Increasing the Efficiency of a Solar Power Supply, Using Water.

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SUMMARY

This master's thesis, includes: 78 pages, 28 subsections, 41 references, 47 figures, 8 tables.

To achieve this purpose we need to **solve the following problem**:

- To review the power supply systems based on photovoltaic cells;
- Analyze the design conditions, namely the cottage house, its location, the electric load, lighting;
- To calculate the power of the PV system required;
- Design a circuit power supply;
- Design of cooling and automation system;
- To carry out an economic assessment of the power supply system of photovoltaic panels.

Goals of the research were:

1. To increase the efficiency of photovoltaic panels.
2. To analyze and develop a cooling system.
3. To maximize the solar irradiance of the region.

The following tasks were solved in the diploma thesis:

1. To determine and calculated the specific load required;
2. To determine the efficiency of the battery;
3. To protect the system from overloads or damage;
4. To design and achieve an energy efficient system;

CONTENT

LIST OF ABBREVATION

PV	Photovoltaic.
CIGS	Copper indium gallium (di) selenide.
CZTS	Copper zinc tin sulfide.
P3HT	Poly (3-hexylthiophene).
PCBM	Phenyl C61-butyric acid. methyl ester.
VB	Valence Bond.
CB	Covalence Bond.
Cz	Czochralski.
FZ	Floating zone.
DC	Direct current.
AC	Alternating current.
CPU	Central processing unit.
LED	Light emitting diode.
RAM	Read available memory.
ROM	Read only memory.
EPROM	Erase-able programmable read only memory.
EEPROM	Electrical erase-able programmable read only memory.
LCD	Liquid crystal display.
W	Watts.
V	Volts.
A	Amps.
Kwh	Kilowatt hour.
Ah	Amps hour.
NOCT	Nominal operating cell temperature.
T_w	Water temperature.
VOC	Open circuit voltage.
ISC	Short circuit current.
VDC	Direct current voltage.
OSHA	Occupational safety and health organization.

INTRODUCTION

Actuality of the topic. The photovoltaic effect is the development of electric voltage in a system exposed to solar radiation. With the immersion of photons, charge carriers are excited into the conduction band. The mechanism of light-induced electron transition to a higher energy state is similar to that of the photoelectric effect. Einstein explain the PV effect in 1905 stating that a photon carrying a sufficient amount of energy frees an electron from the surface of a metal, through this phenomenon we are able to convert solar radiation into electrical energy this is the PV effect. Devices exploiting the PV effect are called solar cells, also photovoltaic cells, or photovoltaic devices.

It is known that the Sun provides a specific amount of power density for a surface perpendicular to the Sun's rays at sea level on a clear day. The actual power at specific area varies with seasons and depends on the geographic position of the area. The Sun only shines during the day, and the path of the Sun rays shifts during the day if the PV systems do not move and it would be noticed. It is also estimated that 70 percent of sunshine days occur in a year. If a vast area of land like the Sahara desert can be exploited, there will become enough landmass to install solar systems enough to generate the required electricity needed.

The purpose and Objective of the masters thesis is to develop a cooling system that increases the efficiency of photovoltaic panels with redundant networks. To achieve this purpose, we need to solve the following problem:

- To review the power supply systems based on photovoltaic cells;
- Analyze the design conditions, namely the cottage house, its location, the electric load, lighting;
- To calculate the power of the PV system required;
- Design a circuit power supply;
- Design of cooling and automation system;

To carry out an economic assessment of the power supply system of photovoltaic panels.

The object of the research – the process of increasing the efficiency of solar power supply by using water.

The subject of the research – Defining the cooling and heating level of solar panels using the nominal operating cell temperature.

The scientific novelty of the obtained results – using automated systems improves performance and efficiency.

The practical significance of the obtained results - using the application of this research will reduce the adverse effect of heat buildup on solar panels.

Approbation. The research results on this topic of the thesis were presented at the IX International scientific and technical conference of young researchers and students.

The structure of the work. The work consist of an introduction, 4 sections, conclusion and a list of references. The total volume of the text is 79 pages 8 tables, 47 figures and 28 subsections.

SECTION 1

ANALYSIS

1.1. The principle of the solar cell

PV is a technique of transforming solar radiation directly into electricity utilizing semiconductors exhibiting the PV effect. Solar energy is the most significant energy reserve in the world; being an indispensable part of the energy system is almost guaranteed. PV has a higher overall efficiency as compared to other energy conversion paths, from solar to electricity.

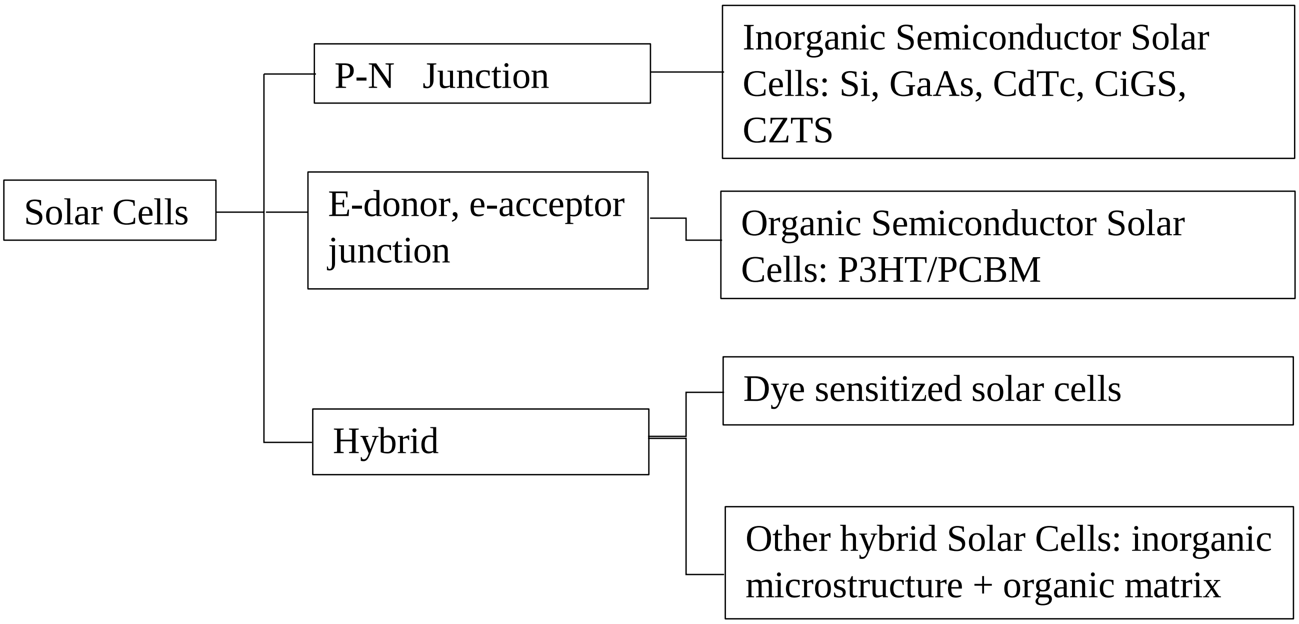


Figure 1.1. Classification of solar cells depending on the junctions used. CIGS, copper indium gallium (di) selenide; CZTS, copper zinc tin sulfide; P3HT, poly (3-hexylthiophene); PCBM, [6, 6]-phenyl C61-butyric acid. methyl ester.

Additionally, PV is the only form of clean energy that can be used everywhere. So far, solar cells have been of many kinds. Solar cells have traditionally been classified according to the materials used in the absorber layers, i.e., generation of charges in essence [1].

Different authors have developed a slightly different approach, which could provide more understanding of the working principles of solar cells. These cells may be divided into three major classes, i.e., inorganic p-n junction-based solar cells, organic e-donor / e-acceptor solar cells based on junction, and hybrid solar cells based on junction, based on junctions implemented in Figure 1. Hybrid solar cells based on connection can also be classified into two subgroups: dye-sensitized solar cells and other hybrids. In recent years, new model solar cells, especially those focused on nanostructures and quantum containment, have also been researched [2, 3].

In figure 1.2, the fundamental operating rules of a solar cell under illumination by sunlight are shown. For a solar cell, there are three key steps. First, there is the production of charge carriers (or light pumping). In the presence of sunlight, electrons in the semiconductor (with correct bandgap Eg) absorber are transferred from the valence band (VB) to the conducting band (CB). Second, separation of the carrier charges is in place: Electrons in the CB and holes in the VB must move in different directions to be physically separated from each other to minimize direct recombination within the device, which is often performed with selective contacts. Finally, there is load carrier transport/collection: carrier transportation through the absorbing material, particular connections, metal wire, and interfaces between them must be smooth, that is, the resistance must be significantly reduced, requiring the selection of suitable materials with the right energy band alignment between them and fewer defects.

