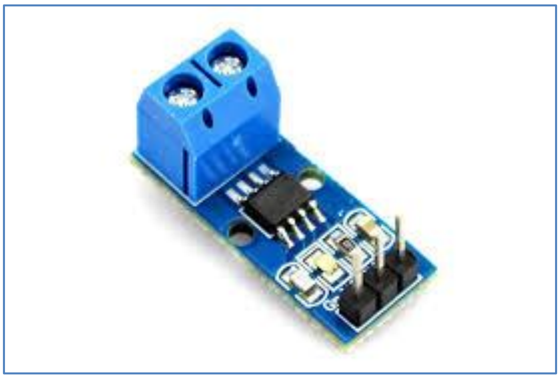

Figure 3.1: Current Sensor

The ACS712 current module is designed for the purpose of sensing AC or DC current accurately through the built in package. The maximum values of AC or DC can reach up to a maximum of 5A and the present analog value can be read through the Analog I/O pin of the Arduino Board. Some of specifications of the sensor are given below;

- Voltage ~ 4.5V up to 5.5V
- Current ~ -20A up to 20A
- Sensitivity ~ up to 100mV/A

\

3.3 Voltage Sensor

The Voltage Sensor ZMPT101B is a one of its kind sensor which is easy to use in DIY projects. Accurate calculation of AC voltage is necessary for such projects and setups with no chance of discrepancy. This IC is ideal for the open platforms like Arduino and Raspberry pie when interfaced with each other. Engineers deal with exact measurements in projects with keeping in mind about some particular aspects mentioned below;

- Complete Galvanic Isolation
- High Accuracy
- Broad Range
- Consistency
- Easy Availability

ZMPT 101B is a précised and up to mark voltage Transformer which can easily monitor and measure values up to 1000V in circuits. The sensor is shown in the image below while the prominent specifications of the sensor are listed below in the Table 3.1.

Figure 3.2: ZMPT101B with Pin Configuration

The operational details of the ZMPT101B are mentioned in the Table on the next page while interfacing the Sensor with Arduino or Raspberry Pie is a separate process [9].

Model	ZMPT 101B
Rated input current	2mA
Rated output current	2mA
Operating range	0-1000V , 0-10mA(resistor 100 ohms)
Linearity	≤0.2%(20%dot~120%dot)
Isolation Voltage	4000V
Operating temperature	-40℃~+6
Turn ratio	1000:1000
Permission-able error	-0.3%≤ f ≤+0.2%（input 2mA, resistor 100Ω）

Table 3.1: Standard Specifications of ZMPT101B

3.4 Relay Module

Relay is an Electrical Device used generally as a safety device or switching device in circuits. It is generally divided into two parts which are; input contacts or input part and output contacts or output part. It is frequently used in automated circuits where optimum solutions are required. In short, it is a switch which controls a high current with a significant low amount of electric signal. The device used in this project is a 5V 4 channel relay with maximum 4 relays at work. It can be controlled directly through platforms like Arduino, PIC, Raspberry Pie, AVR and much more.

There are total 4 Relays in this module with ports mentioned as NC (normally connected to Com) and NO (normally open to Com). LEDs connected with each relay can indicate the status of the Relay.

The advantages of relay are in its non-moving parts, stability, long term reliability and compact structure. It is widely used in automation technologies, protection schemes, communication and reconnaissance setups, sports technology, power electronics and electro mechanical circuits. In general a relay contains an inductor which can reflect the value of input parameter such as voltage, resistance, power etc. It also contains a secondary side which can control the energizing or de-energizing of the control circuit. There is an intermediate part which isolates and couples the input current.

When the rated value of input parameter increases the threshold, it will be either energized or de-energized [10].

Some features of relays are given below;

- In high voltage or power systems, the high current is controlled through low current and signals which provides maximum safety for the procedure.
- High voltage system output with 4 channels meeting the needs of a single channel control
- Controllable voltages of wide range
- High load currents can be controlled up to 240V/10A
- Normally open(NO) and Normally closed(NC) contacts making it easy to use

The specifications of relay are listed:

- Module Type: Control.
- Weight: 70 gram
- Level of operation: 5V Digital.
- Input power: 5V external.

Figure 3.3: 4-Channel Relay module

3.5 Wi-Fi Module

The Wi-Fi module ESP8266 is a SOC (System on chip) type device which is integrated with TCP/IP protocols giving access of internet to any Microchip IC’s. The ESP8266 is able to share the data from Microchip to any external device or receive any data from external device and send it to the Microchip or related platforms. These modules are usually preprogrammed for AT commands firmware making it simple and easy to access Wi-Fi in simple steps. The ESP8266 Wi-Fi module is a cheap and reliable device for Smart Electronic setups with ever-growing users worldwide [4].

