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ALTINBAŞ UNIVERSITY

Electrical and Computer Engineering

DESIGN AND IMPLEMENTATION OF AN ELECTRONIC DC- AC INVERTER BASED ON THE ARDUINO MICROCONTROLLER MONITORING VIA IOT

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Master Thesis

Supervisor

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DESIGN AND IMPLEMENTATION OF AN ELECTRONIC DC- AC INVERTER BASED ON THE ARDUINO MICROCONTROLLER MONITORING VIA IOT

by

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Murad Irfan Akram

DEDICATION

I would like to dedicate this work to my first teacher, my mother, my first supporter and role model, my father and my companion throughout the journey. Without you, this dream would never come true and to my brother and my sister who stood with me in order to achieve my dream.

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In the beginning Praise be to Allah, the Lord of the Worlds very much, always stay with us in the end of this work. I thank my father and mother for what they had as well as a great and influential in my life and they have always been my supporters and support me in this world. Acknowledgment and appreciation to my dear supervisor prof. Dr. Osman Nuri for his cooperation and support to complete this work. Thank you my dear friends and my beautiful friends

ABSTRACT

DESIGN AND IMPLEMENTATION OF AN ELECTRONIC DC- AC INVERTER BASED ON THE ARDUINO MICROCONTROLLER MONITORING VIA IOT

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In view of the problems of conservation and generation of electricity and most of the problems resulting from the deficit in the total product of electric power in some countries of the world and with the development of modern technology has become necessary to resort to other solutions through the use of alternative energy, such as the use of solar energy or wind energy or water energy to generate energy In our proposed system, we will design a one-phase inverter based on solar energy and based on the Arduino microcontroller. The devices connected to the inverter will be controlled through the Internet in order to carry out the operation and extinguishing of the devices. Strapped as well as monitor the status of the battery and the status of current and emerging voltages drawn from the inverter as well as protection from overload all this is done through the specific GUI and are accessing through local IP granted by the microcontroller. Different sensor will have used with the design such as current sensor to monitor the drawn current, voltage sensor to monitor the output voltage and monitor the battery voltage and temperature sensor to monitor the heating of the inverter all these readings will processing by the microcontroller and then will appears on the specific programmed GUI programming via HTML inside the Arduino IDE.

Keywords: Arduino Microcontroller, Current Sensor, HTML, Voltage Sensor, IoT.

ÖZET

IOT ÜZERINDEN İZLENEN ARDUINO MIKRODENETLEYICI iLE ELEKTRONIK DC-AC İNVERTöRLERININ TASARIMI VE UYGULAMASI

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Elektriğin üretimi ve depolanmasıyla ilgili sorunlar göz önüne alındığında, sorunların çoğu dünyadaki bazı ülkelerin, toplam elektrik gücü üretimindeki eksikliğinden kaynaklanmaktadır. Modern teknolojinin gelişmesi ile birlikte, enerji üretmek için güneş enerjisi, rüzgâr enerjisi ya da su enerjisi gibi alternatif enerjiler kaynaklarını kullanması gerekli hale gelmiştir. Bizim önerdiğimiz sistemde, güneş enerjisi ve Arduino mikro denetleyicisi ile çalışan tek fazlı bir invertör tasarlayacağız. Cihazların çalışması ve kapatılması için invertöre bağlı cihazlar internet üzerinden kontrol edilecektir. Akünün ve akımın durumunu, invertörden çekilip ortaya çıkan gerilimlerin izlenmesinin yanı sıra aşırı yüke karşı koruma sağlanması gibi tüm bu işlemler, özel GUI (Grafiksel Kullanıcı Arayüzü) aracılığıyla yapılır ve mikrodenetleyici tarafından verilen yerel IP üzerinden erişir. Tasarımda, çekilen akımı izlemek için akım sensörü, çıkan gerilimini ve akü voltajını izlemek için gerilim sensörü, inventörün sıcaklığını takip etmek için sıcaklık sensörü gibi farklı sensörlerin kullanılması gerekir. Tüm bunlar ise mikrodenetleyici tarafından işlenecek ve Arduino IDE (Entegre Geliştirme Ortamın)‘da HTML yoluyla özel olarak programlanmış GUI programlaması ile görünecektir.

Anahtar Kelimeler: Arduino Mikrodenetleyici, Akım sensörü, HTML, gerilim sensörü, IoT(Nesnelerin İnterneti) .

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LIST OF ABBREVIATIONS

WI-FI	:	Wireless-FI.
AC	:	Alternating Current.
DC	:	Direct current.
IoT	:	Internet Of Things.
LED	:	Light Emitting Diode.
IDE	:	Integrated Development Environment.
SRAM	:	Static random access memory.

1. INTRODUCTION

The one of the more necessary for daily survival is Energy. Long-term availability from reliable, safe and environmentally sustainable sources in increasing amounts Future energy development is critical. presently, there is no single source or mixture of sources to meet this future requirement. Concern about a trustworthy future in the energy field only comes when energy provides ' essential services ' to human lives – warmth, cooking, industrialization or transmission and mechanical power. The energy source currently comes from fuels (oil, gas, wood, nuclear, charcoal and other primary sources) that are used for these services until they are all converted into the necessary energy supplies by machinery or other end-user devices such as turbines, cookers or engines. The supply of electricity for these services. In many countries around the world, because of the ineffective design or running of the equipment used to convert it into the services required so a lot of primary energy is wasted; although the awareness of energy conservation and efficiency has increased considerably. Today mainly non-renewable energy sources include natural gas, carbon, oil, peat and conventional nuclear energy. Renewability also includes timber, dug, wind, plants, geothermal power, water falling, solar energy, wave power, wave and muscle power for humans and animals. This category includes nuclear reactors producing their own fuel (' breeders ') and eventually incorporating reactors. Theoretically, the future energy mix world-wide can include all different energy sources. The factors that interact strongly with other governmental and global priorities are economic, health, environmental costs, benefits, and risks. but each has its own. Must be made options, but in the specific knowledge that choosing an energy strategy necessarily means choosing an environmental strategy. The next century Patterns and changes of energy use are already dictating well patterns today. We oncoming this question from the viewpoint of sustainability see the table (1.1). The key sustainability elements that need reconciliation are [1]:

- Adequate energy supply growth to satisfy needs of people (which means combining at least 3 percent growth per capita in development countries);
- Energy expertise and reservation measures to reduce primary sources waste;
- Public health, recognition of the safety risk problems of energy sources inveterate ;
- Biosphere protection and safety of concentrated forms of contamination.

Table 1.1: Global Increase In Renewable Energy.

Energy source	2004	2030	Approximate Increase (times)
Electricity Generation (TWh)	3 179	7 775	>2
Hydropower	2 810	4 903	<2
Biomass	227	983	>4
Wind	82	1 440	18
Solar	4	238	60
Geothermal	56	185	>3
Tide and Wave	<1	25	46
Biofuels(Mtoe)	15	147	10
Industry and Buildings (Mtoe)	272	593	2
Commercial biomass	261	450	<2
Solar heat	6.6	64	10
Geothermal heat	4.4	25	6

The time ahead has to be seen to be transitive from an era of unsustainable use of energy. In general, agreeable passageway has not yet been found to a safe and prospective energy future. We do not think that these dilemmas have yet been handled by the international community with an adequate sense of insistence and in a global perspective. The growth or demand in energy in response to manufacturing, urbanization, and social abundance has led to a highly disparate global distribution of primary energy consumption. For instance, the consumption of energy per person in manufacturing market economies is more than 80 times utmost than in sub-Saharan Africa. The figure.1.1 is found in three quarters of the main energy produced by about one fourth of the people in the world.

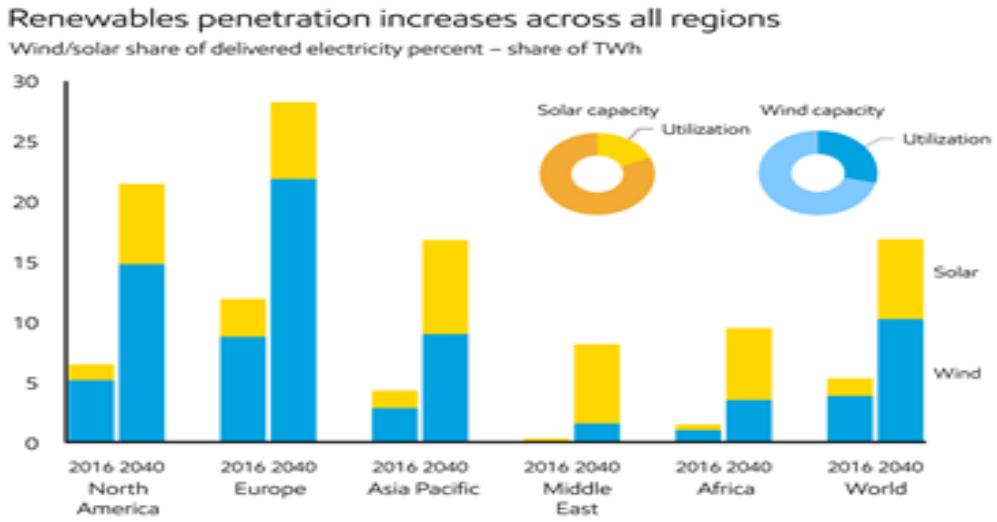

Figure 1.1: Renewables Penetration Increases Across All Regions.

Even though the personage smart house can generate only a small amount of power by interconnecting all using micro grid, it gives a big benefit to power system. The main advantages are can decrease the nominated generation capacity, decrease the power grid failures by decreasing the burden on main grid. Energy mainly obtained through non-renewable energy sources is still the most essential resources in human life and it is on the brink of consumption. Solar photovoltaic products have been extensively expanding and reflect the significance of energy savings and renewable energy consciousness. The Solar Inverter must be monitored and built, to guarantee sufficient levels of input to the inverter of pv modules. Conventional methods of monitoring require close service for on-going monitoring by staff. Results from the equipment are directly available. Occasionally, solar power system is putted in outlying areas. PV power can be degraded by the environmental factor. Solar inverter is monitored in various ways. Wireless transmission is one of the alternative options for solar inverter monitoring. Wireless transmission is most importantly controlled and monitored by a function of flexibility where no personnel are needed in the area in which solar panels are located. It is clear from past work that wireless sensor networks can be used to monitor systems. However, the fact that wireless sensor network can use for data transfer obviously has many disadvantages. In the case of the wireless sensor network, more energy is wasted. Moreover, malignant interference and attacks present higher risks. These disadvantages make data transmission less reliable. For control purposes, many transport techniques like the Ethernet network may be used. To overcome such problems, the ESP8266 Wi-Fi module surveillance

system is used. Wi-Fi has a limited error margin, low rates and a large coverage of signals. Users can easily contact the Wi-Fi module to monitor at whenever and anywhere. As a consequence, there is higher reliability in data conveyance [2].

The PV consists of a collection of photovoltaic cells which can be installed to convert solar radiation into energy via a photoelectric action. Photovoltaic cells made from quartzite gravel raw material to produce silicone used to make them. The quartz will be mashed to obtain silicon dioxide and the raw material must be processed fundamentally until photovoltaic cells will be made. [3].

A PV is basically a p-n semiconductor crossover. A DC current is generated when exposed to the light. PV has different advantages, including lower maintenance costs, highly reliable, noise lack and no environmental pollution [4].

The house holder can produce a daily demand for electricity on the domestic pV power system, which exchanges excess power during daytime for renewable energy needs (i.e. night time use). The house is always linked with the power supply so that the energy needed beyond the power of the solar system can simply be drawn from the power supply. The PV systems may also contain battery or unbroken electrical power supply (UPS) for hours or days during a power failure, which can operate select circuits in the home [5]. As a result of an increasing number of new photovoltaic elements and devices arrays and inverter come on to the PV markets, [6]. Some environmental conditions, such as temperature, sunlight intensity, sunlight spectrum and sunlight direction specify the energy generated by the transformation. Constantly changing environmental conditions at all times cause fluctuate solar panel output power . Numerous control systems were designed to measure solar panel performance parameters. PLX-DAQ software programs are used for data acquisition and storage of the backup data by means of the Arduino ATmega 328P system based microcontroller connected to the computer via the RS232, serial port RS232. These data acquisition systems are supported by calibrated current and voltage sensors [7].