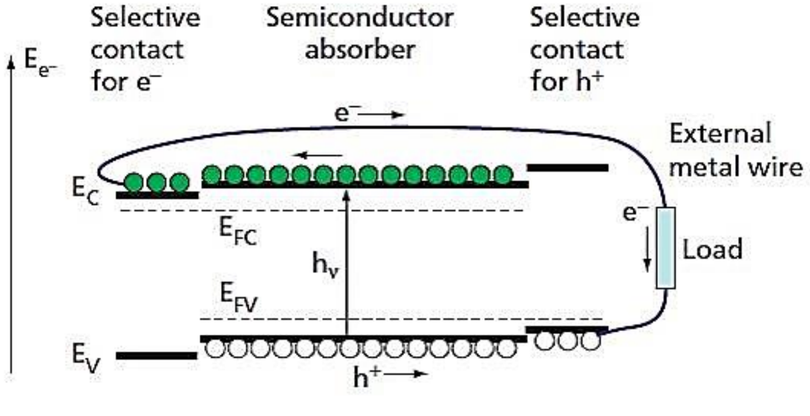


Figure 1.2. Working principle of solar cells under sunlight illumination.

Overall, electrons migrate through the route loop, collecting solar energy as transferred from the lower VB to the higher CB stage and increasing their power by acting on the load similarly to the hydrological process of hydropower [4]. The photovoltaic effect and photoelectric effect are closely linked, in which electrons are generated from a substance that has absorbed light at a frequency above a metals-dependent threshold. In 1905, Albert Einstein realized that this phenomenon might be clarified by believing that the light consists of a well-defined quanta of radiation, called photons. The energy of this photon is supplied by E = hv, in which h, is the constant of Planck, and v is the light frequency. In 1921, Einstein was awarded the Nobel Prize in Physics [5] for his description of the photoelectric influence. The photovoltaic power can be broken down into three fundamental processes:

1. Production of charge carriers caused by the absorption of photons in products creating a junction.

The absorption of a photon in a substance means that its energy is used to excite an electron from the original energy level of Ei to the higher energy level of Ef. Photons are only consumed if the electron energy ratios Ei and Ef are present such that their gap is equivalent to the photon intensity, hv = Ef – Ei [6]. The ideal semiconductor electron can generate energy levels below the so-called valence band edge, EV, and above the so-called conduction band edge, EC. There are no allowed energy states between these two bands, which could be populated by electrons. Therefore, this energy difference is called a bandgap, EG = EC-EV. If a photon with an energy lower than EG enters the perfect semiconductor, it is not absorbed but travels through the metal without any interference. In the real semiconductor, the valence and conduction bands are not flat. Still, they vary depending on the so-called k-vector that describes the momentum of the electron in the semiconductor.

2. Subsequent isolation of photo-generated load carriers at the junction.

Usually, the electron-hole pair must recombine, i.e., the electron must collapse down to the original energy level of Ei, as seen in Figure 1.3. Energy is then be emitted either as a photon (radiative recombination) or passed to other electrons or holes or lattice vibrations (non-radiative recombination).

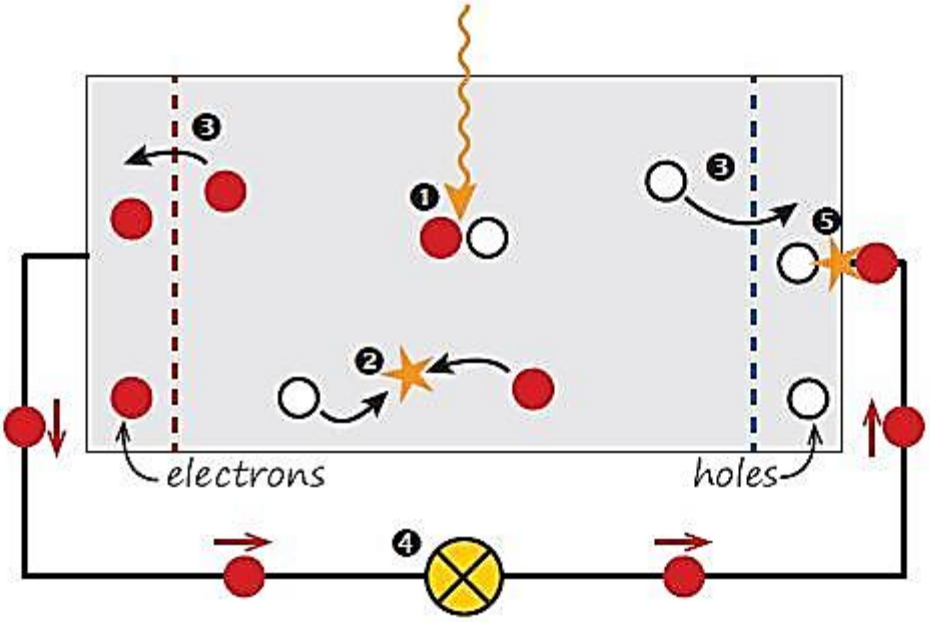


Figure 1.3. A straightforward solar cell model. 1 Photon absorption contributes to the creation of an electron-hole pair 2. Usually, the electrons and holes recombine 3. The electrons and the holes can be isolated with semipermeable membranes 4. The separated electrons can be used to drive an electric circuit 5. After the electrons passed through the course, they recombine with holes.

If one wishes to use the energy contained in the electron-hole pair to do work in the external circuit, the semipermeable membranes must be present on both sides of the absorber. Such that the electrons may only pass through one membrane, and the holes can only pass through the other membrane [6], as seen in Figure 1.3.

3. Set of the charging carriers' photo-generated at the junction terminals.

Finally, through electrical connections, the charge carriers are separated from the solar cells such that they can do the job in an external circuit figure 1.3. The electron-hole pairs' chemical energy is eventually converted to electric power. They can recombine with holes at a metal-absorber interface after the electrons have gone through the circuit, as shown in figure 1.3.

1.2 The Solar Cell Structure

There are many materials available for semiconductors; single crystal silicon is currently the most popular option for commercial cells. Let us first discover how single-crystal silicon solar cells are made, and then look at several other essential PV materials: polycrystalline silicon, amorphous silicon, copper indium diselenide, cadmium telluride, and gallium arsenide.

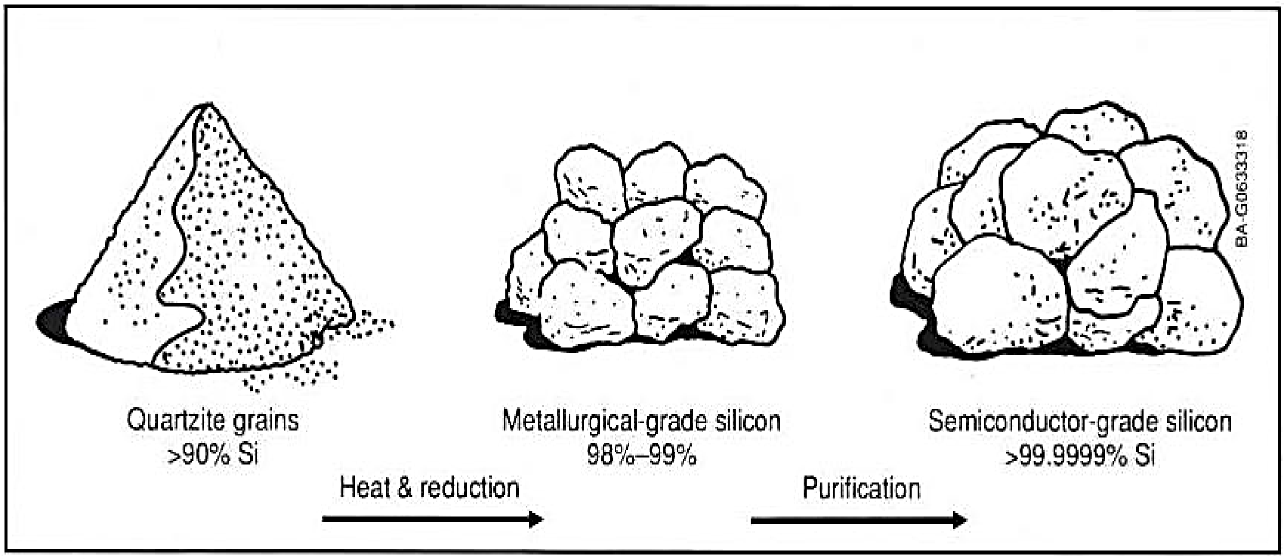


Figure 1.4. In order to obtain the pure silicon required for solar cells, quartzite grai ns, which are 90 % silicon, are heated and reduced to produce metallurgical grade s ilicon, which is 98% to 99 % pure. This material is then refined to produce semico nductor-grade silicon, which is at least 99.9999 % pure silicon.

Silicone Manufacturing

To start the process, we first technically reduce quartzite to polycrystalline (polysilicon) grade metallurgical grade, which is 98% to 99 percent pure silicon, as shown in the diagram above. However, photovoltaic cells need polysilicon that wo uld be even purer, so more processing is needed. Currently, one of the highest-purity polysilicon is used in semiconductor devices, called polysilicon grade semiconductor [7].