The module is equipped with a powerful processor and a sufficient memory chip to make the interfacing of sensors and devices easy and fast. The unique and effective chip integration makes it compact with minimal external circuitry including the front end design of limited PCB area. It gives support to APSD (Automatic Power Save Delivery) for VoIP (Voice over Internet Protocol) applications with Bluetooth services, contains a self-calibrated RF (radio frequency) settings for operation in every conditions limiting the usage of External RF devices. This module is surely transforming the digital world and making it easy for everyone to digitize their surroundings. It can be used with any application which needs access to the local area network for operation having a flash memory of 1mb making it enough for the given purpose.

Figure 3.4: ESP8266 Wi-Fi Module

3.6 Arduino Mega 2560

Arduino Mega 2560 is a Microcontroller type board which is based on AT Mega 2560 technology. It has a staggering total of 54 Digital I/O pins of which 14 can be used for a PWM output, 16 analog inputs, 4 UARTs (Hardware serial ports), a 16 MHz crystal oscillator, USB connection, power jack, ICSP header and a reset button. It simply is equipped with everything which makes it perfect for connecting to the computer and powering it with an AC/DC adapter or a battery.

It can be powered with a USB cable or external source. The power source is selected automatically. External power can come from an AC/DC adapter or a simple battery source. The adapter can be connected by 2.1mm center oriented plug into the power jack. Leads from the battery can be connected to the ground and Vin terminals for operation. The external supply of 6-20V can be enough for the board however if less than 7V the 5V pin may supply less which can make the board unstable. Using voltage in access of 12V can overheat the board and the regulator. The recommended range of operation should be between 7 and 12V. It differs from every other board because it does not use FTDI USB to Serial Drive Chip. It features the Atmega8U2 programmed as a USB-to-serial converter. The power pins are as follows:

- **VIN**: Supplies the board with external source can be powered also from a USB jack if used.
- **5V**: A Regulated power supply used to power up the Micro controller and other devices on the board. It can be powered from VIN via regulator or from a USB 5V source.
- **3.3V**: A minimum available voltage generated by the on board regulator which draws up to a maximum value of 50mA. Can be Used to drive Wi-Fi modules like ESP8266.
- **GND**: Ground pins

There is a total of 256 KB flash memory for storing the code in AT mega 2560, further divided in to 8 KB for boot loader, 8 KB of SRAM and 4 KB for EEPROM. All 54 Digital pins can be used as Input/output pins using the simple commands like pinMode(), digitalWrite() and digitalRead () functions from the library. They are operated at 5V with every pin capable of supplying or taking a maximum of 40mA and are connected to a pull-up resistor of 20-50 KOhms.

Some pins have special functions and they are listed below:

- **Serial, Serial 1, Serial 2, Serial 3:** 0 (RX), 1 (TX); 19 (RX), 18 (TX); 17 (RX), 16 (TX); 15 (RX), 14 (TX). Pin 0 and Pin 1 are also connected with USB-TTL serial chip.
- **Interrupts:** The pins can be configured to make an interrupt on rise or fall edge, low value or change in the value. A total of six interrupts namely interrupt 0, interrupt1, interrupt 5, interrupt 4, interrupt 3, interrupt 2. They are connected with 2, 3,18,19,20 and 21 number pins respectively. The function of attachInterrupt() can be used.
- **SPI:** The pins offer support to the SPI communication which is still not included in the Arduino language. 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS) are the pin numbers for the SPI operation.
- **PWM:** There are a total of 14 pins for the PWM output starting from 0 up to 13. The command is analogWrite().
- **LED:** Built in LED is connected to the pin number 13 which indicates high value when on and vice versa for when a low value appears at the pin.
- **AREF:** It is used for reference voltage at analog Inputs. Can be used by analogReference() function.
- **Reset:** Used to reset the Microcontroller when a low value is passed to it.

There a total of 16 analog Input pins with every pin capable of providing 10 bits resolution making it 1024 unique values. The default configuration is from 0 to 5V but it can be increased by using the analogReference (Aqe18) () function [11].

Figure 3.5: Arduino Mega 2560

There are a number of facilities in connecting Arduino Mega2560 with a PC, Arduino to Arduino or other Pic type microcontrollers. There are 4 UARTs for TTL (Transistor-Transistor logic) pins of 5V for serial communication.it incorporates a USB port which is used for Virtual com port connecting to the software on a PC. Serial monitors in the software allow you to send text from the board or receive it. LEDs for RX/TX will flash when data is being serially sent or received through USB and PC connection. While the Pin 0 and pin1 are exempted from LED indication. Key specifications are given in the Table 3.2 below.