In some cases, the PV power plant monitoring system is very important and insistent to resolve, analyze and resolve problems [8]. A wireless ZigBee MS system was designed to monitor the solar radiation, the power generation, the temperatures and the output of the grid using a PV-

Grid System [9]. A ZigBee wireless microcontroller is used for the monitoring of voltage, current and energy with low cost, reliable PV power plant performance control systems [10]. A simple but efficient approach to the construction of an IoT platform for remote monitoring and data sensing, home automation, industrial automation and much more [11].

The growth in PV for electricity is one of the most important factors in the field of renewable energy, and this will continue in the following years [12].

1.1 SOLAR CELL

A solar cell or solar cell is the electrical instrument which, by means of the photovoltaic effect, transforms light energy into electricity, a physics and chemistry phenomenon. It is a form of a photoelectric cell, defined as an instrument that is different from light-exposed electrical characteristics such as power, voltage or resistance. The main photovoltaic modular structures are solar cells, also known as solar panels. The photovoltaic solar cells, regardless of the sunlight or artificial light source, are described. 3 basic attributes are necessary for operating a photovoltaic cell [13]:

1. The absorption of light, which generates electron-holes or accuracies.

2. The separation of carriers of different types.

3. The separate removal of these transport companies to an external circuit.

The solar energy supplied and received to the Earth it’s an incredible. The sun is an average star, it’s a fusibility reactor that has been burning over 4 billion years. It supplies enough energy in one minute to provide the world's energy requirements for one year. In one day, it supplies more energy than our current inhabitants would consume in 27 years. Actually, "The amount of solar radiation beating the earth over a three-day period is tantamount to the energy stored in all fossil energy sources". Solar energy is an inexhaustible, free resource, harnessing it is a comparatively new idea. The extension of the companies that develop specialized photovoltaic systems for individual homes means that solar power is no longer taken into account for your home. With the introduction of transistor and the supporting semiconductor technology, the greatest jumps were made in efficiency. Photovoltovoltaic energy has several

advantages making it "one of the world's most favorable renewable energies". It is non-polluting, does not have moving parts that can damage, requires low maintenance or surveillance, and has a 20-30-year life with low operating costs. It is not unrivaled especially because there is no need for a large installation. Far-away areas can easily produce their own power supply by building a system as small or as large as necessary. Solar power is simply distributed to homes, schools or businesses that don't need any additional development or land for their installation and its function is quiet and safe. More solar power can be added as societies grow. The fastest growing section of the photovoltaic market, solar energy, is the highest demand in developing countries today. Electricity is lacking as the sun is on the earth, making Solar Energy the clear choice of energy. "Governments are finding its modular, decentralized character quixotic for meet the electric needs of the thousands of remote villages in their countries". It is far more feasible than the expensive electricity line to remote areas that do not have income to pay for renewable power. Solar energy can be used in two main disadvantages: sunlight amount and equipment cost. Depending on the location of the area, the number of days, times and clouds depends heavily on the sunlight figure.1.2 shows solar cell and solar cell structure [14].

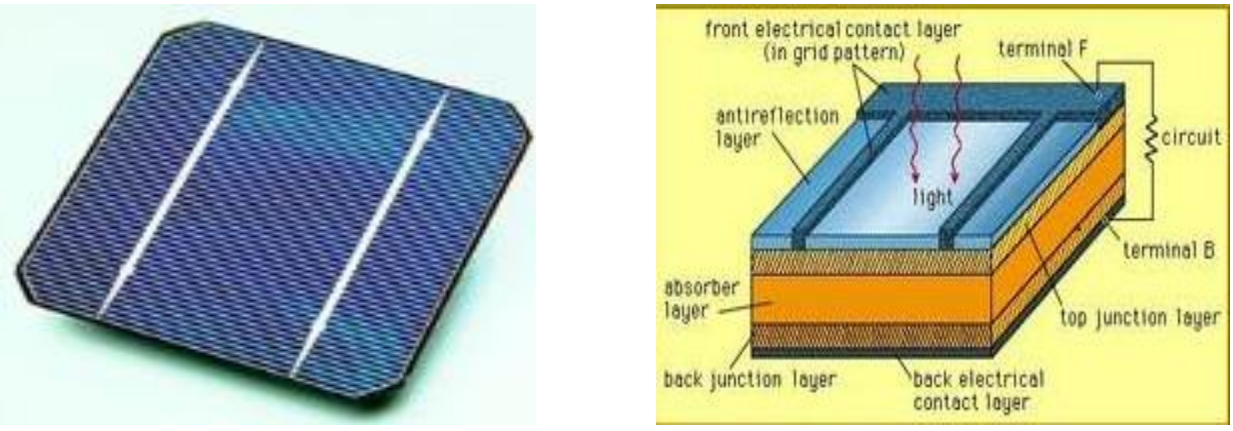

Figure 1.2: Solar Cell and Its Structure.

- Certain solar energy applications

1. Power plants: Non-renewable energy resources are used in conventional power plants to boil water and to shape current so that turbines can rotate and generate water to generate electricity.

However, by applying the solar heat from the sun, that water can boil to create steam and turbines. Photoelectric, thermoelectric and other technologies are used to convert sun light into solar electricity panels.

2. Homes: In households too, solar energy is being used. Residential equipment can use solar-generated power easily. Photovoltaic cells on the roof of the building capture and store energy on battery for different purposes in homes throughout the day. This reduces energy expenditure by domestic users.

3. Commercial use: Glass PV modules or any other type of solar panel may be found on roofs of various buildings. These panels are used in different offices and other building sections in a reliable way to supply electricity. These panels collect solar power from the sun and turn it into electricity, enabling offices to use electricity for different purposes.

4. Ventilation system: Solar power is used for air-conditioning purposes in many places. It supports running bath fans in buildings, floor fans and ceiling fans. Fans almost always run in a building to control moisture, smell and heat from the kitchen in homes. It can increase large amounts on the power supply bills, to reduce solar power to ventilate these bills.

5. Power pump: Solar power helps not just in the improvement of the ventilation system at home but in every building, too, in the flow. It can be connected to a 6-power pump, but must be powered by DC, so water can flow in your home.

6. Swimming pools: In every season, swimming pools are an excellent glee for children and adults. But in winter, it is hard to keep water heat with minimum power consumption in these pools. In this matter too, solar energy may help many. The pool is equipped with a sunblock that keeps the water warm with sunlight. In addition, a solar hot water system with solar hot water heating systems can be installed.

7. Solar Lighting: These lights are also called daylight and work with solar power. These lights are used to save natural sun power over the day and then convert this power into electricity to light up over the night.

8. Solar Cars: The electric vehicle is a recharged solar or sunlight vehicle. This car uses solar panels that absorb light and transform it into electricity. This electricity is stored in car-used batteries, so that we can operate these vehicles in the evening.

9. Remote applications: The large-scale use of solar power is taken from remote buildings. Remote schools, community chambers and clinics are able to use solar panels and batteries for electricity production and use.

- There are Common Types of Solar Cells [15]:
  1. Silicon Solar Cells
  2. Mono-crystalline Silicon Solar Cells
  3. Polycrystalline Solar Cells
  4. Thin Film Solar Cells
  5. Amorphous Silicon Solar Cells
  6. Cadmium Telluride Solar Cells
  7. Copper Indium Gallium Selenide Solar Cells.

1.2 SINGLE PHASE INVERTER

A device that converts direct current (DC) to alternating current (AC) is an inverter or power inverter. The output waveform of a square wave and the modified-sine wave are three types of inverters, and a pure-sine wave is a non-sinusoidal waveform, usually seen in electronics and signal processing. The output of the modified sine-wave inverter is more like a square wave output but a level more, i.e., before switching positively or negatively, it goes into zero volts. the Square Wave has two levels (positive and negative) and alternates between these two levels. Although it is straightforward and low cost, the majority of AC engines are powered at this energy source or inverter and can produce hissing sounds during operation, reducing the life of the equipment and. The DC input changes or converts into a near perfect synthetic wave by a pure or true sine wave converter. The Sine Wave has very little harmonic distortion, which results in a clean and efficient supply and makes it suitable for the operation of electronic systems, such as computers. Things like power supplies also work better with pure sinusoidal wave converters. The output waveforms of an inverter should ideally be sinusoidal. The waveforms of the practical inverter do not contain any sinusoidal elements, however. By using swiping techniques, the harmonic contents present in the output tension can be significantment

reduced by the availability of high speed power semiconductor systems. The ideal switch is to use BJTs, MOSFET or IGBT. IGBT is more popular, however, because it combines BJTs ' and MOSFET advantages. An IGBT has features such as high input impedances like MOSFET and low state losses like BJTs. The IGBT is a plurality transporter with a high capacity for the bipolar transmission of current. The IGBT is suitable for many power systems such as modular pulse width and three-phase servo drives with a high dynamic range control system and low noise level. A harmonic is called an integrated multiple of the frequency of some reference signal or wave. The ratio of the frequency of this signal to the reference signal frequency can also be termed harmonic. Let an alternate current signal show the main or fundamental frequency as f. The frequency f is expressed in hertz and most of the energy at that frequency is present or the signal at that frequency is defined. The wave form seems to repeat at a rate corresponding to f HZ when the harmonic signal is displayed on an oscilloscope.

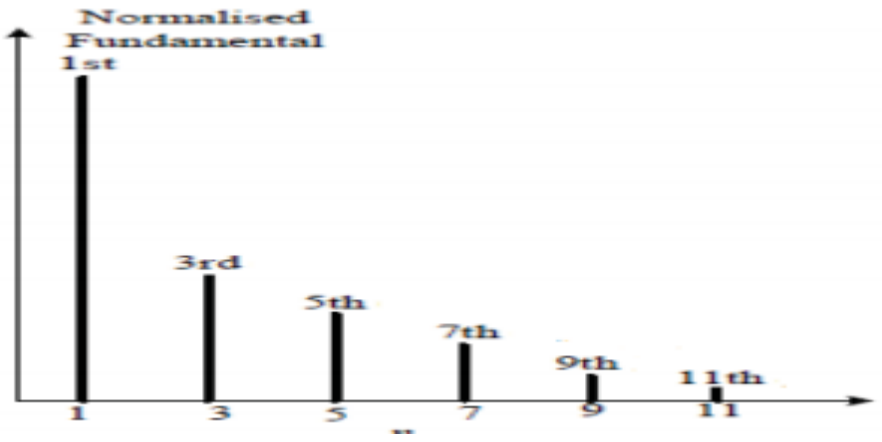

Figure 1.3: Harmonic Spectra of an Inverter.

As shown in the figure.1.3 above, the harmonic reduces as a factor of (1/n) n increases. There are stranger harmonics; the closest harmonic is the 3rd harmonic, even without harmonics. The closest harmonic is 150Hz when the basic frequency is 50Hz, as it is the 3rd harmonic. It is not easy to design low-pass filters because there is little distinction between fundamental and harmonics. Unpleasant effects such as imbalances and excessive neutral currents cause harmonics. Some problems result in harmonic interference and disruption to other consumers in the immediate communications networks, torque pulsing and gripping electric motors etc. The network drawing of non-sinusoidal voltage and current is used when the non-linear charge is inserted into the system, thus creating harmonics. Harmonics cause problems, for example low

power, malfunctioning, poor efficiency, shortened lifetime of the equipment, overheating of the lines, etc. Due to these issues, energy is an issue for end users and it is a challenge for power engineers to solve these harmonic problems [16].