Preparing silicone with single crystal

We first melt the polysilicon to transform it into a single-crystal state. The polysilicon adapts to the pattern of the single-crystal seed as it cools and solidifies very gradually; the new ingot of single-crystal silicon is said to have been "grown" out of the molten polysilicon. [8]. It would be achieved through a selection of various techniques. Czochralski (Cz) process and floating-zone (FZ) methodology they are the most advanced ones and dependable methods.

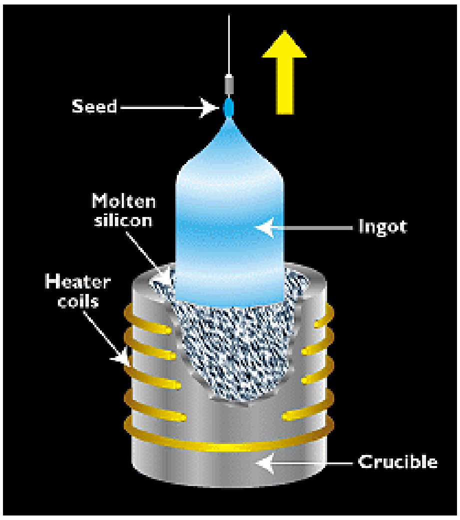


Figure 1.5. The Czochralski method is more commonly used as the single-crystal silicone procedure. [8]

The FZ cycle creates purer crystals, just as Cz crystals do not pollute the crucible. The silicone rod is mounted on the surface of the crystal seed in the FZ process and lowered by an electromagnetic coil. The magnetic field of each coil generates an electrical current in the rod that heats and melts the connection between the rod and the seed. At the interface, single-crystal silicon emerges, as the coils are gently lifted [8].

Making silicon crystalline cell

The PV cell could be fabricated after the production of a single crystal silico n wafer. Although different designs are used by manufacturers, some elements are common to all PV cells.

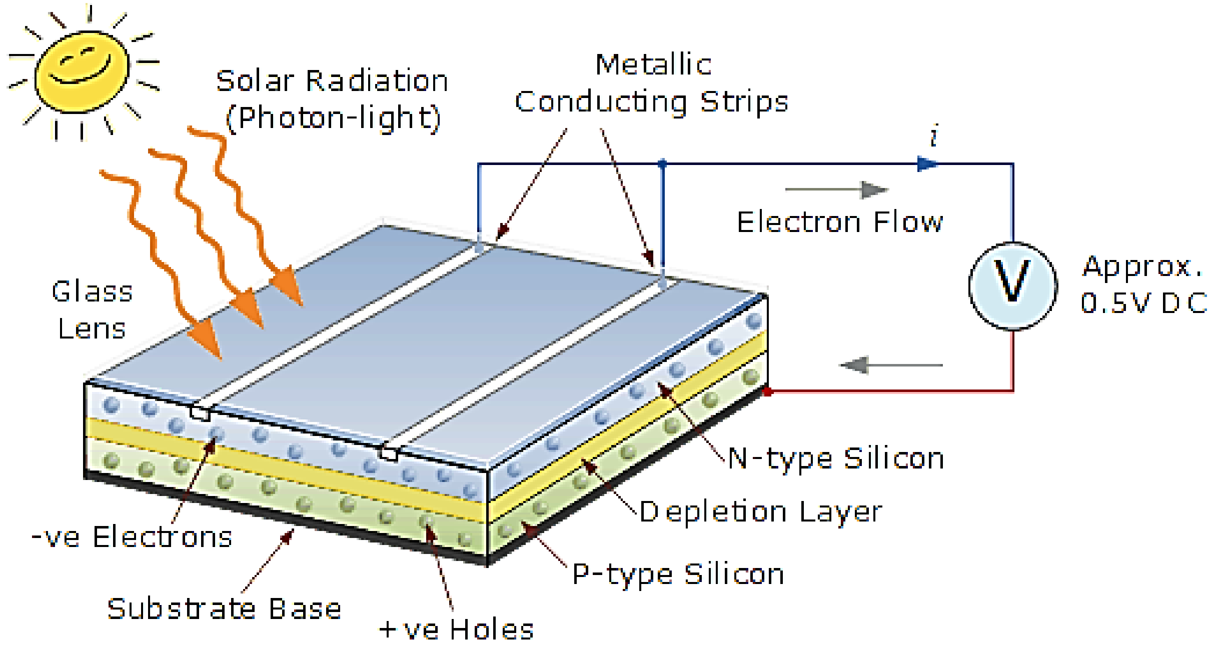


Figure 1.6. The top-surface grid, an anti-reflection coating, n-silicon p-silicon, and a back-metal contact consist of a standard single-crystal silicon cell.

A typical single-crystal silicon PV cell consists of several layers: a conductive grid on the upper surface; an anti-reflective coating or a treated surface layer; a thin layer of silicon (usually n-type) about one-millionth of a meter (micrometer or micron) thick, called a collector; a very narrow electrical field at the junction that allows the current to be produced if the base layer of silicone (usually p-type) is doped in the opposite direction to the collector; and the back-contact electrode.

Add Anti-Reflex Coatings

Silicon is a shimmering gray material. Left abandoned, the PV cell surface serves as a mirror, reflecting more than 30% of the light it hits. Therefore, the top surface through which the light passes must be treated to minimize reflection [9]. Treatment of a thin film of silicon monoxide (SiO) to the top surface significantly reduces the reflection to 10%.

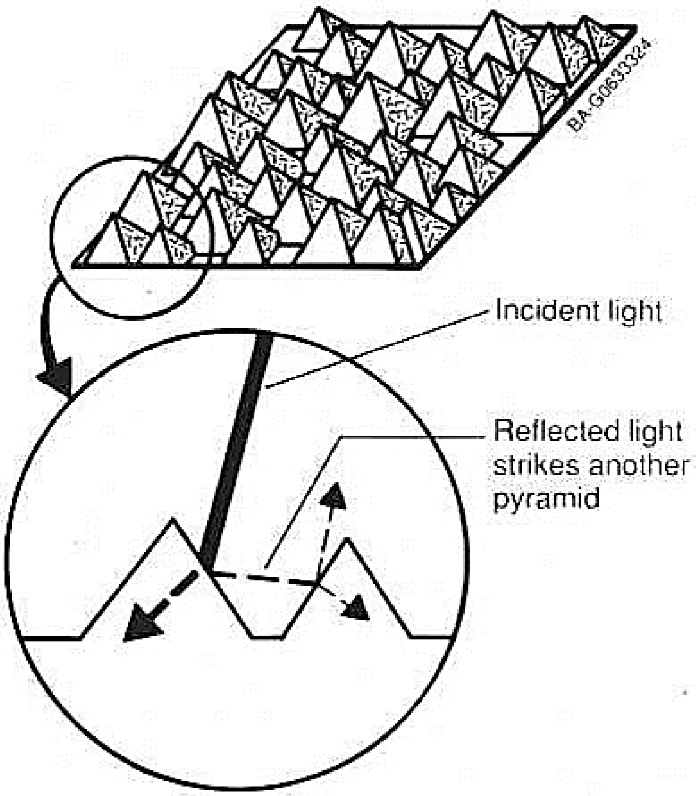


Figure 1.7. Texture, which produces small pyramidal structures on the top surface of the cell, increases the likelihood that light will be absorbed into the section. Light that might otherwise be reflected strikes another surface, giving it another chance of being absorbed.

Another way to reduce reflection is to texture the top surface of a cell. Texture allows the mirrored light to reach the second surface until it disperses, increasing the likelihood of absorption of the material.

1.3 The High-Temperature Effect on Solar Panels

Solar panels have immense benefits to render our world more eco-sustainable and safe by turning solar irradiance into electrical energy. Still, their performance is challenged by unnecessary heat on the panels, among others. Most panels have a limited range of operating temperatures, so as they surpass this limit, and their output drops; usually, solar panels run between 15 ° and 45 °, during which their performance is at the highest point. Throughout the day, while the sun is at its height, the panel temperature can rise as high as 60 °, and even at this stage, the output would be small. An ideal temperature characteristic for a solar panel is given between 0° and 75° and is shown below [10]...