Microcontroller	AT mega2560
Operating Voltage	5V
Input Voltage	7V-12V
Input Voltage	6V-20V
Digital I/O Pins	54 (of which 14 provide PWM output)
Analog Input Pins	16
DC current per Pin	40 mA
DC current for 3.3V Pin	50 mA
Flash Memory	256 KB

Table 3.2: AT Mega2560 Specifications

3.7 Boost Converter

This specific DC-DC boost converter can supply up to 4A of load with super line and load regulatory performance. IC XL6009 is available in many output ranges like 3.3V, 5V, 12V or an adjustable output version of it. The efficient output and excellent switching regulatory makes it better from the other available Boost ICs. The board is capable of operating at 400 KHz even at higher input values making it compact and efficient.

The switching frequency for the used model of XL6009 is 400 KHz which makes the filter size smaller on this specific device. This is a significant advantage over low frequency devices. It is a new version of LM2577 module [12].

Pin	Function
IN+	Regulated or Unregulated Power input
IN-	Ground for negative input
OUT+	Regulated output power
OUT-	Ground for negative input

Table 3.3: Pin configuration for XL6009

The features and key specifications of the XL6009 module are given below:

- 3 to 32V of input voltage
- Adjustable out of 5 to 35V
- Max output current of 4A
- Load current increases with High Voltages
- Up to 94% efficiency
- 0.5% load and voltage regulation
- Output voltage adjusted by built in potentiometer

Figure 3.6: DC-DC Boost converter XL6009

3.8 Charge Controller

A solar charge controller is generally a controller or limiter used to control the voltage and current required for charging batteries. This prevents the overcharging of batteries in case of PV panels. The normal voltage of PV panels is about 16 to 20V which can easily damage charging of the batteries. Regulation of charge into the batteries is of utmost importance in this case. Batteries generally require up to 14V charging completely. The positive point of such device lies in the fact that it is available in numerous sizes and costs with extra features.

3.8.1 Features and Function

- Protection of the 12V battery from Overcharging
- Increases the total lifespan of the battery by reducing maintenance
- High reliability
- Ranging current from 10A to 40A
- Blocks the reverse current flow

The most important function of the Charge controller is to control the voltage flow and disconnecting the circuit when the battery voltage level exceeds a certain defined value. There are some charge controllers which are incorporated with mechanical relays for opening or closing a circuit in case of High loads.

12V batteries are well known to be used with the PV panels in normal operations while the panel can provide voltage in excess of that. One can configure the output by using this controller in order to charge the battery in less time and with greater efficiency. This allows the system work without any disturbance or interruption. The main part of the Charge controller used in this case is the L8712CV fixed positive 12V IC. It restricts the output to 12V for batteries. 7812 is a part of 78XX voltage regulator family, the XX is replaced with the value of output voltage is supplies. Its main applications include circuits requiring 12V steady supply, high specific voltage sensitivity circuits, using with varying voltage supplies (in our case the PV panel).

This IC is used with capacitors for filtering purpose with the PV panels. The output from the PV panel is connected to the input of charge controllers. The input can vary from14.5V up to 35V DC. The output of this controller is connected with the battery. The current output is about 1.5A.

3.8.2 Applications

In recent times, the usage of energy obtained from the sunlight is advancing on a mega scale all over the world. Renewable sources like Solar and wind power are taking over the classical and conventional resources. They are pollution free and easy to use with minimal complications.

Street lights equipped with solar panels can be assisted by using these type of controllers for better and economic operation. Home automation systems can use an advanced charge controller for diverse operations and indications. It is indeed the backbone of the Hybrid systems.

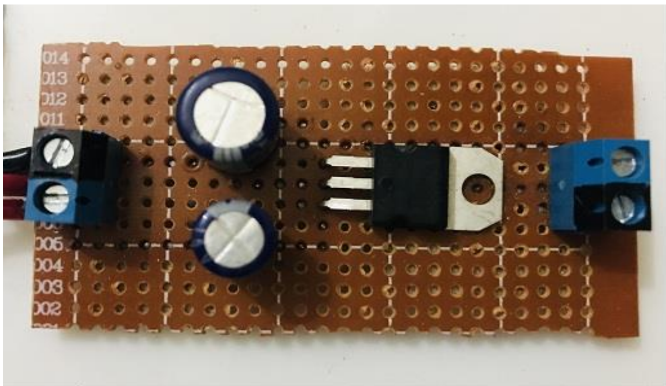

Figure 3.7: DIY Charge controller

3.9 Inverter and Battery

A 12V battery is a perfect choice for a Hybrid project in our case. It is connected to the sensor board and PV panels. It further supplies DC supply to the Arduino and connected to the load through inverter.

Power inverter is used with the battery to invert DC to AC. Designing an inverter is a complex task. Many types of inverters are available and can be chosen according the load and desired frequency. We have used a simple 200 Watt inverter.