1.3 STATEMENT OF PROBLEM

Electricity is the main source of power for country's most of the economic activities. But in most countries, they have suffering from electric crisis for a long time. To diminish this problem, there are some substitutional ways which can help in this purpose. But through all of the ways solar system may be a soft and effective one essentially in the rustic areas where the electricity has not reached so far. This solar energy is a renewable energy which is inefficiently exploited. The importance of solar energy is that it’s free, clean and with very high possibility in the future. Photovoltaic systems (PV) are used to exchange the solar energy into electrical energy using photovoltaic panels which can be used into local electrical applications. The DC-AC converter that transforms the DC voltage from an electronic component battery into an electronic voltage is an important element of the solar electricity supply. Because this equipment is specific, an inverter that is able to generate a pure sinus wave must avoid noise and wear with accurate and costly equipment. Many of these appliances are very costly, and the object of this project is to design an inverter for DC / AC that can manufacture a pure sine wave for home appliances.

1.4 LITERATURE REVIEW

There are definitely two types of electrical transmission in our world today: DC (direct current) and AC systems with each its own benefits and inconveniences. DC power is the application of continuous voltage over load, which produces a constant current. A battery, along with various forms of power generation, is a popular power source for DC. The Digital Circuit offers constantly high and low values, representing the 1 and 0 bit basics of the computers. The initial commercial electricity transfer was made by Thomas Edison, the inventor of the light bulb. It could not carry long distances, as the technology did not exist to increase the voltage along the transmission path that would dispel the power. The following equation illustrates how much power needs to be reduced by high voltage.

$$V=IR \tag{1.1}$$

$$P=I^2*R=\frac{V2}{R} \quad (1.2)$$

The current decreases as the voltage increases, with a concomitant reduction of the power loss. High voltage transmission therefore reduces power loss. It was determined that AC power is much more efficient for transfer of power since it alternates between two voltages at a certain frequency to facilitate either up or down with adapters. In the present day, electric transmission is mainly driven by AC power, which delivers 240V AC power to houses and businesses at 50 Hz. While the DC power in many digital applications is used in many other fields, AC power is also used in power tools, Medical equipment, televisions, radios and lighting. An effective way of transforming DC to AC and vice versa must therefore be used. Without this ability, people would only use devices that only work on the power they receive [17].

1.5 OBJECTIVES

The goals of the project are to design a one-phase inverter based on solar energy and using the Arduino microcontroller. which is use to share in the solve of the problems of conservation and generation of electricity and most of the problems resulting from the deficit in the total product of electric power in some countries of the world. The system's main properties are reducing the dependency on the fossil fuels and limited energy source.

2. INVERTER

An inverter is a device that ultimately transform DC energy into AC energy. The goal of DC-AC is to take DC power from the source of the battery and turn it onto AC. The household inverter is, for example, supplied with DCs from the 12V or 24V battery and converted into 240V AC with a desired 50Hz or 60Hz rate. These DC-AC inverters are commonly used for production purposes including uninterruptible power supply (UPS) and AC motor drives. In recent years, the inverters have also played an important role in various renewable energy applications, as used in wind or photovoltaic power systems grid connections. Furthermore, the control strategies used in converters are similar to those used for DC-DC converters. In practical applications, power-mode control and voltage-mode control are used. DC-AC inverter usually works by Pulse Width Modulation (PWM) technology. PWM is a very advanced, useful mechanism for controlling the width of the gate pulses by various techniques. The PWM inverter holds the inverter voltage at the rated voltage, independently of the output charge (depending on the user's choice). The output voltage changes depending on changes of load on a traditional inverter. The inverter PWM rectifies the output voltage by changing the width of the pulses to remove this effect from the various loads and the output AC depends on the frequency and width of the pulses, regulated by the output-connected value of the load in order to provide a fixed rated output. In general, inverters are modulated in pulse width (PWM) way and switch between different circuit topologies, meaning that the inverter is nonlinear, particularly in part smooth. Over the last decade, the studies of complex behavior of switching power adapter both academic and industry have been increasingly focused on the figure (2.1) shows the inerter block diagram.

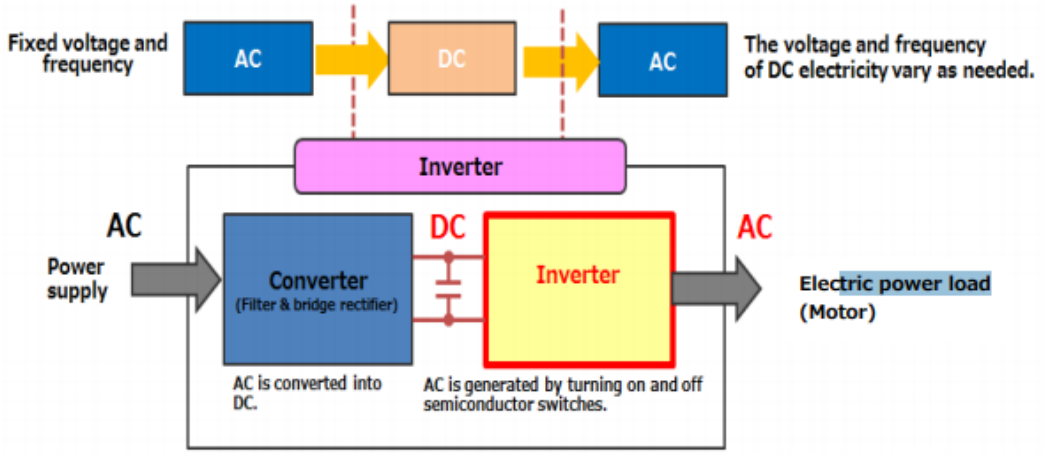

Figure 2.1: Inverter Block Diagram

Efficiency and output are greatly different today for power inverters currently on the market. In general, the output waveforms seen by the higher-end inverters are either pure sine or modified sinus. The power output at watts is another determining feature of quality and price of an inverter. In addition, many circuit boards are available for those wanting to structure their own inverter. Their strength / faintness is different depending on what the points are [18], [19].

2.1 INVERTER CLASSIFICATIONS

The inverter can be classified by output, source, load type etc in many types. Below is the whole inverter circuit ranking [20]:

I- Depending on the output feature

1. Square Wave Inverter
2. Sine Wave Inverter
3. Modified Sine Wave Inverter

II – Depending on the inverter source

1. Current Source Inverter
2. Voltage Source Inverter

III- Depending on the Type of Bridge circuit and number of phases

1. Single Phase Inverter

   A- Half Bridge Inverter

   B- Full Bridge Inverter

   Three Phase Inverter

   A- 180-degree mode

   B- 120-degree mode

IV – Depending on the various PWM technology

1. Simple Pulse Width Modulation (SPWM)
2. Multiple Pulse Width Modulation (MPWM)
3. Sinusoidal Pulse Width Modulation (SPWM)
4. Modified sinusoidal Pulse Width Modulation (MSPWM)

V- Depending on the output level number

1. Regular Two-Level Inverter
2. Multi-Level Inverter

I. Depending on the Output Characteristic

There are three different types of inverter depending on an inverter's output characteristics.

- Square Wave Inverter
- Sine Wave Inverter
- Modified Sine Wave Inverter

2.1.1 Square Wave Inverter

The power waveform is a square wave for the inverter. This kind of inverter is not very common between all other inverter types, because all devices are for sine wave supply. If the square wave is supplied to a device based on the sine wave, it may suffer damage or very high

losses. The costs of this inverter are very low but very rare. It can be used with a global engine in simple tools [21].

2.1.2 Sine Wave

The voltage output wave is a sinusoidal wave and gives us a very similar output for this inverter as all the equipment we use have been designed for the sinusoidal wave. This is also the perfect output, guaranteeing that equipment is working properly and costly but widely used in home and commercial applications. This type of inverter [22].

2.1.3 Modified Sine Wave

This type of inverter structure is a complex structure compared to simple square-wave inverters, but easier compared to the pure sine- wave inverter. Two square waves provide the same output from this inverter. The output waveform is not exactly sinus wave but it looks similarly sine wave-shaped the figure (2.2) shows the waves shape [23].

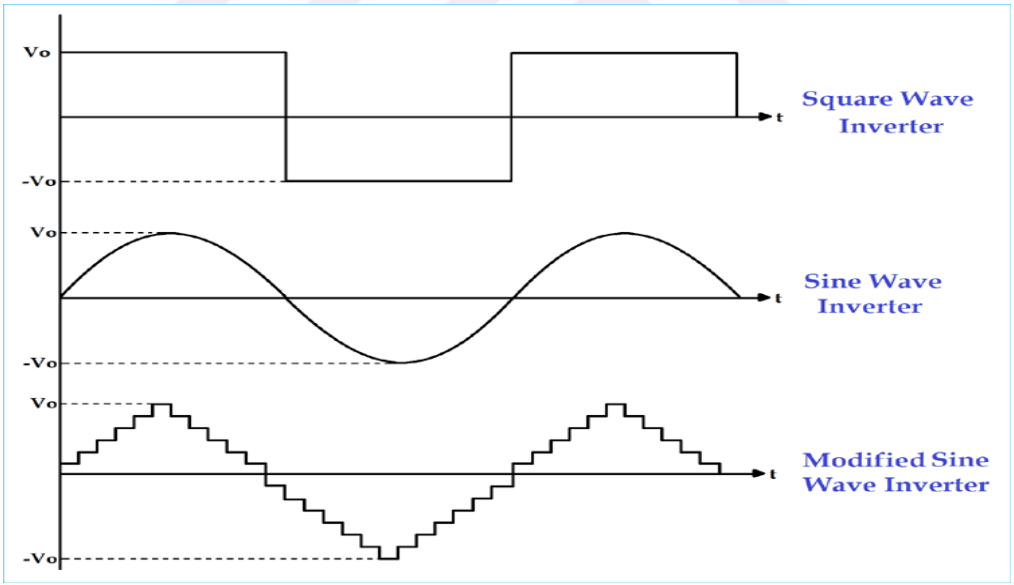

Figure 2.2: The Waves Shape.

II. Depending on the Inverter Source

- Voltage Source Inverter
- Current Source Inverter

1. Current Source Inverter

In the field of CSI, the input is a current source. In the median voltage industrial applications, such inverters are used where high-quality current waveforms are imperative.

2. Voltage Source Inverter

This type of inverter is used in every application because it is more efficient and more reliable and more dynamic response. VSI can operate motors without de-calcifying. In VSI, the input is a voltage source.

III. Depending on the load type

- Single-phase Inverter
- Three-phase Inverter

2.2 SINGLE-PHASE INVERTER

Residential and commercial loads are generally powered by single phase power. For this type of application, the one-phase inverter is used. In addition, the single-phase inverter is divided into two parts [24];

- Single Phase Half-Bridge Inverter
- Single Phase Full-bridge Inverter

2.2.1 Single Phase Half-Controlled Bridge Inverter

This inverter type is made up of two thyristors, two diodes and the linkage is as show in the figure (2.3).

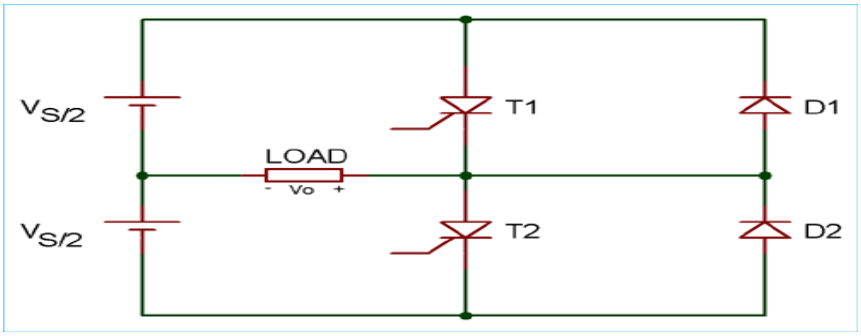

Figure 2.3: Half-Controlled Bridge Inverter Connection

Total DC voltage is Vs in this case and is divided in two equal Vs/2 components. One cycle time is T sec.

T1 thyristors are used for half cycle of 0 < t < T/2. The Vs/2 load voltage is due to the Vs/2 high voltage source.