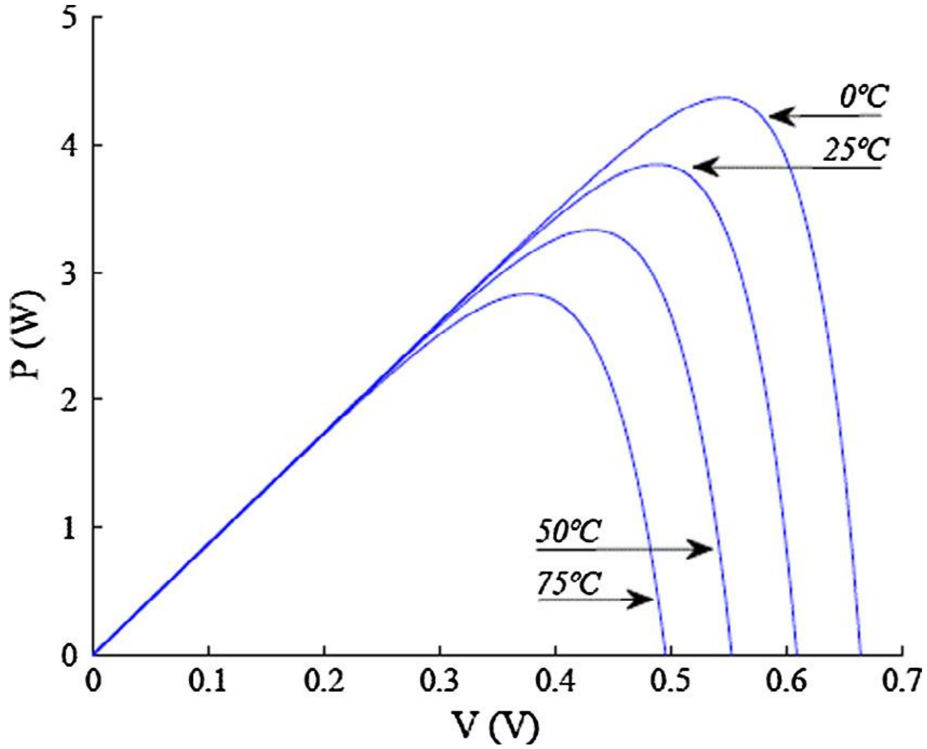


Figure 1.8. Photovoltaic characteristic of a solar panel temperature.

To further explain the negative effect of excess heat on panels, thermodynamics laws explain that when there is an increase in heat, power output decreases. The efficiency of a solar panel has a maximum energy it can generate this maximum energy is also known as maximum power point. The maximum power point is being calculated by [11];

$$\eta = \frac{Imax \cdot Vmax}{SI} \qquad \textbf{(1)}$$

where

η is the efficiency

Imax is the maximum current

Vmax is the maximum voltage

SI is solar irradiance

An increase in heat on solar panels raises the above current, from the rule of thermodynamics, it induces a decrease in voltage; as a consequence of this reality, the resultant output decreases. It can be seen in a solar cell's graph below, which indicates its maximum power point [11].

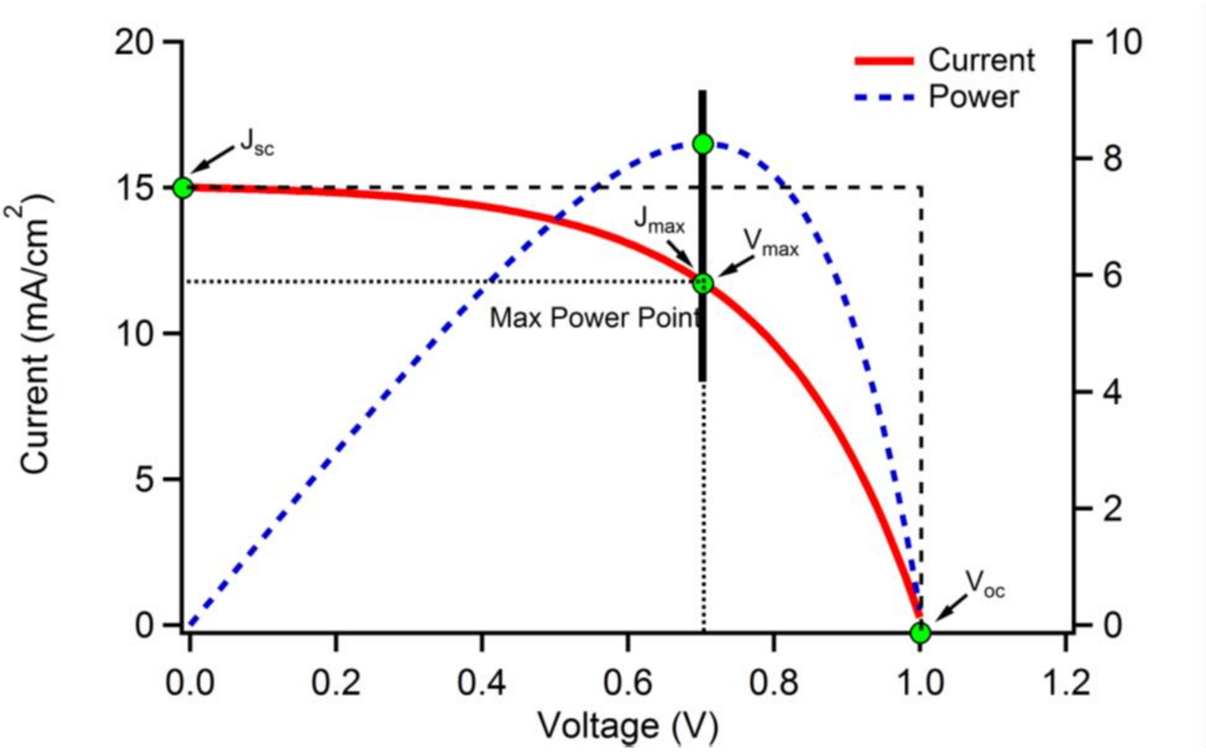


Figure 1.9. The highest power point of a solar module [11]

It is also worth noting that temperature varies depending on certain factors, the level of direct sunlight, the temperature of the air, the proximity of the equator to the region, and the difference between the roofs and the solar panels.

RELATED WORK

Shenyi and Chenguang [12] built a cooling mechanism to lower the temperature of the solar panel by utilizing gas and water. There is a gas chamber, two water-holding containers, and a gutter on the roof of the building. Their device uses solar energy to heat and enlarge the gas chamber, and this extension forces the water up and sprays it onto the grid through the injection hose. The performance of the PV panel was improved by 8.3%.

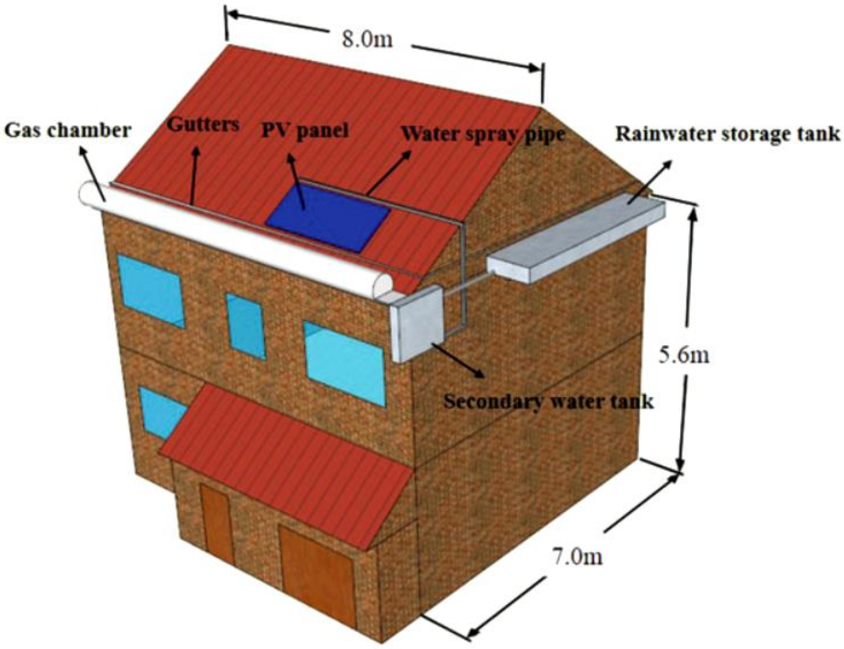


Figure 1.10a. 3-D model of the solar-driven rainwater cooling system installed on the roof.

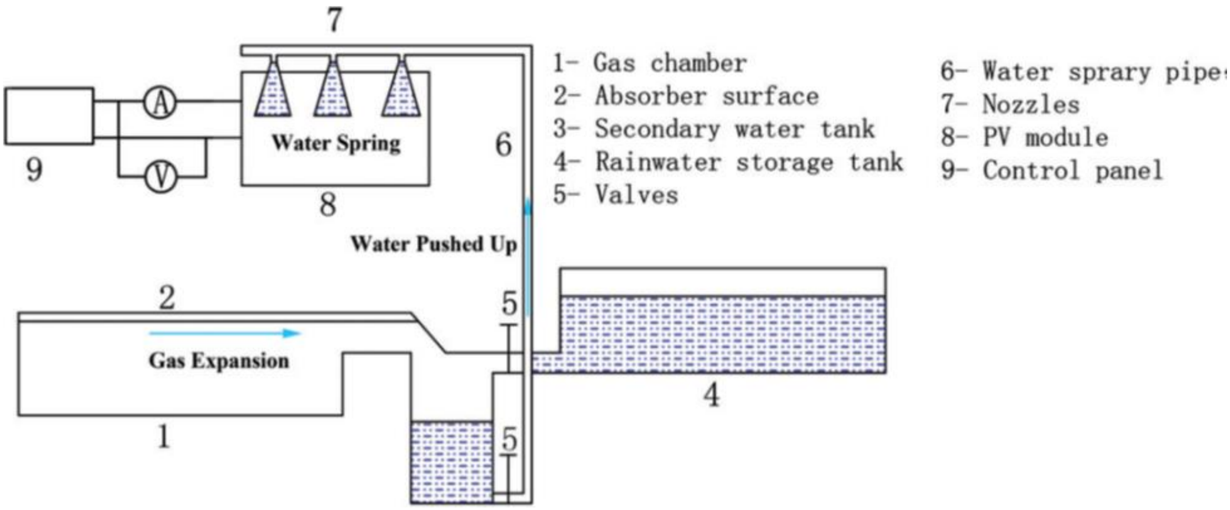


Figure 1.10b. Schematic diagram of cross-section of the solar-driven rainwater cooling system [12].