3.10 Solar and Piezo Panel:

A solar or PV panel is a collection of many solar cells arranged in a pattern of series connection to work on maximum efficiency. It uses ohmic material for the connections between the cells and also on the external terminals. The electrons created in the n-type material passes through the connections to the battery and from there they reach the p-type material holes. When we connect a solar panel to a battery it acts as a battery source in series with the other. The out of the panel is connected to a MOSFET switch which is further given to battery. In case of overcharge, the power from the solar panel is passed through the Mosfet. In case of very low power, the supply to the Mosfet switch is cutoff hence breaking the supply to the load.

75 Watt solar panel is used with a charge controller circuit in order to work on optimum level. The specs of panel are given below:

- Max Power: 75 W (+/-5 %)
- Short circuit current: 4.76A
- Max power current: 4.41A
- Max voltage: 17V
- Open Circuit voltage: 21V
- Type: Mono Crystalline
- Frame: Aluminum

Figure 3.8: 75 Watt PV Panel

The most important component of our project is the piezoelectric disc. There are many Piezo ceramics which exhibit the property of piezoelectricity. For our project, we studied the behavior of two of the most widely used piezoelectric ceramics PZT and PVDF. The criteria set for selection was the maximum value of voltage for different magnitudes of pressure. PZT was the better of these two after studying these two. The output voltage of a PZT transducer was about 2V while of the PVDF was 0.4V.

The concept and operation of a Piezo sensor was discussed before. To obtain the maximum output from the sensors, series and parallel combinations were checked with some interesting results. In a series combination, the Voltage was good but the value of current was small. In parallel combination, the voltage level was not so good but the current was good. To improve the voltage levels, boost converter was used with the output of the Piezo sensor board which increases its voltage to constant 12V DC.

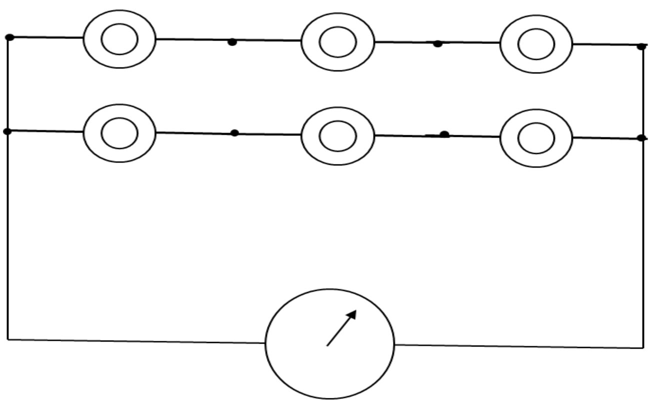

Figure 3.9: Cascaded arrangement of Piezo Sensors

The sensor arrangement was attached on an Acrylic sheet sandwiching the sensors from both sides. This provides the normal space for pressing the sensors and equally divides the force over all sensors in the arrangement. The sheets are weather proof and shatter proof. It’s less in weight and can be useful for such purposes.

Figure 3.10: Piezo Sensor Board

Chapter 4

Project Execution and Results

4.1 Implementation

Initially, the software simulation is performed to understand the nature of the devices which are going to be arranged into a circuit for Hardware operation. However, sensors like Voltage and Current sensors are unable to operate in the simulation. This is required to observe the relay operation with Arduino.

The idea of using Piezo is intriguing yet complex in its nature. The PZT cells are arranged in parallel arrangement and the combined output of the cells is given to the input of Boost circuit. The cells were attached symmetrically on the surface of an Acrylic Sheet. This sheet gives a solid support to the arrangement while plane cork pieces are attached in the same symmetry on another sheet. The Sensor arrangement is sandwiched between the Acrylic sheets and the corners of the Double sheets are drilled and fitted with bolts. Springs are added before tightening the screws which brings the Upper sheet back to its place when the pressure is removed from top of the sheet.

The output of the PV panel is given to Charge Controller which is used to regulate the Voltage form variable value to a fixed 12V DC output. The outputs of both Piezo and PV Panel are supplied to the 12V DC battery with 20 AH current ratings. The battery charges with both of these sources when available. In order to charge the battery with Piezo Sensors, pressure is applied on top of it and kept constant for some time then released. The crystals produce a considerable amount of charge with a Boosted 12V DC. The Solar panel also charges the battery in the presence of sunlight when available.

The battery is used to supply voltage to the Arduino, Voltage sensor and 4-channel Relay Module through 7805 Voltage regulators. The 5V output of Arduino is given to the current sensor however it can be operated with the battery. The 3.3V output of Arduino Mega is given to the ESP8266 Wi-Fi module. The communication pins RX/TX of Arduino are connected to the Wi-Fi module for information and command exchange. Analog input pins of the Voltage and Current sensors are given to the Analog port of Arduino. The Relay Module is connected to the digital output pins of Arduino.