The T1 thyristors are switched and T2 leads in the second half-cycle of T/2 < t < T. The charging voltage on is -Vs/2 because of the lowest source Vs/2.

$$Vo = Vs/2 \tag{2.1}$$

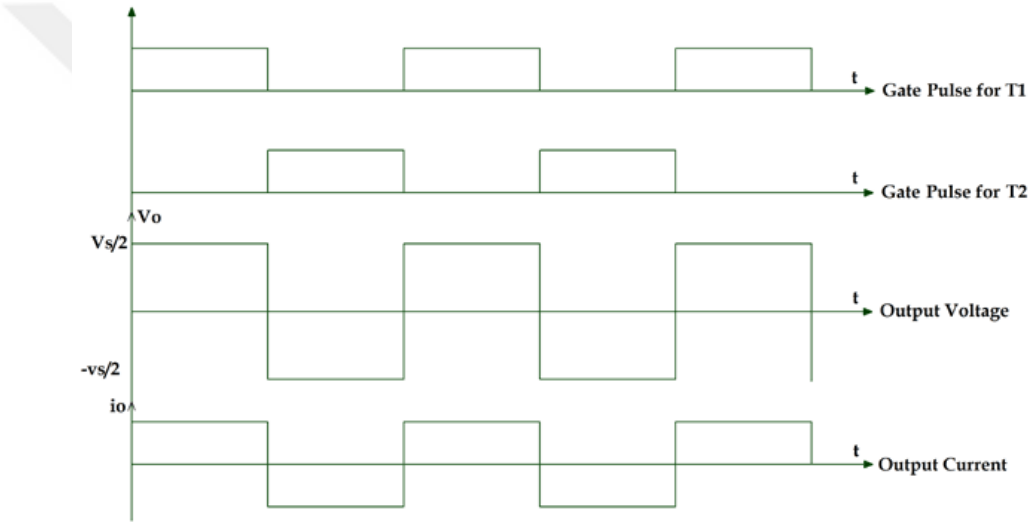

Figure 2.4: The Trigger Pulses and O/P Voltage of Half-Controlled Bridge Inverter.

By this operation, we can achieve a 1/T Hz frequency and Vs/2 peak capacity for alternating voltage waveforms A square wave is the output wave shape. It passes through the filter and removes unpleasant harmonics, giving the pure shape of the sinus. The waveform frequency can be regulated by the thyristor ON Time (Ton) and OFF Time (Toff).

The voltage is half the voltage, and the source usage is 50 %. Half a bridge inverter has a disadvantage, and the solution of this is full bridge inverter.

2.2.2 Single Phase Full-Bridge Inverter

Four thyristors and four diodes are used for this type of inverter. The single phase full bridge circuit diagram is as shown in the figure (2.4).

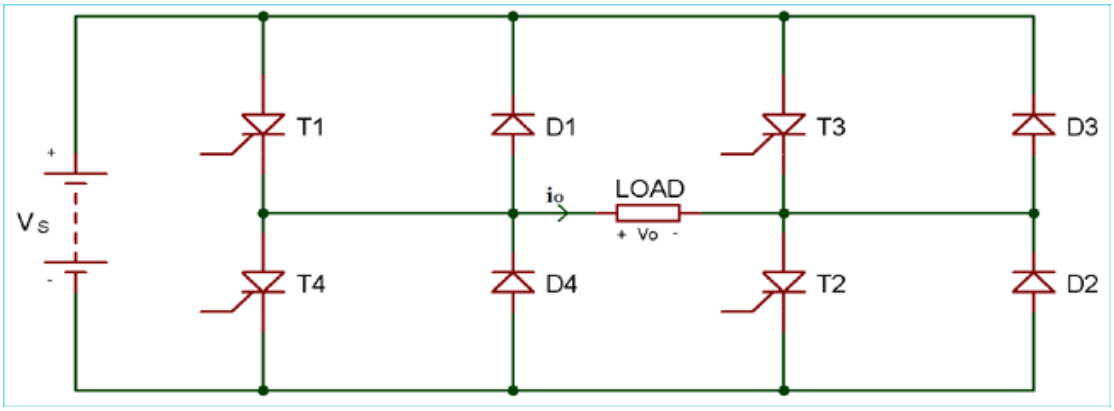

Figure 2.5: Circuit Diagram of Single-Phase Full Bridge

In the first half of the cycle, two thyristors T1 and T2 conduct 0 < t < T/2. The load voltage during this period is Vs which is similar to the load voltage of the DC supplied.

Two thyristor T3 and T4 conducts for second half cycle T/2 < t < T. During this period the load voltage is -Vs.

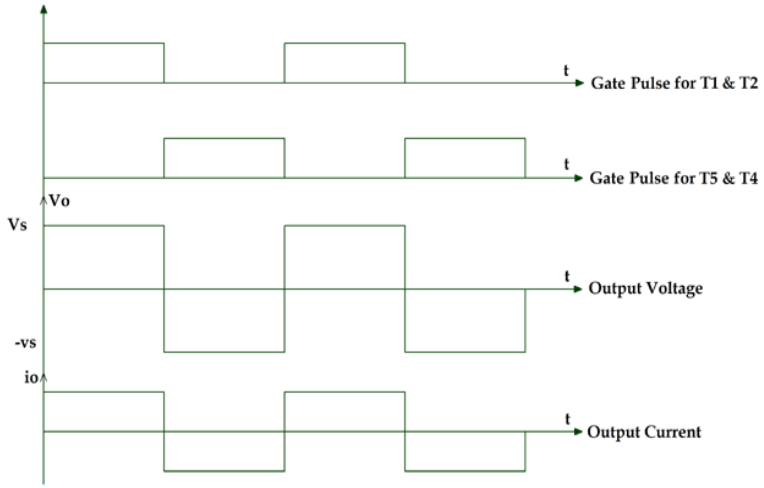

Figure 2.6: The Trigger Pulses and O/P Voltage of Full-controlled bridge Inverter.

The AC output voltage can be achieved here, the same as the DC supply voltages and 100% of the source usage. The output voltage waveform is a square waveform and is converted into a sinus wave through the filters. When the attitude of each thyristor is simmering, or a pair of them (T1 and T3) or (T2 and T4), the source is shortened. Diodes in the circuit are connected as a feedback diode because they are used to provide energy feedback to the DC source.

When we compare the full bridge inverter with the halving bridge inverter, the power is twice the power output and four times in the whole bridge inverter. For the given DC supply voltage.

2.3 ARDUINO MICROCONTROLLER

An Arduino is a single-board microcontroller and a software suite for programming it. The hardware composes of a simple open hardware design for the controller with an Atmel AVR processor and on-board I/O support. The software composes of a standard programming language and the boot loader that runs on the board. The software composes of a standard programming language and the boot loader that runs on the board. In other hand, an Arduino is a teeny computer that you can program to process inputs and outputs between the appliances and external components you link to it. The Arduino board is used to execute the code you write. The board can only control electricity and react to it so that specific components are linked to it to enable it to interact with reality. These elements may be sensors that convert certain sides of the physical world into electricity so that the board can feel it, or actuators that obtain electricity from the board and turn it into something that changes the world. Included for example sensors are switches, accelerometers and ultrasound mile sensors. Actuators are things like lights and LEDs, screens, speakers and engines. Pulse Width Modulation is a procedure that is used in many applications. One of the easiest ways to fulfillment this is by using an Arduino. Figure (2.7) shows some of Arduino types [25][26].

There are several types of Arduino:

- Arduino Uno
- Arduino Leonardo
- Arduino LilyPad
- Arduino Mega
- Arduino Nano
- Arduino Mini
- Arduino Mini Pro
- Arduino BT
- Arduino Micro
- Arduino Due
- Arduino YUN

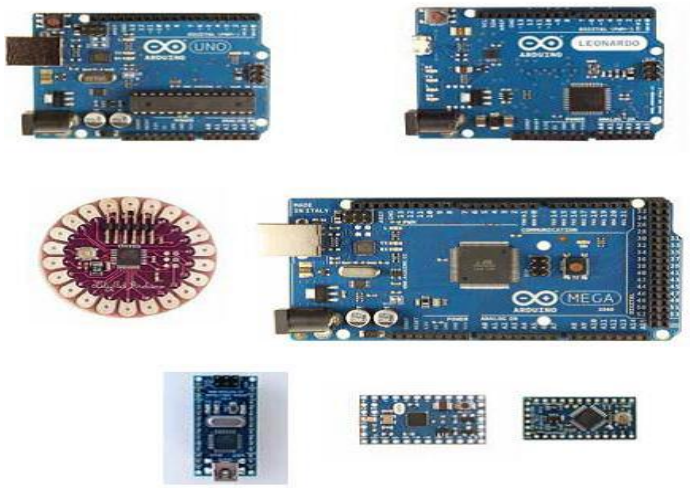

Figure 2.7: Some Arduino Families.

2.4 ARDUINO NANO

Arduino Nano, formulated by Arduino.cc in Italy, is a broad module board, consistent, scalable and supporting breadboard depending on the atmega328p (Arduino nano v3.x) / atmega168(Arduino nano v3.x). It occurs exactly in the same way as in Arduino nano but instead in small sizes. The voltage of the input is supplied with operating voltages of 5V. Nano Pinout comprises 14 pins, 8 similar pins, 2 reset pins and 6 pins of power. So each Digital & Analog Pin has several functions, but its main function must be set up input or output. When linked up with a sensor, they act as input pins, but using them as output when you drive a load. Digital pin operation is controlled by pin Mode() and digitalWrite() functions, and analogRead() is used for control of analog pin operations. The programmable clamps were equipped with a complete precision of 10bits that quantify zero to 5v. A 16 MHz frequency crystal oscillator is provided to Arduino Nano. It is used for the production by constant voltage of an exact frequency clock. There is a shortcoming with Arduino Nano, i.e. that there is no DC power supply, so that an external source of power cannot be supplied with a battery. Instead, it is supported by Mini USB support. This board does not use the standard USB connection. Small sizes and friendly breadboard actually make this device an obvious choice to most applications with a large number of electronic components. The flash memory of the ATmega board, i.e. Atmega168, is 16 KB or 32 KB and all of this depends on a flash board while Atmega328 has 32 KB of flash storage. For code storage, Flash memory is used. A boot

loader uses 2 KB of memory from the full flash memory. Arduino Nano has been programmed with IDE, the common software for almost all the board types available is called Arduino software. Just get the software download and select the board. There are two options to program the controller, one is included in the software by the boot loader which allows you to free yourself by creating and burning a program with an external function and the other via ICSP. The software for Arduino boards is Windows, Linux or MAC equally compatible, but Windows is preferably used. The Figure.2.8 below shows the Arduino nano[27],[28].

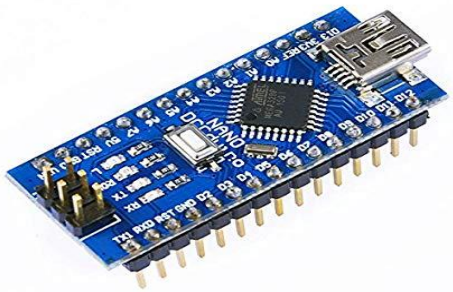

Figure 2.8: Arduino Nano**.**

For Atmega168 and Atmega328 SRAM may vary from 1 KB or 2 KB, and EEPROM is 512 bytes or 1 KB. The board is very much like other boards from Arduino, but the small size differentiates them from other boards. Arduino IDE is the programmed environment that operates in both online and offline. It is an integrated development environment. The board must not be run by prior arrangements. The computer-a board, a mini cable and Arduino IDE software are all necessary. The program is moved from the computer to the board with USB cable. The program must not be compiled and burned separately as this board has an integrated boot-loader. The figure.2.9 below shows the Arduino Nano Board specifications [29][30].

Table 2.1: Arduino Nano Board Specifications.

Microcontroller	Atmega328p/Atmega 168
Operating Voltage	5V
Input Voltage	7 – 12 V
Digital I/O Pins	14
PWM	6 out of 14 digital pins
Max. Current Rating	40mA
USB	Mini
Analog Pins	8
Flash Memory	16KB or 32KB
SRAM	1KB or 2KB
Crystal Oscillator	16 MHz
EEPROM	512bytes or 1KB
USART	Yes

A special function is attached to each pin on a nano board. The analog pins are also analog to a digital converter, which is used as A4 and A5 pins, where the I2C is also analog. Additionally, 14 digital pins are available, 6 of which are used to generate PWM. Figure (2.10) shows Arduino nano Pinout.