Filip et al. [13] Listed different methods for cooling solar panels, one of which is heat pipe cooling by way of heat transfer process, one side of the cooling medium evaporates and spreads. In contrast, the other side of the liquid condensates and releases heat into the air.

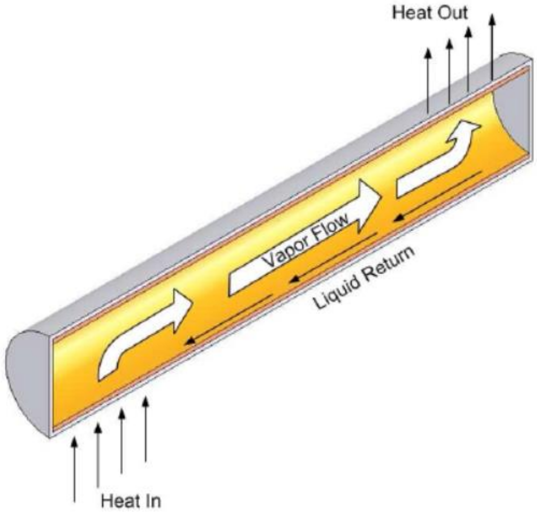


Figure 1.11. Heat pipe mechanism [13]

Bahaidarah, H. et al. [14] cooled a voltaic photo module from the back using a closed enclosure through which water flow is established. The water pump has a mechanical power consumption of 0.5 hP, and an average flow mass is 0.06 kg / s. They could reach 2.8%efficiency.

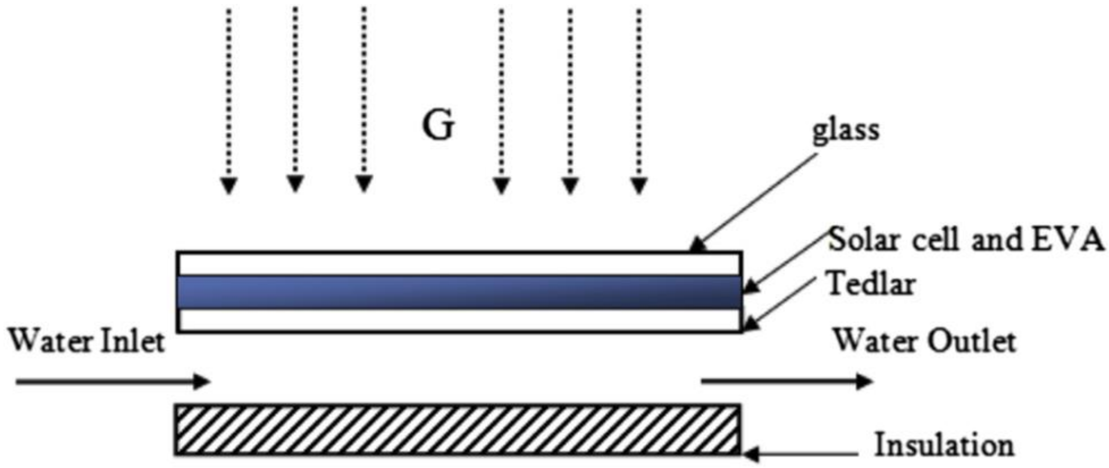


Figure 1.12. Water cooling technique as used in an enclosure [14].

Moharram et al. [15] cooled the photovoltaic module with a water flow on the front of the panel. The pump used consumes approximately one hp of mechanical power. The cooling was conducted for 15 minutes at intervals of 5 minutes, and a cooling rate of about 2 °C / min was achieved. Efficiency is increasing to 1.5 percent.

1.4. Types of Solar Accumulators Used In Solar Systems

The solar accumulator is a reservoir that separates the energy supply from the capture of energy. Since we do not necessarily require energy at the moment of solar exposure, the accumulator is responsible for preserving this energy and supplying it when needed.

Lead-acid batteries

The most used lead-acid battery was historically open form, requiring regular maintenance of the electrolyte by adding purified water. Nowadays, there are different types of primary lead-acid batteries, and the suitability for PV systems depends mainly on the performance of the cyclic life. So-called SLI (Starting-Lighting-Ignition) batteries can be classified as simple car batteries and truck batteries [16].

Figure 1.13. Flooded lead-acid deep cycle batteries

Nickel-based batteries

Batteries containing Nickel Cadmium (NiCd) have strong load characteristics; they are easy to use and commercially priced. The NiCd batteries can be designed with different charging speeds. They have a memory effect that makes them unfit for most PV systems.

Figure 1.14. Ni-CD (Sunica plus) Ni-MH (NHE) battery storage for PV applications

The NiMH is called "environmentally safe," and NiMH batteries are usually 100 percent recyclable thanks to the low toxic metals content. The operating temperature of the NiMH battery (e.g., Saft NHE) is – 20 °C - +40 °C, cyclic lifespan ~2000 cycles.

Lithium-ion batteries

Figure 1.15 Li-ion (lithium nickel oxide) battery solution for residential PV system.

Lithium is an extremely reactive substance, and lithium cells can achieve exceptional high voltage (Li-cobalt 3.2-3.6 V, Li-phosphate 3.2-3.3 V, Li-manganese 3.7-3.8 V, Li-cobalt oxide 4.2 V) relative to 1.2 volts of Ni-based batteries. Lithium-ion batteries have a low discharge compared to other rechargeable batteries, but the aging process is already starting on the storage shelf. Lithium-ion batteries give an energy capacity of 100–150 Wh / kg with a charge/discharge performance of 90–100% percent. The cycle life is long, depending on the type of battery, from 3000 cycles to 16000 full cycles and even 250000 partial cycles [16].

1.5. Connection to Gridlines

There are four different configurations in connection with gridlines, which can choose from when creating a solar power installation. These are stand-alone (sometimes called off-grid), grid bound, grid bound with power back-up (also known as interactive grid), and grid fallback.

1.6. Structure of PV System

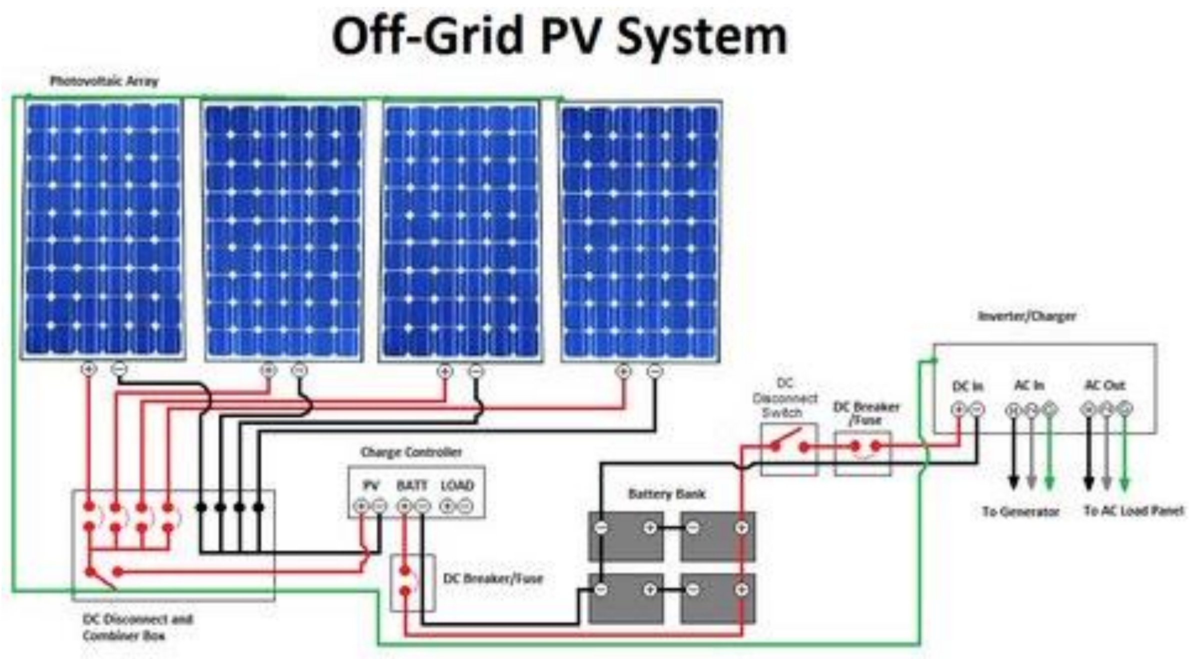


Figure 1.16. Off-grid residential solar PV system

Photovoltaic device systems contain all the main components required for its operation before the system is built and assembled. The following details should be known; where it is mounted, the house needs, PV panels, mounting rack, combiner unit, inverter, batteries, charge control, and disconnectors, residual current breakers, and distribution board [18].