A 200 Watt inverter is connected to the battery output supplying 220V AC to the three test Loads which in our case are 60 Watt bulbs. The loads are also connected to each of the 3 Relays in the module while the 4th relay is left for further use. AC output from the inverter is given to the connected current and voltage Sensors in order to measure total current and voltage for power calculations.

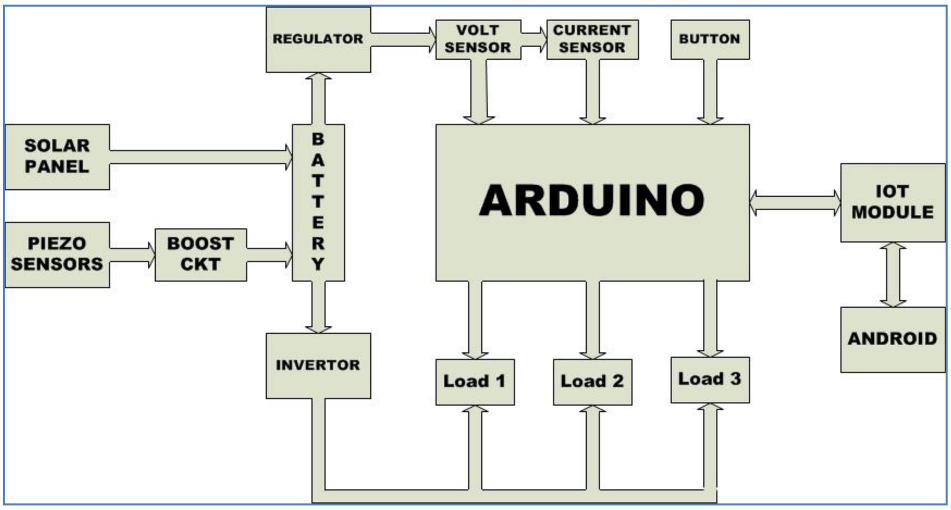

Figure 4.1: Block Diagram

4.2 IoT and Coding

In our case, a fully functional code is required for running the hardware of the project and monitoring through IoT. The libraries of ESP8266 are added to the Arduino IDE and the SSID credentials of the Wi-Fi source for ESP8266 are written. The Blynk app is serially connected with a specific Baud Rate and executes the commands; refreshes data after a significant defined delay. The pin numbers are defined and voltage value of 220V with a fix tariff of Rs. 25/ unit is entered in the main setup of the program. A main loop runs continuously while the circuit is connected to the load and sources. The Blynk App constantly monitors the data and updates the values accordingly. The values of current and voltage from the analog inputs are used to calculate power and display it. The whole process is divided into functions which are repeated in a loop for continuous readings. Load can be connected or disconnected by constantly monitoring the high/low status of the digital pins from the App. The calculation of power and bill is explained below with their formulas.

$$Power = Voltage \times Current$$

The value of fixed voltage which is 220V is multiplied within the code with the instantaneous value of Current. The value of current drawn is dependent on the Load being used. In case of a 60 watt bulb, the current drawn is 0.27 A. the value gets updated when a load is added or turned off.

The criteria of calculating bill is based on Watt-hours consumed every 2 sec. the final value is converted into Kilowatt-hours and multiplied with the flat unit rate of Rs. 25/KWh. The final value is updated after every 2 seconds in the App depending on the load.

$$Wh = power \times \frac{2}{3600}$$

$$KWh = \frac{Wh}{1000}$$

$$Total\ Charges = KWh \times 25$$

4.2.1 Blynk App operation

Blynk App was basically designed for the purpose of IoT. It is used to control and monitor the hardware remotely with ease and effectiveness. It can display and store the data from the sensors. The setup is divided into three parts which are Blynk App, Blynk servers and Blynk Libraries. The App gives you the full control of designing an interface for your operations. The cloud server stores and directs the data to the designated location. The libraries are used in the Arduino, Raspberry Pie or other IDEs. Every time a button is pressed in the App, the message enters the cloud server and finds its way to the hardware. The connection to the cloud can be given through Wi-Fi, Bluetooth or Ethernet.

After creating an account in the App, GUI with simple drag and drop is easy to follow for the project. In our case three buttons were assigned to the digital pin numbers on the Arduino board. “On” status of button means a high signal from the app which reaches the Arduino through ESP8266 module and operates the relay. The load switches on with minimum delay and can be controlled from a remote area.

Similarly, the data from the sensors is used to display on the Blynk App screen using digitalwrite command. The program in the Arduino keeps checking the values and sends it over the cloud to the App. It's one of the most used Apps for IoT operations. The silky interface with no pre-coding requirements makes it a perfect choice.