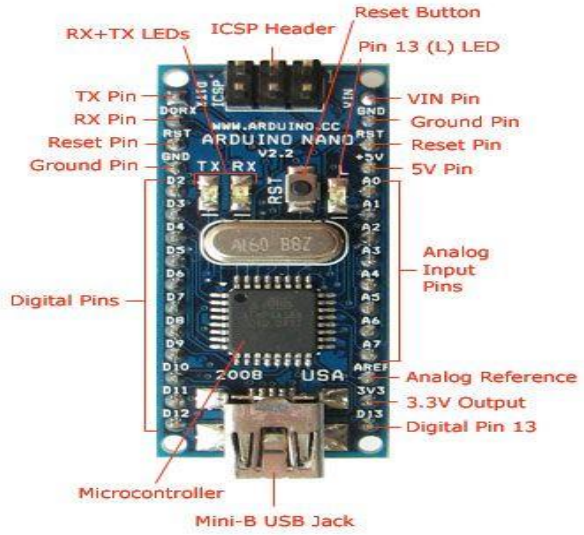

Figure 2.9 : Arduino Nano Pinout.

- Vin: From use an external 7 to 12 V power source., the input energy supply voltage to the board.
- 5V: The controller and other components are driven with the controlled supply voltage of the board.
- 3.3V: The voltage regulator on the board is created at a minimum voltage.
- GND: On the board are several pins, which can then be connected if more than one pin is needed. There are various pins in the board. These are the foundation pins.
- Reset: On the board resetting the board, the reset pin is added. If the program is executed too complex, and the board picks up it is very helpful. The LOW value resets the controller for the reset pin.
- Analog Pins: The board contains eight A0 – A7 analog pins. The analog voltage varying between 0 and 5V is measured using these pins.
- Rx, Tx: The pins for serial communication where Tx stands for data transmission and Rx for data recipient.
- Digital pins 13: The built - in LED is activated with this pin.
- AREF: This pin is a reference for the input voltage.
- PWM: For six pins 3,5,6,9,10 and 11, the PWM (Pulse Width Modulation) output. It is a method for achieving analog digital results.

- SPI: Four SPI pins (SS),11(MOSI),12(MISO),13(SCK) are used for SPI (Serial Peripheral Interface). SPI is an interface bus mostly used for the transmission of data from Microcontrollers and other peripheral devices like sensors, registers and SD Cards.
- External Interrupts: Pin 2 and 3 are utilized as external interference when the main program is stopped and important instructions are called up at this point, in the event of an emergency. When the interrupt command is called and executed, the main program continues.
- I2C: The A4 and A5 pins are used to develop I2C communication, Where A4 is the serial data line (SDA), and where A5 is a serial clock line (SCL), the master clock signal generated by the clock is used for data synchronization among the I2C bus devices [31].

2.5 CURRENT SENSOR

A current sensor is a device which senses electrical current within wire and produces a signal proportional to the current. The signal produced can be analog or current voltage or even digital output. The generated signal can be applied then to display the measured stream in an ammeter or stored in a data procurement system for further analysis or used for control purposes. Depending on the principle of the Hall Effect, if a current carrying conductor has been placed into a magnetic domain, a voltage is produced by the vertical edges of both the current and the magnetic field. It is clarifying in the figure (2.11) shown below. A thin plate of semi-conductive material carries a flow (I) and is placed on a magnetic field (B), vertical to the flow direction. Because of the existence of Lorentz force, the current distribution through the Hall element is no longer uniform and therefore an likely change is created via its orthogonal edges towards both the current and field directions. The Hall voltage of this voltage is known and its characteristic value is in the order of few microvolts. The voltage in the Hall is directly proportional to I and B. Therefore, when one of them (I&B) is known, the Hall voltage observed can be used to evaluate the other[32].

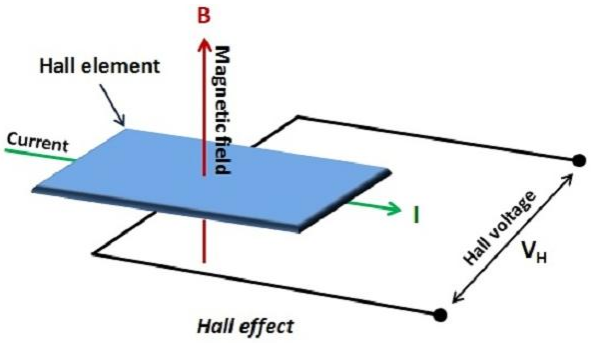

Figure 2.10: Principle of Half-Effect.

The ACS712 sensor shown in figure (2.12), works depending of the hall impact principle this sensor can deal with both of alternating current (AC) or direct current(DC) to determine the current. The ACS712 is designed to three ranges of current 5A,20A and 30A, the sensor composes of incorporated circuit that works depends on Hall-Effect principle it produces voltage ratio with the flowing current in the electric device [33].

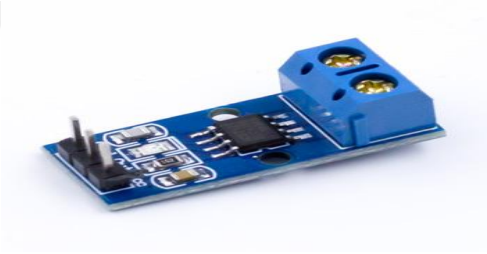

Figure 2.11: ACS712 Current Sensor.

2.6 VOLTAGE SENSOR

The module shown in figure (2.13) it depend on resistance points (voltage divider) pressure principle and it can make the input voltage of red terminal decrease five times of original voltage. The max analog input voltage can Arduino read it up to 5 V, thus the input voltage of this module should be not more than 5 V * 5 = 25 V. Because the Arduino plate have 10-bit ADC, thus this module emulation resolution is 0.00489 V (5 V / 1023), and the input voltage of this module should be more than 0.00489 V x 5 = 0.02445 V. The working principle of this sensor based on divider the input voltage onto two series resistors, and then calculation the

output voltage and read it by the Arduino; the Special Parameters of the voltage sensor are listed below [34]:

1. The range of the input voltage are from 0V to 25V (DC).

2. The range of voltage detection are from 0.0244V to 25V (DC).

3. The resolution of analog voltage is 0.00489V.
4. DC input interface: red terminal positive with VCC, negative with GND

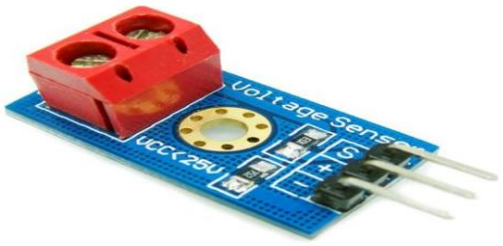

Figure 2.12: Voltage Sensor Module.

2.7 NODE MCU

NodeMCU is an expansion board featuring the popular ESP8266 Wi-Fi chip. As we see, you can program the ESP8266 just such any other microcontroller. Its evident feature over the Arduino or PIC is that it can easily connect to the Internet via Wi-Fi. Therefore, the ESP8266 breakout board has limited pins though the chip itself has a lot of output ports. The Node MCU fix this problem by show 10 GPIO pins each capable of using PWM, I2C and 1-wire interface. NodeMCU is an eLua based firmware for the ESP8266 Wi-Fi SOC from Espressif. The firmware is based on the Espressif NON-OS SDK and uses a file system based on spiffs. The code depository composed of 98.1% C-code. The NodeMCU firmware is a comrade project to the popular NodeMCU dev kits, ready-made open source development boards with ESP8266-12E chips. This ESP8266 development board actually like an Arduino Nano. Speaking of Arduino, other advantage of this board is that you can connect it directly to your PC or Mac and program it like an Arduino [35].

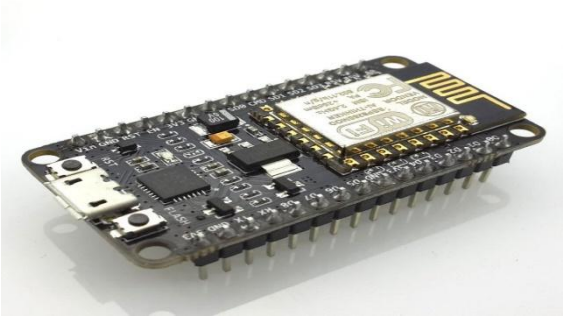

Figure 2.13: Node MCU.

Advantages of using NodeMCU platform:

- Low cost.
- Built-in WI-FI network.
- Small size.
- Low energy exhaustion.
- Higher speed than Arduino.

Disadvantages of using NodeMCU platform:

- Reduced pin out
- infrequent documentation.
- Contain a single analog input pin.
- Output voltage 3.3v.

2.8 SOLAR CELL

A solar cell are photovoltaic converters that convert direct sunlight into electricity. They are semi-conductive, light sensitive and surrounded by a front-end and conductive envelope. Many technologies have been developed to produce solar cells through a series of chemical, physical and electrical processes in the form of self-condensing and the development of various materials of semiconductors for the manufacture of solar cells in the form of elements as a silicon element or in the form of compounds as a compound gallium arsenic and carbide Cadmium, phosphide, and copper sulphide and other promising materials for the photovoltaic

industry. In order to use solar electricity for practical devices, which require a particular voltage or current for their operation, a number of solar cells are connected together to form a solar panel, also called a PV module. For large scale generation of solar electricity, the solar panels are connected together into a solar array. Through which sunlight is converted directly into electricity, by using semiconductors such as silicon, which is extracted from pure sand. In general, the materials of these cells are either a crystalline material as thick as crystalline silicon or a thinly amorphous material, such as silicon-like amorphous material, which is deposited as layers above semiconductor segments consisting of gallium arsenide. Its energy is a form of renewable and clean energy, because it can't operate polluted waste, noise, radiation, or even fuel. But its initial cost is high compared to other sources of energy. Solar cells generate continuous and direct electricity (as in ordinary liquid and dry batteries). The intensity of their current depends on the time of sun's brightness and the intensity of the sun's rays, as well as the efficiency of the photovoltaic cell itself to convert solar energy into electrical energy. DC power is continuous and these cells are connected respectively, and the resulting energy can be stored in the acidic batteries made of lead or base metal made of nickel and cadmium metals. The DC current can be converted to AC using reflectors for the use and management of ordinary household and industrial electrical appliances. It works in satellites with high efficiency, especially as it does not need maintenance, repairs or bio-energy works in silence, but the pollution of photovoltaic cells due to pollution or dust leads to a reduction in efficiency, which requires cleaning at intervals. Finally, the solar system involves products such as household appliances; radio or TV set that use the solar electricity for their operation. We refer to these products as a load. In summary, the PV solar system consists of three parts:

1- Solar panels or Solar arrays.

2- Balance of system.

3- Load.

Several kinds of solar cells exist. But more than 90% of solar cells in fact made up of silicon wafer cells worldwide. These silicone solar cells are either separated from a single crystal rail or a large-scale block and are correspondently referred to as the solar cell monocrystalline or multicrystalline silicone. Another important solar cell family is based on thin-films, which are about 1-2 μm in thickness and therefore need substantially less active semi-conducting material.

The production of thin-film solar cells in large volumes at reduced costs will therefore likely continue to increase their market share. However, the qualifications for the wafer based silicone solar cell are lower, which means that the same performance needs a higher exposure surface and structural material. A number of solar cells that are electrically attached and installed in a single support structure or frame are referred to as the "photovoltaic module." Modules are ready to power at some voltage, including a common 12-volt system. The current manufacture depends immediately on the light intensity of the module. A number of modules for the composition of an array may be wired together. The two main types of photovoltaic systems are connected with networked systems (surgical systems) and inject electricity into the grid. The grid is connected with the grid and the electricity is injected into the network in the electricity supply. This is why the direct current produced by the solar modules is converted into a suitable electricity alternation. But solar manufacturing can be operated without the grid as well and is then known as separate (off-grid) systems. More than 90% of photovoltaic systems are currently performed as networked systems around the world. In the event of a failure, the electricity conditioning unit also monitors the working of the system and the grid[36],[37],[38].