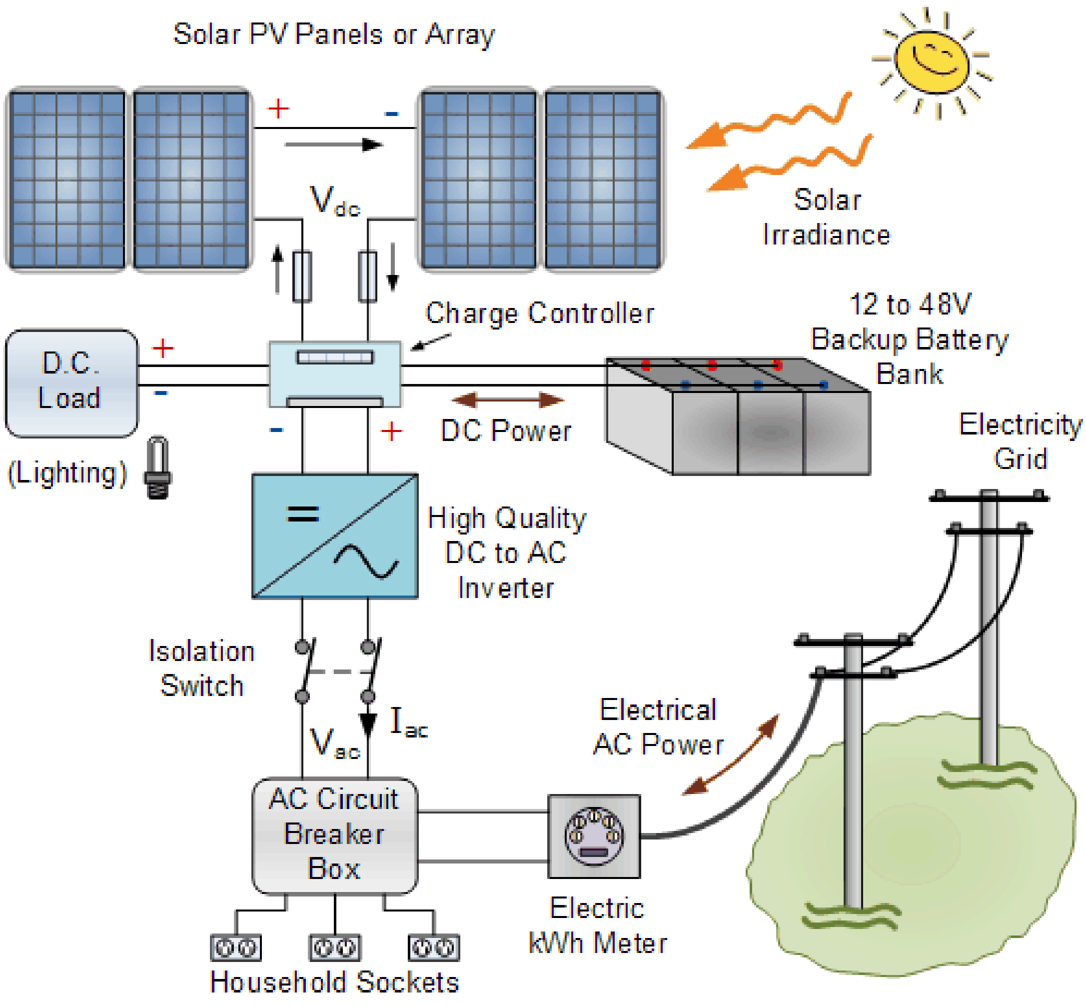


Figure 1.17. On-grid residential solar PV system

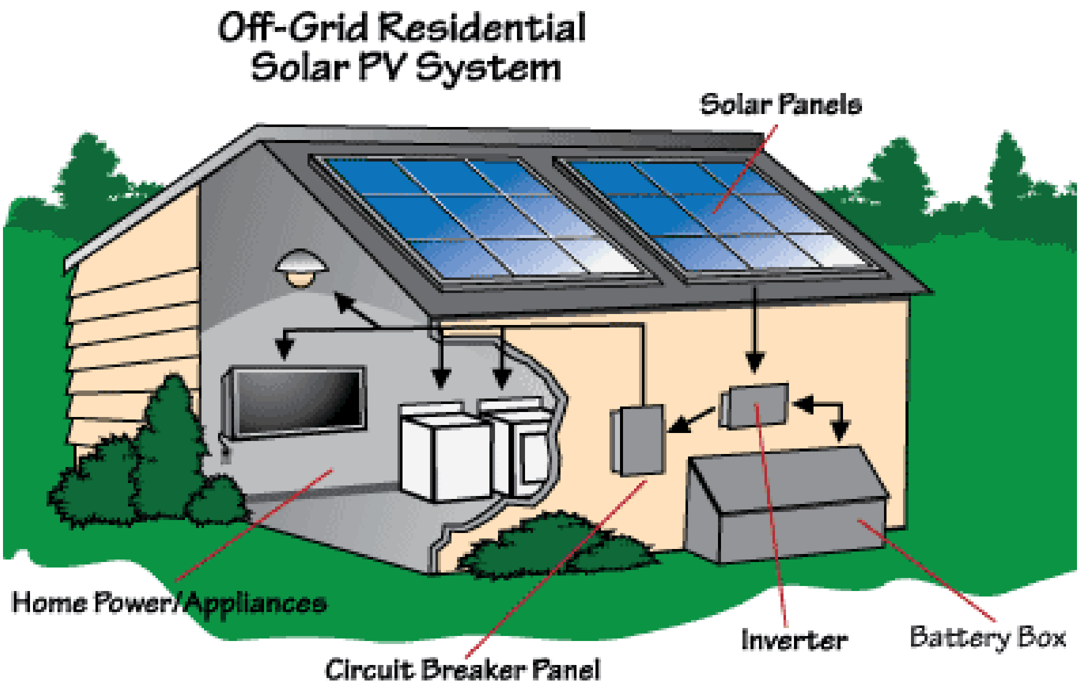


Figure 1.18. Off-grid residential solar PV system

1.7 Conclusion to section 1

This work aims to use a minimal amount of water and resources to cool the solar panels. Different cooling technologies have been introduced, including heat pipe cooling to air cooling devices and water cooling as well. The cooling device built for this study is a cooling water device by sprinkling water on the solar panels. This device is being used as water-cooled solar panels are achieving better performance for now than air-cooled panels or some other refrigeration method.

- They are solar panels of different types; monocrystalline and polycrystalline
- Four types of connections exist; stand-alone (sometimes referred to as off-grid), grid, power back-up grid (also referred to as interactive grid), and grid fallback. The most effective option is the off-grid.
- Throughout the solar system, accumulators and charge management are essential because they tend to conserve power for later use.
- Inverters serve as a dc to ac conversion tool.

SECTION 2

CALCULATION AND RESEARCH

2.1. PV system power supply

A solar photovoltaic (PV) system provides usable solar energy [20]. It consists of an assembly of many elements, including solar panels to capture and transform sunlight into power, a solar inverter to invert the electrical current from DC to AC, as well as installing, cabling, and other electrical equipment to set up a functioning network. [20]. It can also use a solar monitoring system to boost overall system efficiency, including an integrated battery solution, as costs for storage devices declines [20].

A stand-alone PV system, also known as a remote power supply area, is an off-the-grid electricity system for locations not equipped with an electricity distribution system [21]. These include solar panels, combiner tray, breakers, charging controls, batteries, and an inverter. In stand-alone photovoltaic systems, the electrical energy produced by photovoltaic panels cannot always be directly used [21]. As load demand does not always match solar panel capacity, battery banks remain commonly used. Primary storage battery functions in a stand-alone PV system are [22 23]:

- **Energy storage power and autonomy**: store and supply electricity when surplus is available [22].
- **Voltage and current stabilization**: providing stable power and voltage by eradicating transients [22].
- **Supply surge currents:** provide surge currents for motor-like loads when required [22].

2.2 Automation

The concept automation was used not commonly until 1947 when Ford founded the automation department, which was influenced by the earlier word automatic (from automation). It was during this period that industries quickly adopted feedback controls introduced in the 1930s [24]. Automation has typically remained accomplished in conjunction with different approaches like mechanical, hydraulic, pneumatic, electrical, electronic, and computer hardware. Complicated structures such as industrial plants, aircraft, and ships typically use both of these techniques [24]. The advantages of automation include decreased workload; it remains often used to conserve resources and materials and to increase efficiency, performance, and consistency [24]. The planet and the future would look very different without automation [25].