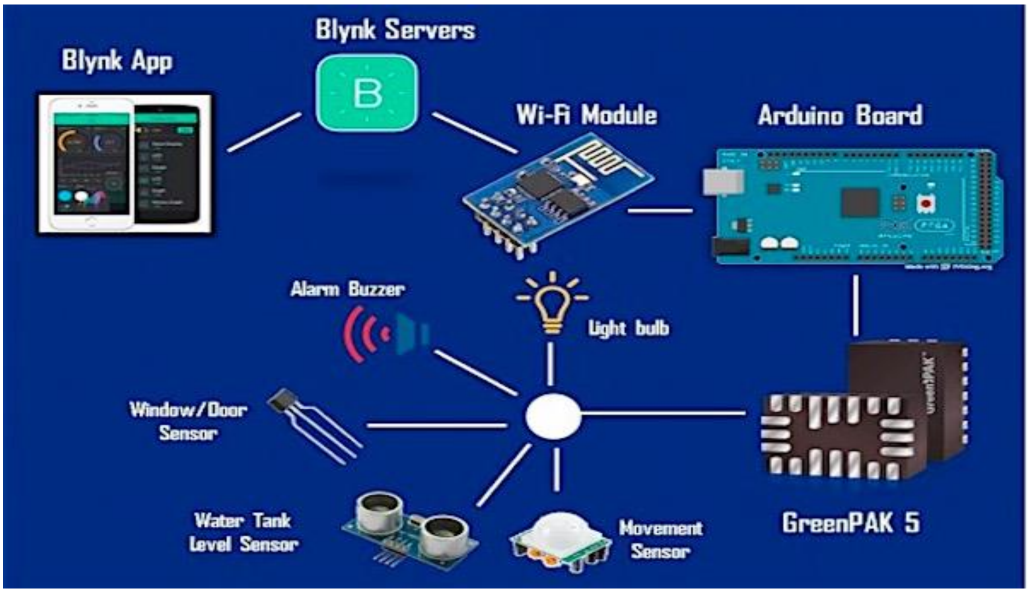

Figure 4.2: Blynk App Operation Mechanism

4.1 Working

The components are arranged and now the final operation is to be done. The circuit is attached to the surface of a hard plastic for integrity purpose.

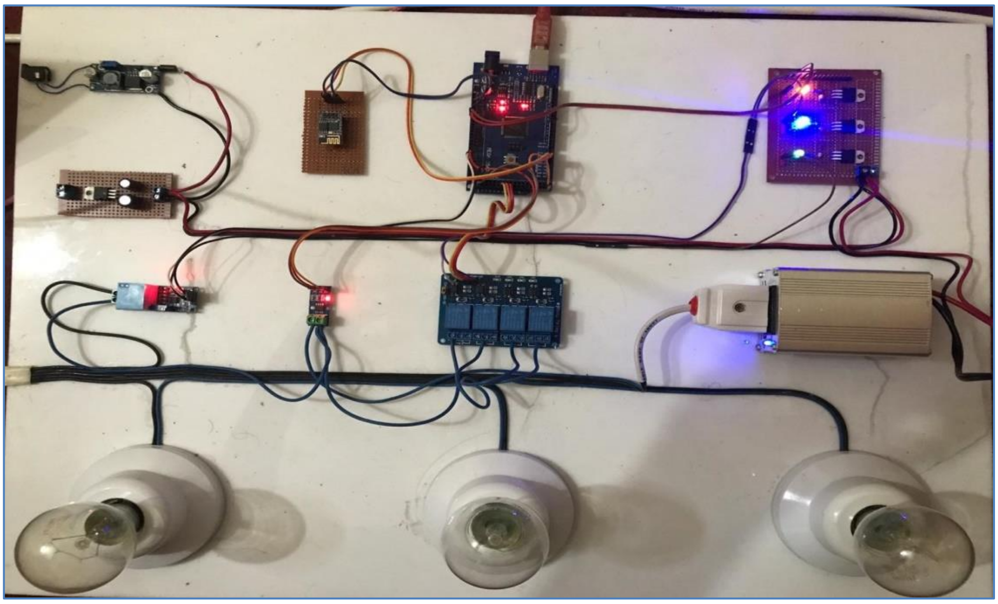

Figure 4.3: Circuit Arrangement

The battery is charged from the Solar and Piezo sensors depending on their availability. The battery supplies DC to the Electronic components and AC to the sensors and load through inverter. After that, Blynk App is connected to the Wi-Fi or any internet network. The Blynk App shows a notification when it connects to the internet. Whenever we press a button in the Blynk App for switching on a Load, a high signal is sent to the Arduino through Virtual Pin. The signal is first stored in the Cloud servers and then processed to Arduino through ESP8266 Module. The Arduino sends digital signal to the designated relay on the Relay Module which switches on the Load. The whole process takes about a second or two. The value of current drawn by the Load and power consumed is calculated from the sensors and sent through Wi-Fi module to the Blynk App. The tariff is calculated as discussed above and sent to Blynk App. The value updates after every 2 seconds. We can activate all loads simultaneously and the values will update as accordingly. The load is disconnected automatically when the Battery reserves are down. The Basic flow chart of the project is given below;