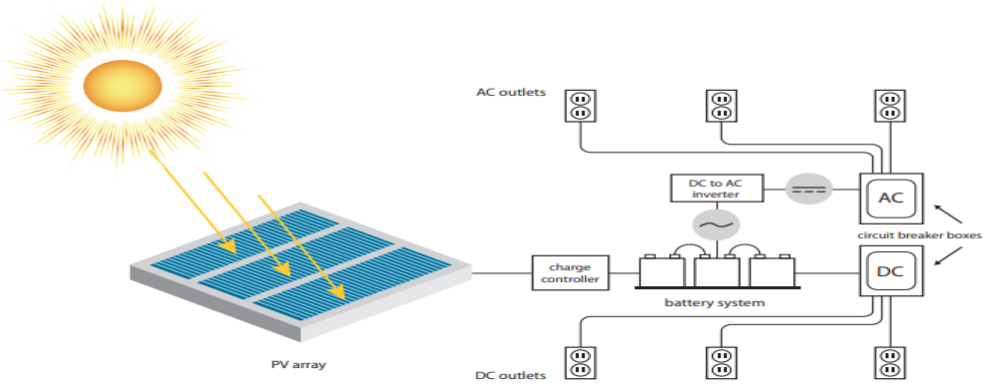

Figure 2.14: Solar Cell Structure.

2.9 LIGHT DEPENDENT RESISTANCE

Photo resistors are resistors which are light sensitive and whose resistance is reduced as the light intensity is increased. Photo resistors are the light-dependent (LDR) devices most commonly used for indicating or measuring light intensity or presence or absence of light. Their resistance in the darkness is very high, sometime up to 1 M tall, but the resistance drops dramatically if the LDR sensor is exposed to light, even to a few ohms according to the

intensity of the light. The sensitivity of LDRs is different from the wavelength of the light and non-linear devices. They are used in many applications, but other devices, like photodiodes and photo transistors, sometimes make them obsolete. In some countries, lead or cadmium LDRs have been prohibited on consumer safety issues. Photo resistance can be divided into two types, intrinsic and extrinsic, based on the materials used. Indictable materials like silicone or germanium are used for intrinsic photo resistors. Photons which fall on the device exciting electrons from the valence band towards the conduction band are freer electrons in the material and therefore less resistant. Extrinsic photo resistors consist of doped materials, also known as doping materials. The drug substances create a new energy band, populated by electrons, above the existing valence band. The transition to the conductor range requires less energy for these electrons thanks to the less energy gap [39].

The result is an apparatus sensitive to various light wavelengths. However, when illuminated, both types show a decrease in the resistance. The higher the intensity of light, the bigger the fall in strength. Consequently, LDR resistance is an inverse, nonlinear light intensity function. Many materials with similar characteristics were found since the discovery of selenium photoconductivity. PbS, PbSe and PbTe were studied in the 1930s and 1940s following the development of silicon-and germanium photoconductors. Modern light resistors are made of plum-sulphide, plum selenide, indium antimonide, and cadmium-sulphide and cadmium selenide. CdS photo resistors are often referred to as popular types of cadmium sulfide. The highly purified powder of cadmium sulfide and inert binding agents are mixed for the production of the LDR cadmium sulphide. Then press and sinter this mixture. In order to forms interlink able peals and connections, electrodes are vaporized on the surface of one side. The disk is attached to a glass envelope or encapsulated in clear plastic in order to prevent surface contamination. Cadmium sulfide's spectral reaction curve corresponds to the human eye. The wavelength of the peak sensitivity in the visible part of the spectrum is approximately 560-600 nm. It should be noted that plumbing or cadmium-containing devices do not conform to RoHS and are prohibited for use in countries which adhere to RoHS law. The Figure .2.16 shows light dependent resistance [40].

Figure 2.15: Light Dependent Resistance.

A LDR circuit such as the one in the figure (2.17) can be used if a basic light sensor is required. When the light intensity reaching the LDR resistance is sufficient, the LED lights up. The variable resistor of 10 KΩ is being used to set the LED threshold. The LED will remain off if the LDR light is under the threshold intensity. The LEDs would be replaced with a relay in real - world applications or the output could be moved to a microcontroller or other equipment. When a dark sensor is required, the LED and the two resistors 10 KΩ should be swapped in the absence of the light [41].

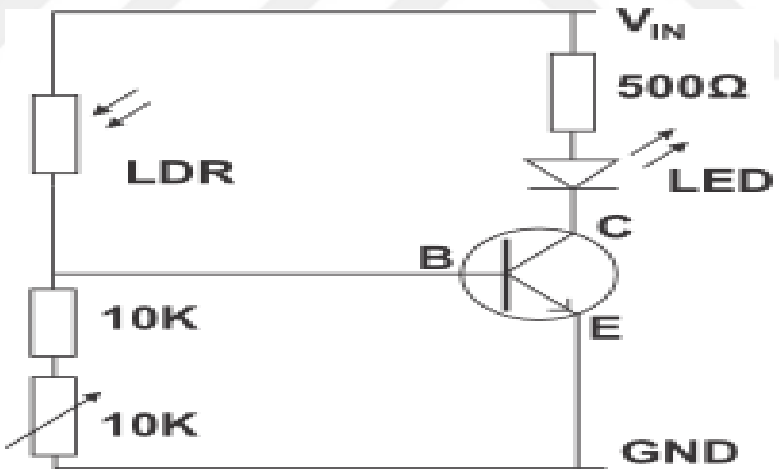

Figure.2.16: Light Dependent Resistance Circuit.

2.10 TEMPERTURE SENSOR LM35

The LM-35 sensor is sensitive to the measurement of the voltage output temperature linearly proportional to the temperature in the centimeter. The LM 35 does not need to be reset every time as it gets in some sensors. The temperature range ranges from -55 °C to 150 °C with 0.05% accuracy. LM35 is an IC temperature sensor of precision with its temperature proportional (in ^{o}C) output. The sensor circuit is closed and not oxidized and other processes

are therefore involved. The temperature with LM35 is more accurate than the thermistor to measure. It also has low self-heating and does not cause an increase in still air of more than 0.1 ^{o}C. The range is between-55 °C and 150 °C. Operating temp. As each rise/ fall of the OC in an environmental temperature, the output voltage is 10mV, i.e. its level is 0.01V / ^{o}C. The figure (2.18) below shows the LM35 Temperature sensor [42].

Figure 2.17: LM35 Temperature Sensor.

Features

- Suitable for measuring heat in remote locations
- Low self-temperature, 0.08 ° C
- With low output resistance
- Sensitivity 10 mv / c

Table 2.2: Describe The Pin Specifications.

Pin no	Function	Name
1	Supply Voltage ; 5v (+35v to -2v)	Vcc
2	Output Voltage (+6v to -1v)	Output
3	Ground (0v)	Ground

2.11 RELAY

A relay is classified into several types, a standard and commonly used relay consists of electromagnet which is usually used as a switch. The relay is called an act of passing from one thing to the next because the signal on one side of the device controls the switching operation. Relays is therefore a switch that electromechanically controls (open and close). This device's

main operation is to establish or break contact with a signal in order to switch it ON or OFF without any human involvement. It is mostly used with a low power signal in order to control a high power circuit. A DC signal is generally used for control of high - power circuits such as controls of AC domestic devices with microcontroller DC signals. The following figure.2.19 shows how a Relay looks internally and how it can be constructed [43].

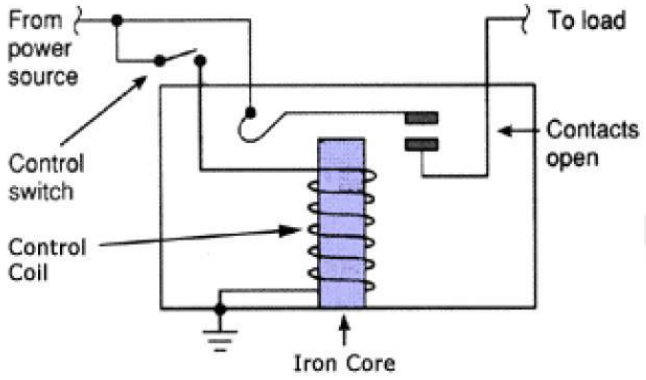

Figure 2.18: Relay Internal Structure.

There is a core on a case that is winded to it by copper hinges (forms a coil). A range of moving components is a spring holder or structure with one end and the other side is a metallic contact. All of this structure is placed over the core to attract the frame when the coil is energized. The moving frame is generally considered to be a joint terminal connected to the external circuit. The Relay is also connected to the rear or common terminal using a normal locking pin and normally opening it (NC and NO), while the normally locked pin is left unlocked (if not powered) by a coil. The armature moves when the spin is energized and is connected to the normal contact until the current flows through the spin. It goes to its initial position if it is de-energized. The general circuit representation of the relay is as shown in the figure.2.20 below [44].

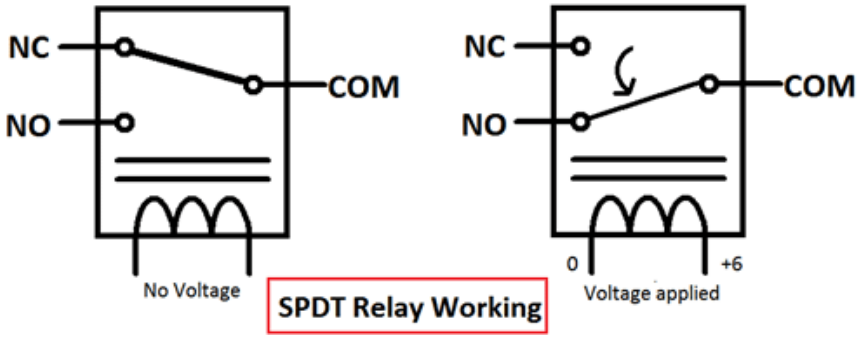

Figure 2.19: General Circuit Representation of The Relay.

2.11.1 Relay in Normally Closed Condition

When there is no voltage on the core, no magnetic field is generated and it does not act like a magnet. Thus, the movable armature cannot be attracted. The initial position itself is therefore the frame, which is normally closed (NC) connected. The figure (2.21) shows Relay in closed condition

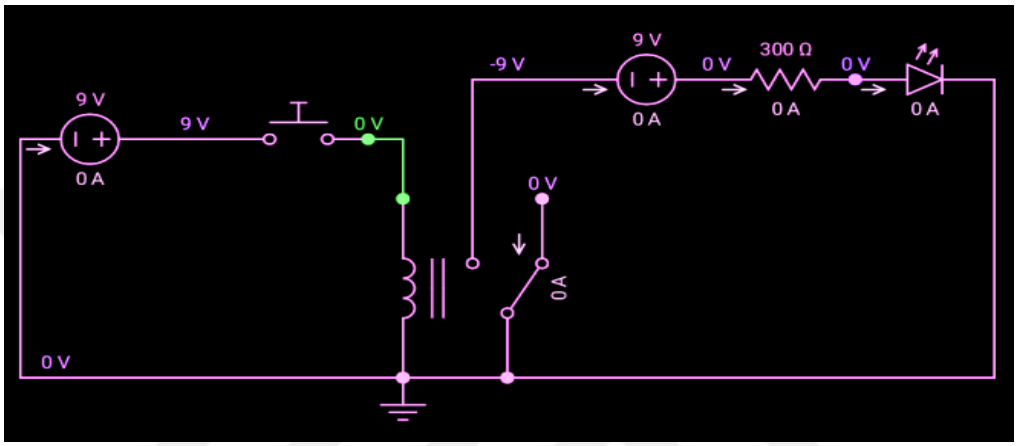

Figure 2.20: Relay Closed Condition.