2.3 Microcontroller

In comparison to such microprocessors found in personal computers or other general-purpose devices composed of various distinct components, microcontrollers remain built for embedded applications. In automatically managed goods and equipment such as vehicle engine control systems, implantable medical instruments, remote controls, office computers, equipment, power tools, toys, and other embedded systems, microcontrollers are used [26]. By minimizing size and costs in contrast with a design that requires a particular microprocessor, memory, and input/output equipment, microcontrollers allow it cheaper to monitor more machines and processes remotely. Mixed-signal microcontrollers are popular and incorporate analog components required to operate electronic non-digital devices. For low power usage (single-digit mill-watts or microwatt), specific microcontrollers may use four-bit-words and operate at frequencies as small as 4 kHz [26]. They typically have the potential to maintain their functionality even though it is waiting for an action to take place, such as pushing a button or an interrupt. Sleep power usage (CPU clock and most outer components) may only be Nano-watts, making all of them ideal for long-lasting battery applications [26].

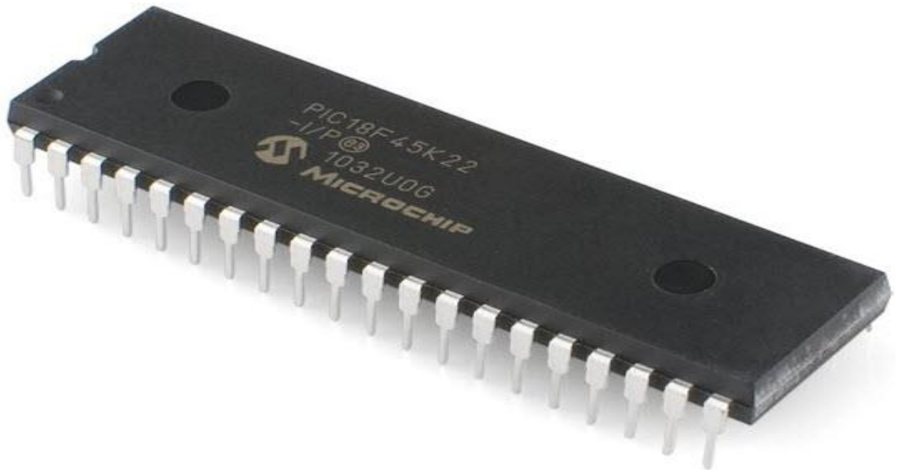


Figure 2.1. 8051 Microcontroller [26]

Overview of Microcontroller

A microcontroller is a lightweight, low-cost microcomputer that performs basic tasks in embedded devices, such as viewing information on a microwave and transmission in remote signals. Below is a diagram showing the overview of the Microcontroller.

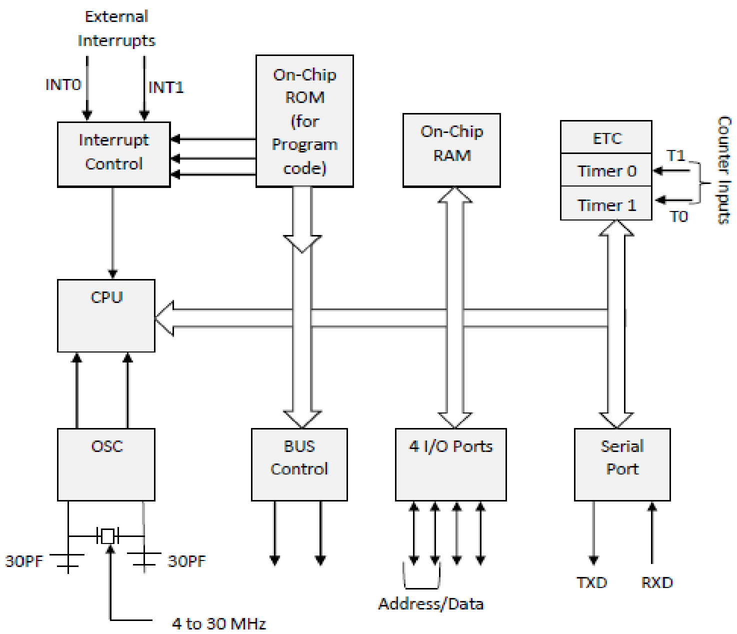


Figure 2.2. Internal Architecture of a microcontroller [26]

The overall Microcontroller includes the processor, memory (RAM, ROM, and EPROM), serial ports, peripherals (timers, counters), and more [27 28].

Applications of Microcontrollers

- Control of light-sensing and equipment such as LEDs.
- Control of temperature monitoring and appliances such as a microwave oven, fireplaces.
- Fire detector and fire alarm protection equipment.
- Measurement equipment such as Volt Meter

The table below differentiates between the Microcontroller and the microprocessor.

Microcontroller-microprocessor differences

Table 2.1

Microcontroller	**Microprocessor**
In an application, microcontrollers are used to perform one task.	For broad systems, microprocessors are used.
Its hardware and construction costs are small.	The design and hardware is costly.
Simple to substitute.	Not easy to substitute.
It is constructed with CMOS technology, which requires less power.	Its electricity consumption is high because the whole system has to be controlled.
It includes CPU, RAM, ROM, I / O ports.	There is no RAM, ROM, I / O ports. It uses its pins to interface with peripheral equipment.

2.4 Temperature sensor

It is a device that monitors or measures the temperature of an environment. It also converts the input data into electronic data to record, monitor, or signal temperature changes [29]. Temperature sensors are not the regular on and off thermostat devices. Instead, these sensors send signals to be process into an output; temperature sensors are classified into two, namely; contact and non-contact temperature sensor.

Types of Temperature Sensor

There are many temperature sensors with different sensing capabilities, and the following are listed for various applications:

- Thermocouples
- Resistor temperature detectors
- Thermistors
- Infrared sensors
- Semiconductors
- Thermometers

Thermocouples

A thermocouple is a voltage system that shows a temperature difference in voltage by calculating it. Two different metals are present: opened and closed. Such metals operate on the thermoelectric effect theory. When the two metals generate a voltage, there is a thermal disparity between the two metals. As the temperature rises, the thermocouple's output voltage always decreases. This sensor is usually shielded within a ceramic shield or metal that defends it against various environments. The best and popular kind of thermocouple is the thermocouple style J, T, and K, which are available in prefabricated form [29].

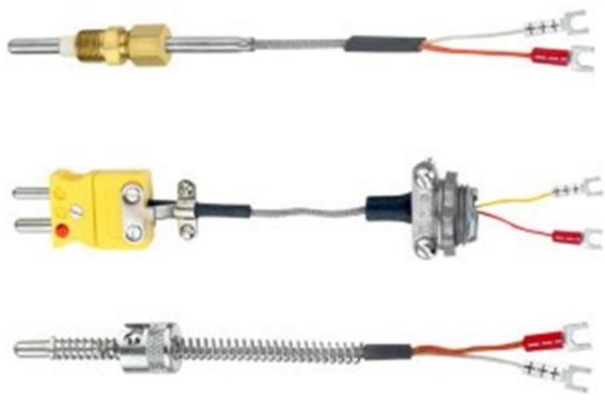


Figure 2.3. Various types of thermocouples

Resistor Temperature Detector (RTD)

One of the most accurate sensors is the RTD sensor. Resistance is proportional to the temperature in a resistor temperature detector.

Figure 2.4. Resistor Temperature Detector (RTD)

This sensor is made of copper metals, platinum, and nickel. It can be used to measure temperature between -270 ° C to + 850 ° C and has a wide range of temperature measurement capabilities. RTD needs the correct operation of an established current source. However, the current produces heat in a resistive element that causes a temperature measurement error. This formula calculates the error:

Delta T=P*S

Where ‘T’ is temperature, ‘P’ is I squared power produced, and ‘S’ is a degree C/mill watt [29].

Thermistor

Another type of sensor is the thermistor temperature sensor, an inexpensive, adaptable, and easy-to-use.

Figure 2.5. Thermistor

When the temperature changes, it changes resistance as an RTD sensor. Thermistors are made of manganese and nickel oxides, making them sensitive to damage [29].

Thermometers

A thermometer is a device used in solid, liquid, or gas temperature calculations. A mixture of two terms, namely: thermos – implies heat, and meter is a measurement tool. The thermometer holds a gas in the glass container that is mercury or alcohol. The thermometer's volume is linearly proportional to the temperature; the thermometer volume always increases as the temperature rises.

Figure 2.6. Mercury thermometer.

Semiconductor Sensors

Semiconductor sensors are the equipment in IC form. Such sensors are popularly regarded as an IC temperature tracker. The current output temperature sensor and voltage output temperature sensor, Resistance output silicon temperature sensor, Diode temperature sensors, and optical output temperature sensor are categorized as separate groups. However, the most common temperature sensors are AD590 and LM35

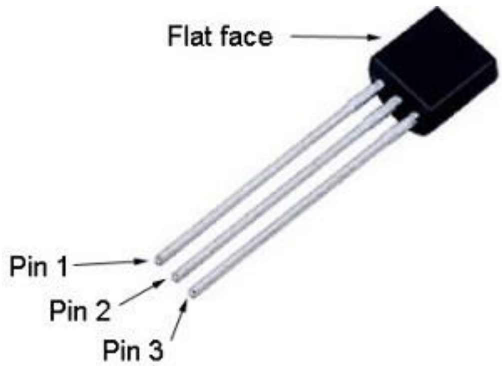


Figure 2.7. A three-pin semiconductor sensor.