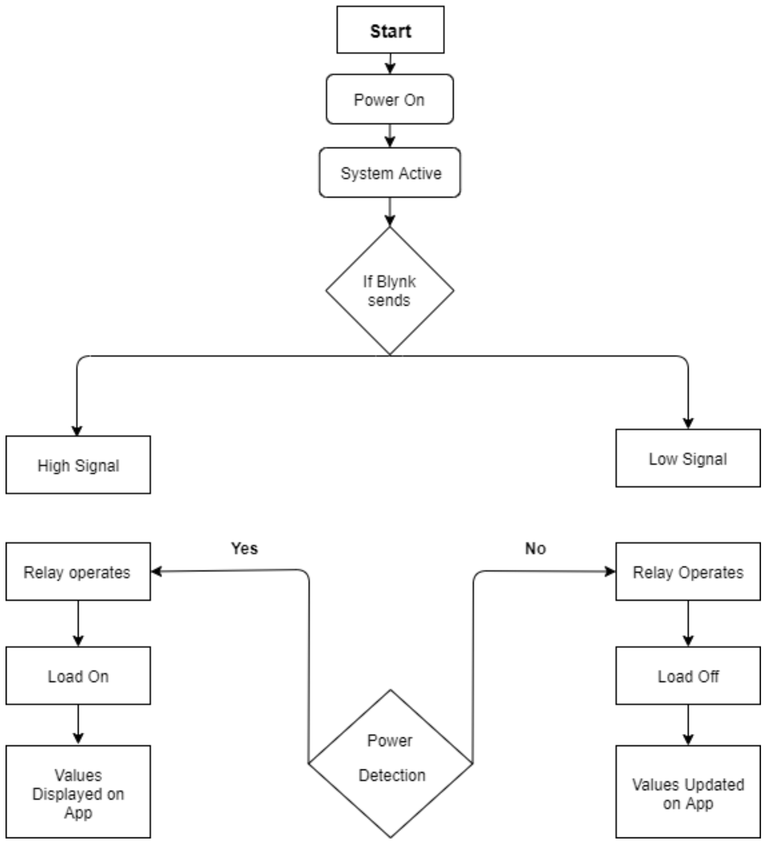

Figure 4.4: Flow char

4.2 Results

The developed design of the Smart Hybrid System is operated and tested ender different load conditions. The results after turning "On" the different loads and then turning them off are obtained on the Blynk Android App. The three loads are associated with button 1, 2 and 3. The values of Bill, Current and Power are displayed below the buttons as shown in the Fig 4.5 and Fig 4.6.

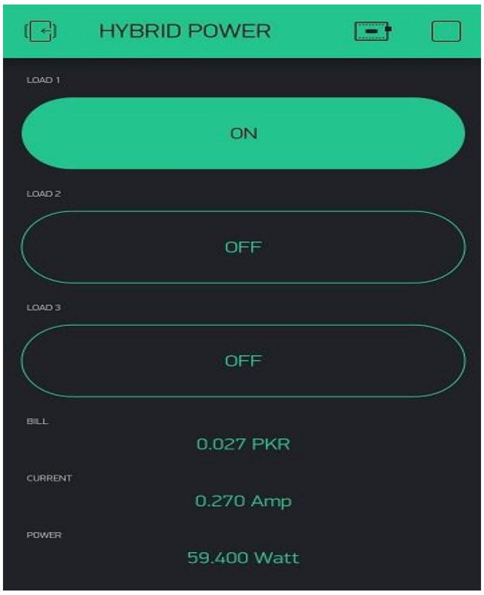

Figure 4.5: Load 1 in active state

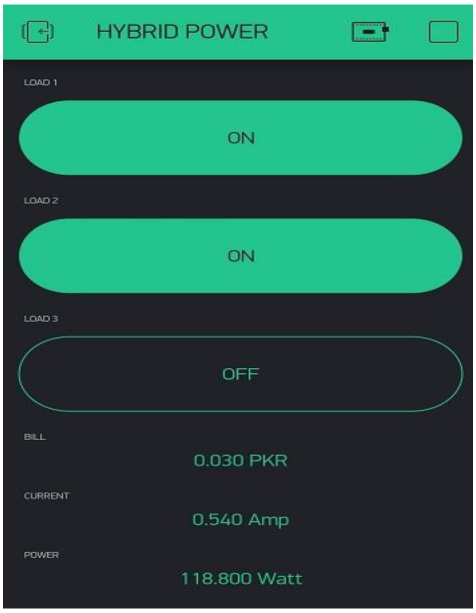

Figure 4.6: Load 1 & 2 in active state

Chapter 5

Conclusion and Future Work

5.1 Conclusion

An attempt has been made to deliver such a project which will help our current conditions and Power Sectors improvement. The model constructed can be used at homes or offices leading to Mega scale Smart Systems which can run a whole city with Green Energy. It is perfect for reducing the total costs and expenditure on Power usage of a Home or community. It also effects the extravagant requirement of Human Resources for Power System Operations. Complex Power systems that require Natural resources for power production are difficult to manage and operate with full efficiency. They require extensive amount of Natural Resources like Water, Diesel, Coal, Natural Gas, Nuclear Material etc. The modern world is facing shortage of these resources which makes the Renewable Energy systems more Realistic for better future.