2.11.2 Relay in Normally Opened Condition

When enough voltage is used for the core, a magnet field begins to be created around it and acts as a magnet. As the moving frame lies within it, The magnetic field produced by the core is attracted and thus alters the frame position. It is now otherwise connected to the normal open relay pin and the connected external circuit. The figure (2.22) shows relay in opened condition[45].

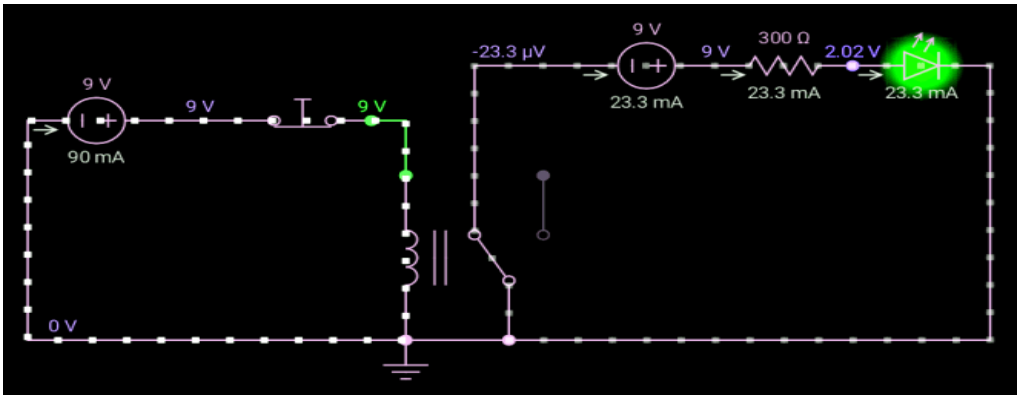

Figure 2.21: Relay Opened Condition.

Finally, when a body is energized, the reinforcement of the armature will be attracted, and if the body is deeper energized, the reinforced armature will become less powered and its initial position will be re - examined.

2.11.3 Applications of Relay

The use of the relay is unrestrained; its central function is to operate the low - voltage power supply high voltage circuit (AC circuit 2300V) (a DC voltage) [46].

- In order to carry out its arithmetical and mathematical operations relays are used both in large electronica circuits but also in computer circuits.
- Used to control switches for electric motors. To switch an electric motor on, we need 230V AC supply, but in a few cases / series, the engine with a DC supply voltage might be switched on. A relay can be used in these cases.
- One of the applications for automatic stabilizers is where a relay is used. When the supply voltage is different from the rated voltage, a series of relays senses the voltage changes and uses circuit breakers to check the charging circuit.
- Used when there are more than one circuit within the system for circuit selection.
- TV used the internal circuitry of an old picture tube works with the DC voltage, but the picture tube requires a very high AC voltage, so we have a relay to turn on the picture tube.
- Temperature controls used in traffic signal controllers.

2.12 ARDUINO BOOST CONVERTER

The XL6009 is a DC booster that can lift the voltage to 35V and lower the input voltage of 3V with a load capacity of up to 4A and up to 90% efficiency. It can be used in many applications, especially in the case of high voltages and low voltages. DSN6009 4A is a module for high-power step-ups (BOOST). In comparison to the LM2577 technology of first generation, the module uses the second generation of XL6009E1 high-frequent switching technology. XL6009 boost module is on the verge of eliminating LM2577 at lower costs and higher performance. 3V~32V broad input voltage, optimum operating voltage range 5~32V; 5V~35V wide output tension; Built-4A powerful MOSFET switch allow for efficiency of up to 94 percent; 400 KHz

High switching frequency, can be used to produce very good results by a smaller and smaller condenser that can achieve very good results. (LM2577 only 50 KHz frequency) [47].

Figure.2.22: Arduino Boost Converter XL6009.

Terminals:

IN-IN + input Positive Input Negative!

Positive output OUT + OUT-output negative

Features:

- Model Specification: DSN6009 boost module
- Module Properties: Non-isolated boost (BOOST)
- Rectification: Non-Synchronous Rectification
- Input Range: 3V ~ 32V
- Output Range: 5V ~ 35V
- Input Current: 4A (max), no-load 18mA (5V input, 8V output, no-load is less than 18mA. Higher the voltage, the greater the load current.)
- Conversion efficiency: <94% (greater the pressure, the lower the efficiency)
- Switching frequency: 400KHz
- Output Ripple: 50mV (the higher the voltage, the greater the current, the greater the ripple)
- Load Regulation: ± 0.5%
- Voltage Regulation: ± 0.5%
- Dimensions: 43mm x 21mm x 14mm .

3. SYSTEM DESIGN

2.13 INTRODUCTION

The DC to AC power inverter is a circuit which modifies and change input direct current (DC) to an alternating current (AC) of a specified voltage and frequency depends on the transformer voltage ratio and the pulse width. The input DC voltage source for this proposed system is a battery supplied by photovoltaic (PV) panels. The DC voltage is therefore likely to be incoherent and considerations must be taken to produce the desired output. This requested AC output is a 120Vrms wave, a 60Hz wave, or a standard 13 US wall plug. The DC output is controlled by 12V. This enables the system to power output that is applicable for any load [48].

2.14 SYSTEM DESIGN AND IMPLEMENTATION

In this section we will explain and describe the smart electric inverter that was designed using Arduino and other sensors. Basically, the idea of designing an electrical inverter is to handle power outages or for emergency use while a temporary malfunction or recreational travel such as camping. The implemented system is based on the Arduino NANO microcontroller, temperature sensor, the voltage sensor and current sensor. The inverter circuit two MOSFET and step-up transformer, the MOSFETS working as controlled switch, the gates of the two MOSFETS are connected to two digital pins of the Arduino board, the MOSFES were responsible on the signal generating, the figure.3.1 shows the circuit diagram of the inverter circuit.

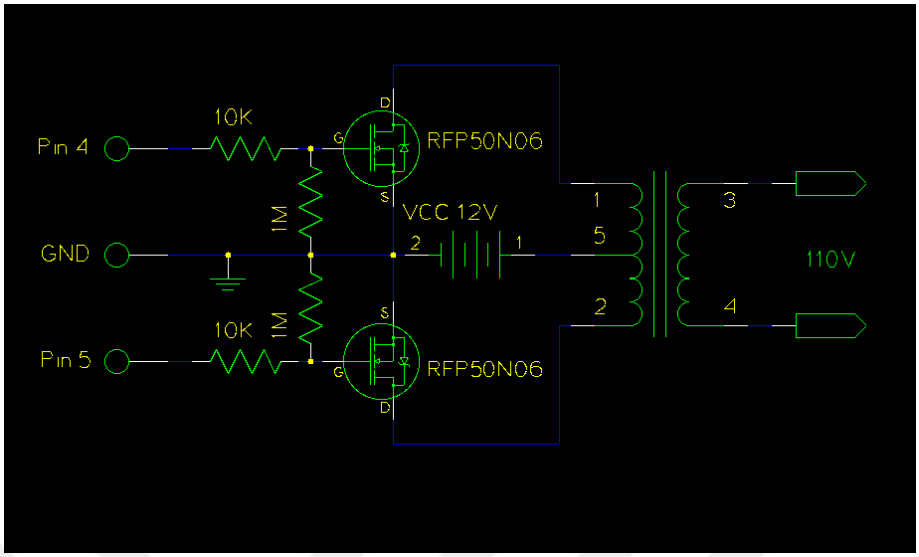

Figure 3.1: The Circuit Diagram of Inverter.

The current sensor responsible on measure the amount of current drawn from the inverter, the voltage sensor used for monitoring the battery stats of inverter and the temperature sensor used to monitor the temperature of MOSFETS, when the temperature exceeds 30 ºC the fan will be turning “on”, the user can monitor the drawn current and battery voltage on the specific programmed GUI via IoT technology through NodeMCU microcontroller, in same time the user can turning ON/OFF the load from a specific button on the GUI was programmed for this purpose. Additionally, the battery of inverter is charged from a solar panel with sun tracker property this to make the implemented system more useful where, the output voltage of solar cell will directly have connected to the boost converter in order to amplify the solar cell output voltage. As known each instruction write inside the Arduino IDE need time for execution this time will added with the time of output signal and lead to the output waveform will be not uniform in other words this will affect the frequency of the inverter. The figure.3.2 shows the manufacturing problem of the implemented system.

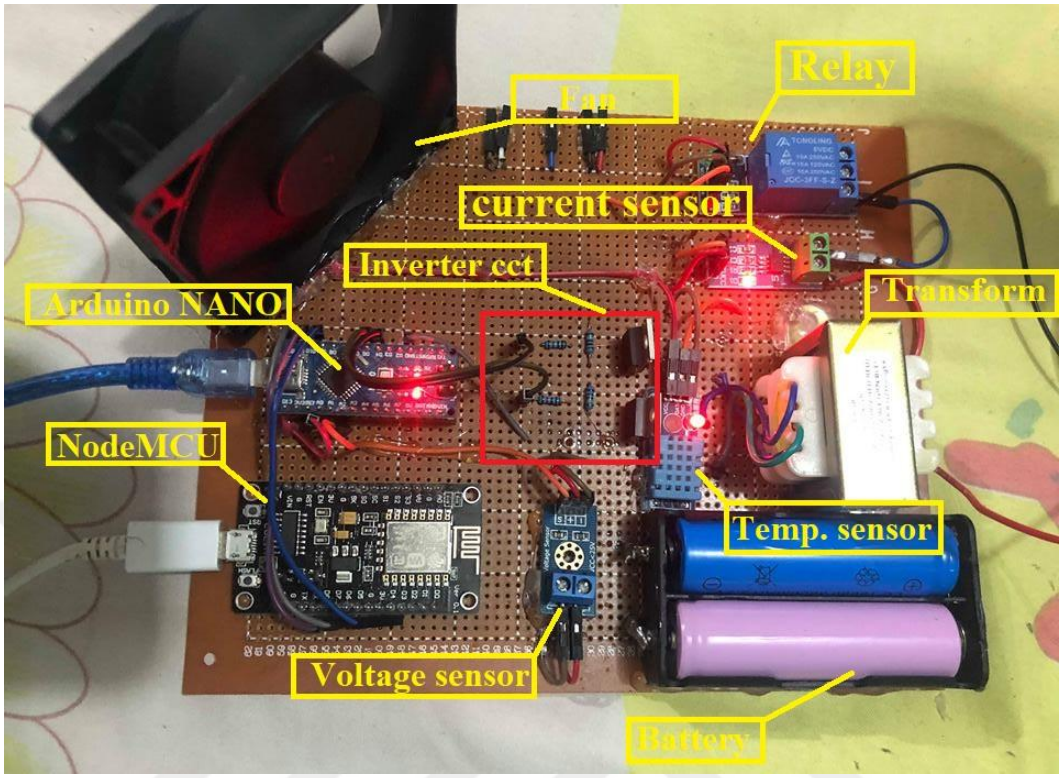

Figure 3.2: The Implemented System.

To solve the problem mentioned above, another Arduino NANO was used to implement the inverter and the another Arduino NANO used to process the data of voltage sensor, current sensor, temperature sensor and doing the job of sun tracking (i.e. drive the servo motor). The figure.3.3 illustrate the completed inverter design.