The idea of implementing Piezo Sensors network on Roadways, Footpaths, Stairs and other public places is relatively new but already in the pipeline to replace other Power production methods. The amount of power generated from our setup is very low as compared to the other resources yet it is Clean and almost free of maintenance costs. Initial setup at home can be a good alternative for PV Panels in case of bad light or no availability of Sun.

Remote controlling of Loads from another place is another positive aspect of our project which is the backbone of IoT related Smart Systems. One can monitor and control the loads at home from office effortlessly.

5.2 Future Work

The world is changing and progressing day by day in order to reduce human efforts in every sector. Smart homes are replacing the conventional homes and urban areas are transforming to Smart Urban Communities with the help of IoT plus Wireless technologies. It is not far when humans will be able to transmit and receive power wirelessly. Several attempts have been done by different Groups and Organizations for enhancing the Hybrid energy systems. It is clearly more efficient and flexible than the conventional system. The positive effect on our environment by the Green Energy is very significant when considering the constantly increasing pollution levels across the Globe.

5.3 IoT assisted Smart Cities

The beginning of 21st century was the start of a new Era for mankind. After achieving numerous feats in every field, the gaze turned towards the betterment of the current facilities. Metropolitans were overcrowded with people who were in search of a better life and using the already diminishing resources up to full extent. The survival of Human made Technology was dependent on old and conventional methods.

With IoT and concept of smart cities, the world will once again enter into a never-ending race for the best technology. Giant Economies are already carrying out experiments and researches on making the Everyday life. Smart city is one of those concepts which involve every single electrical, mechanical or robotic device to be controlled and monitored effortlessly inside a provided network. Services vital to humans can be carried out in no time and less expenditures. From Footpaths to cars and generators to power stations, everything can be operated and diagnostics can be carried out with the help of IoT. More advanced Piezo Sensor Networks, PV panel setups, Tidal Energy plants and Wind Power stations can be used for the purpose of energy production. The advancement in this field is a never ending process. IoT can make our life easy and free of many worries if used for the betterment of Humanity.

References

[1] Das, H., & Saikia, L. C. (2015). "GSM enabled smart energy meter and automation of home appliances". International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE), (pp. 1-5). Shillong.

[2] O, E. (2014). "An Energy Meter Reader with Load Control Capacity and Secure Switching Using a Password Based Relay Circuit,". 2014 Annual Global Online Conference on Information and Computer Technology, (pp. 58-63). Louisville, KY.

[3] Sethi, P., & Sarangi, S. R. (2017). Internet of Things: Architectures, Protocols, and Applications. Hindawi Journal of Electrical and Computer Engineering, 2-3.

[4] Cook, C. (Dec 2008). "Piezoelectric Energy Harvesting: A Green and Clean Alternative for Sustained Power Production.". Bulletin of Science, Technology, & Society, Vol 28, 496-509.

[5] Haroon, A., & Naeem, W. (2016). "Constraints in the IoT: The World in 2020 and Beyond". (IJACSA) International Journal of Advanced Computer Science and Applications, 252-271.

[6] Guo, Q. (2013). Measurements of Piezoelectric Coefficient d33 of Lead Zirconate Titanate Thin Films. Seattle, WA: Journal of Vibration and Acoustics.

[7] Amer, M., & Namaane, A. (2013). "Optimization of Hybrid Renewable Energy Systems (HRES) Using PSO for Cost Reduction". Amsterdam: Elsevier Ltd.

[8] Components 101. (2018, April 17). Retrieved August 17, 2020, from https://components101.com/sensors/acs712-current-sensor-module

[9] Pramil. (2018, July). Innovators Guru. Retrieved from https://innovatorsguru.com/zmpt101b/

[10] Santos, R. (2019, January 15). Random Tutorials. Retrieved August 17, 2020, from https://randomnerdtutorials.com/guide-for-relay-module-with-arduino/

[11] Adnan, A. (2018, June 30). TEP Technopreneur. Retrieved August 14, 2020, from https://www.theengineeringprojects.com/2018/06/introduction-to-arduino-mega-2560.html

[12] (2020, May 6). Components 101. Retrieved August 15, 2020, from https://components101.com/modules/xl6009-dc-dc-step-down-voltage-regulator-module