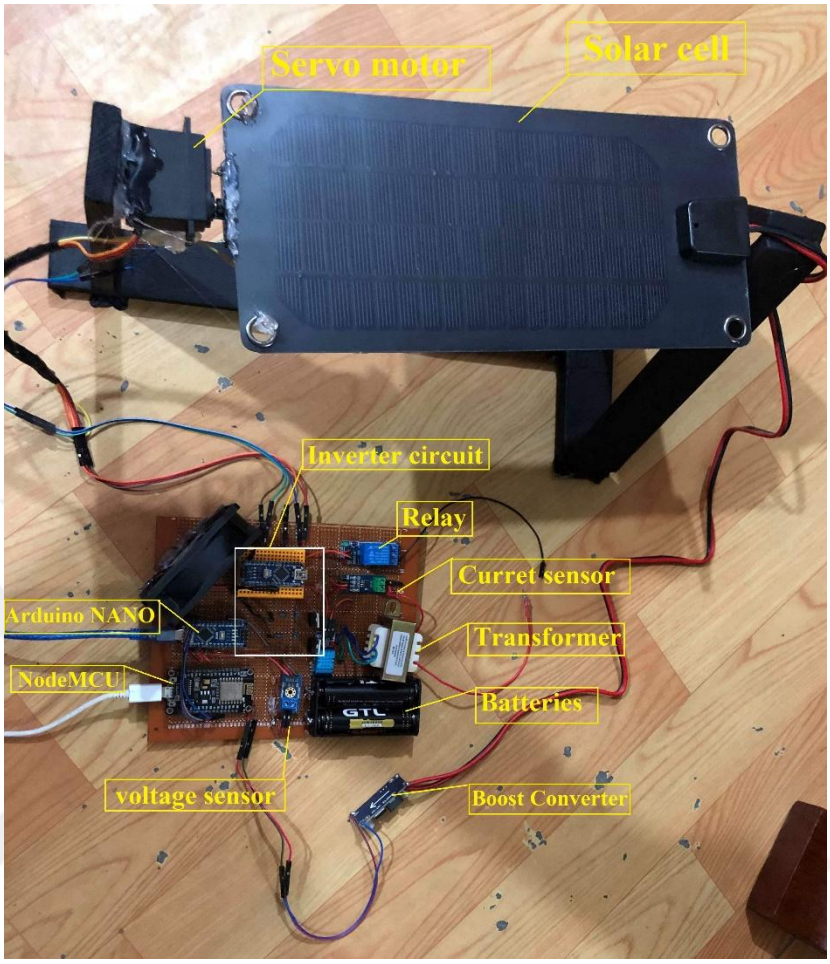

Figure 3.3: The Completed Inverter Design.

2.15 RESULTS

In this section, the obtained results will be discussed after running the implemented system. As illustrated before the boost converter used in order to step-up the DC voltage, in this work the boost converter used to increase the output voltage of the solar cell. The figure.3.4 illustrate the output voltage of the solar cell, this value of voltage received directly from the solar cell without any amplification.

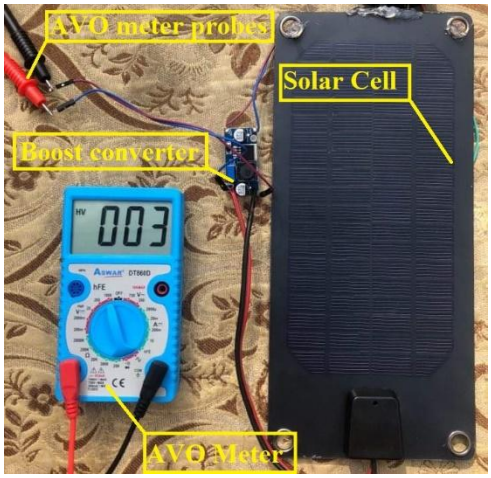

Figure 3.4: The Output Voltage of Solar Cell.

The figure.3.5 illustrate the amplification of solar cell voltage after connects with the boost converter, as shown the boost converter steps-up the output voltage of solar cell from 3V to 43V.

Figure 3.5: The Amplificated Voltage of Solar Cell.

The amplificated voltage of solar cell can be tuned from the potentiometer of the boost converter, in this work the battery capacity of the inverter equal to 7.4 v in this case the boost converter sets with 10v as shown in figure.3.6 to make fast charging for the battery.

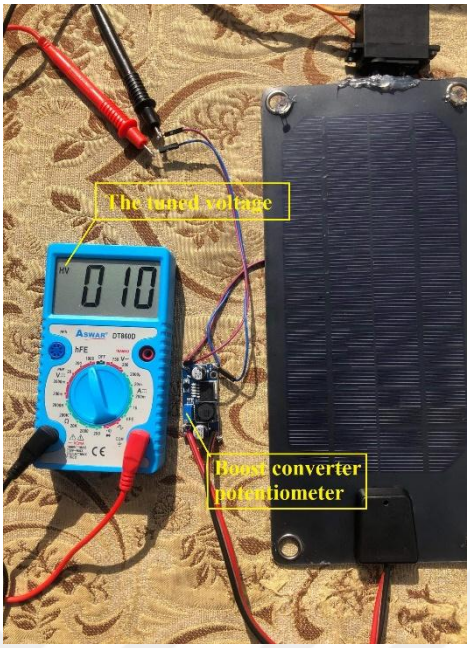

Figure 3.6: The Tuned Voltage of Boost Converter.

When the user need to accessing to the control panel (GUI), the NodeMCU microcontroller will grant a local IP allows the user form accessing into the control panel as shown in figure.3.7.

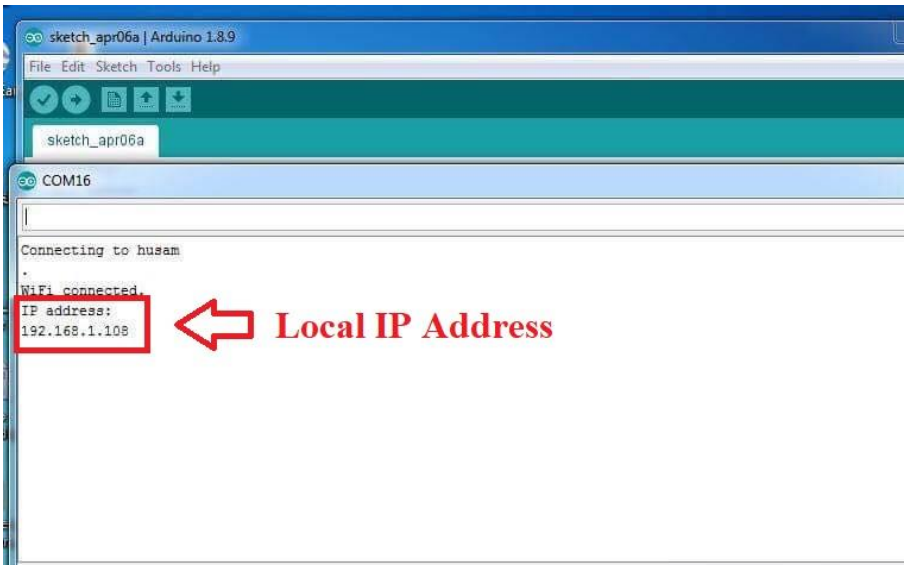

Figure 3.7: The Grated Local IP Address.

After the user entering the IP address in the web browser, the user will be accessing to control panel, where the user will be able to monitor the state of drawn current and battery voltage. Additionally, will be able to turning the load ON/OFF as shown in figure.3.8.

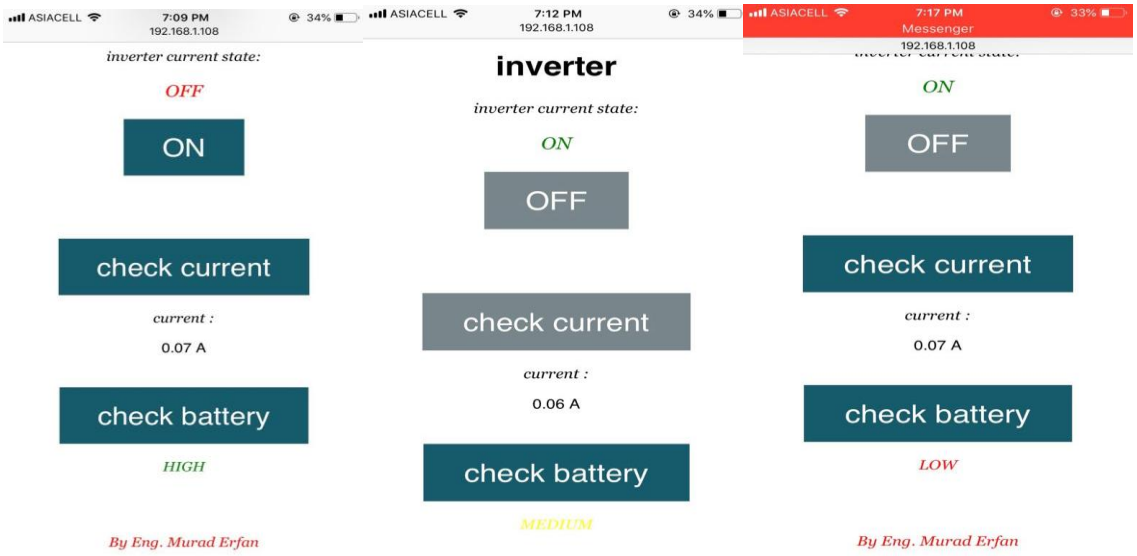

Figure 3.8: The Results on The GUI.

The AC output voltage of the inverter was tested by the AVO meter, as shown in figure.3.9, the output voltage can be controlled via the transformer ratio (N1/N2) and the bias voltage of batteries, in this work the batteries voltage chosen with (7.3V×2) in this case the output voltage approximately equal to 102V as mentioned this value this be controlled (i.e. increase or decrease).

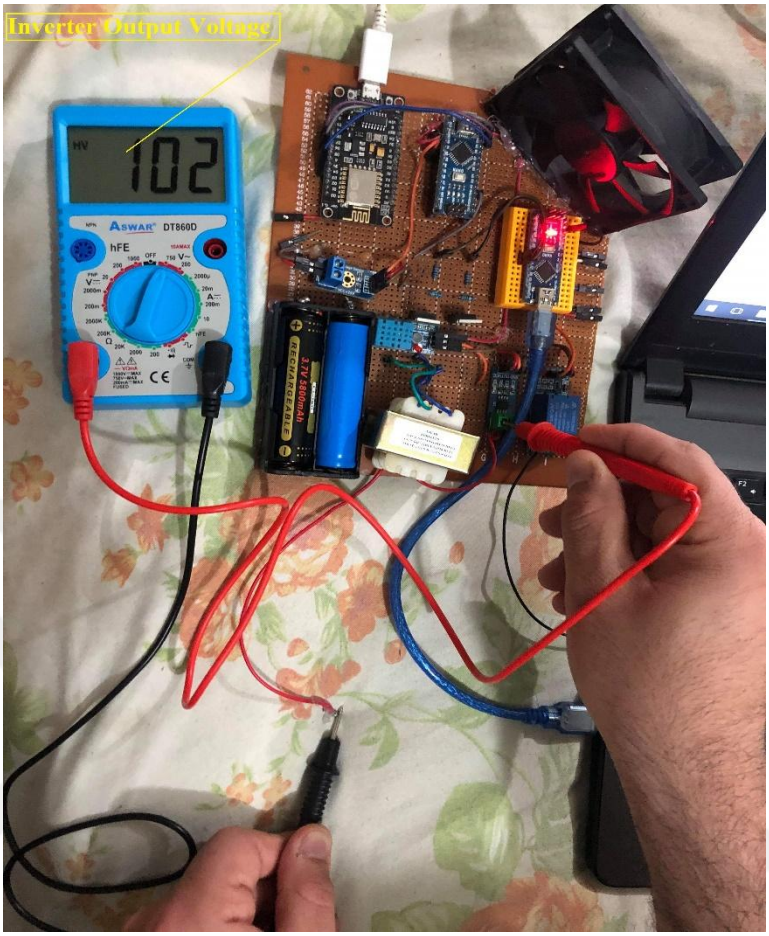

Figure 3.9: The Inverter AC Output Voltage.

4. CONCLUSION AND FUTURE WORK

4.1 CONCLUSION

In this work, a single-phase low voltage electric inverter was designed by using the Arduino microcontroller and other sensors such as temperature sensor, current sensor, and voltage sensor. The system is controlled by Internet of things technology and is equipped with DC voltage through a solar cell with Sun tracking property to achieve maximum utilization of solar energy. Additionally, the boost converter is used to increase the output voltage of the solar panel in order to reduce the battery charging time.

4.2 FUTURE WORK

Many additions and modifications can be used to develop this work and can be summarized as follows:

1.Adding power factor correction in the output side in order to increasing the useful power and decreasing the reactive power.

2. Use special circuit to make filtering to the output voltage waveform to reduce the harmonics and get pure sinewave.

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