Current temperature control for semiconductors provides good linearity and high accuracy over a spectrum of roughly 55 ° C up to +150 ° C [29].

IR Sensor

The IR sensor is an electronic tool used to identify the aspects of its surroundings by the issuance of or the application of IR radiation. These sensors are non-contacting. For example, if you hold an IR sensor in front of your desk without any contact, the sensor senses the desk temperature based on radiation [29].

Figure 2.8. IR sensor.

2.5. Water Pump

A pump is a mechanical tool that transfers fluids (liquids or gasses) or slurries occasionally. Due to the system of movement of fluid, pumps may be grouped into three main groups: automatic lifting, displacement, and gravity pump [30]. In many applications, mechanical pumps are used, such as the pumping of water from wells, the filtration and aeration of aquariums, the automobile industries for water-refrigeration and injection of fuel, the power industry for pumping oil and natural gas, operation of cooling plants, and other components of heating, ventilation and air conditioning systems [30].

2.6. Capacitor

A capacitor is a passive two-terminal electrical component used to store energy in an electrical field. Suitable capacitor types differ significantly; all capacitors include at least two electrical conductors separated by a dielectric (insulator); for instance, a typical configuration consists of metal foils separated by a thin layer of insulating glass. Capacitors are widely used in standard electrical devices as electrical circuit parts [31].

Figure 2.9. Different Types of Capacitors.

2.7. Resistor

Resistance restricts electric current flow; for example, a resistor with a light-emitting diode (LED) is placed in series to reduce the current passing through the LED. Resistors may be wired around the other way.

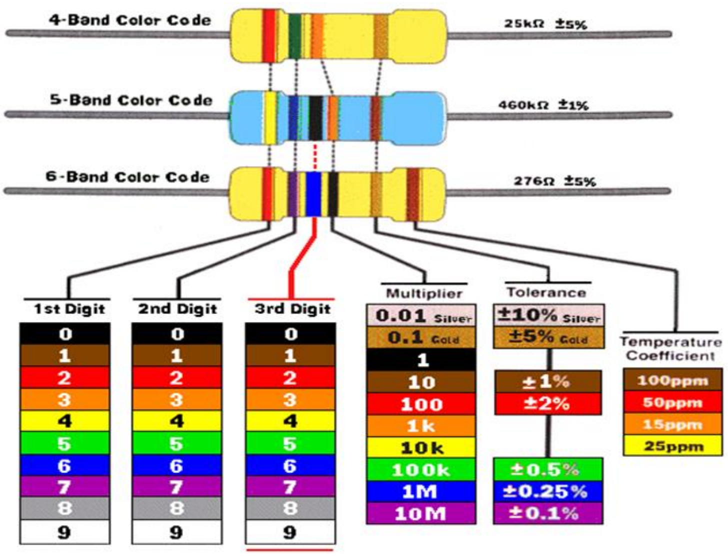


Figure 2.10 Color-coding of resistors.

When soldering, they are not damaged by heat. Resistance measurement is in ohm; the symbol for ohm is the **Ω**. Usually, resistor values are displayed by colored bands. The fourth color code band indicates the resistor tolerance. Tolerance is the consistency of power, and every color is shown as a percentage, as seen in the table.

2.8. Location

Abuja is the capital city of Nigeria, situated in the Federal Capital Territory (FCT) region of Nigeria [32]. The coordinates are: 9 ° 4′N 7 ° 29′E in the northeast, Abuja has a tropical rainy and dry climate under the Köppen climate system (Köppen: Aw) [32]. The FCT has three normal environmental conditions. It includes a warm, humid rainy season and a dry, blistering season and, between the two, the main character is dust haze and dryness [32], a brief interlude of harmattan caused by the northeast trade winds.

Figure 2.11. The location of the house in Abuja.

Daytime temperatures may climb up to 40 ° C, and at night temperatures may drop to 12 ° C (53.6 ° F) during the dry season. The high altitudes and the undulating terrain of the FCT have a moderating effect on the territory’s weather [32]. Below is the solar irradiance for Abuja;

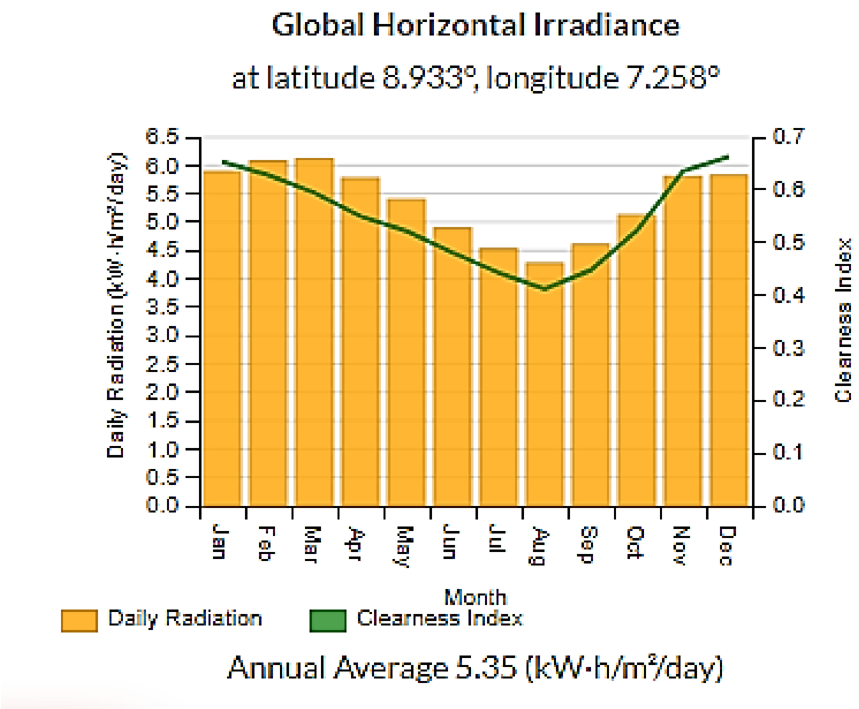


Figure 2.12. Indicate the solar irradiance of Abuja [33].

The measurement of radiant energy released into the natural atmosphere (joules per square meter, J / m2), solar irradiance, is typically measured over a specified time [33]. It's often referred to as sun irradiation, solar light, solar insolation, or insolation [33].

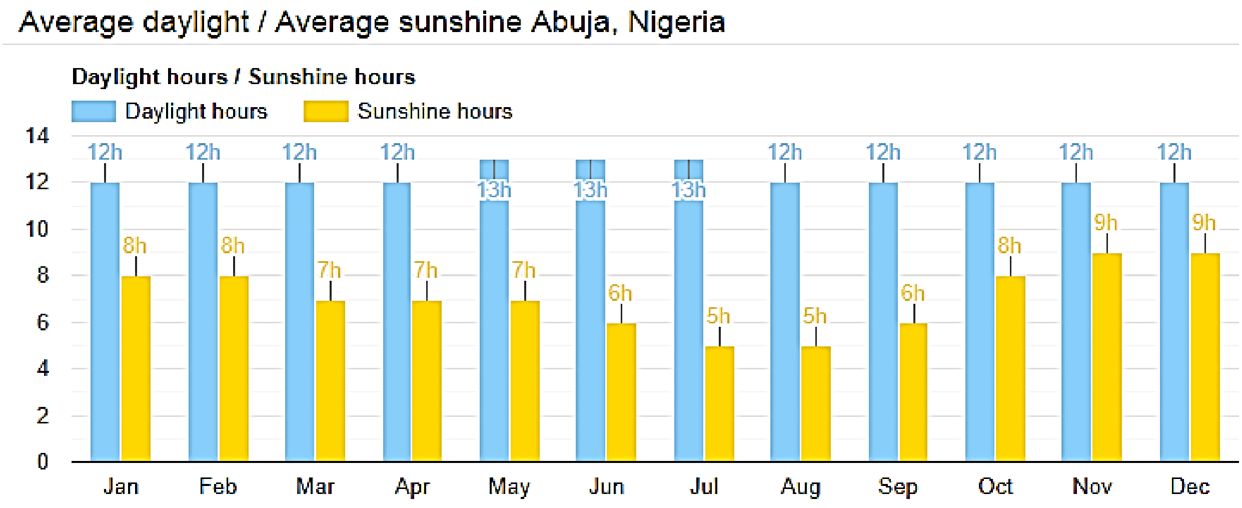


Figure 2.13. Shows the average sunshine/daylight of Abuja [33].

Months with the most sunshine are November and December (Average sunshine: 9h). Months with the least sunshine are July and August (Average sunshine: 5) [33 34].

2.9. House Plan

A floor plan is a kind of drawing which shows you the layout of an above house or property [35]. Floor designs usually indicate where walls, curtains, doors and steps, and set fixtures, such as bathroom furniture, kitchen cabinets, and appliances, are installed. Planes are typically drawn to the scale and show room types, room sizes, and wall lengths [35]. There are two types of floor plans 2D and 3D.

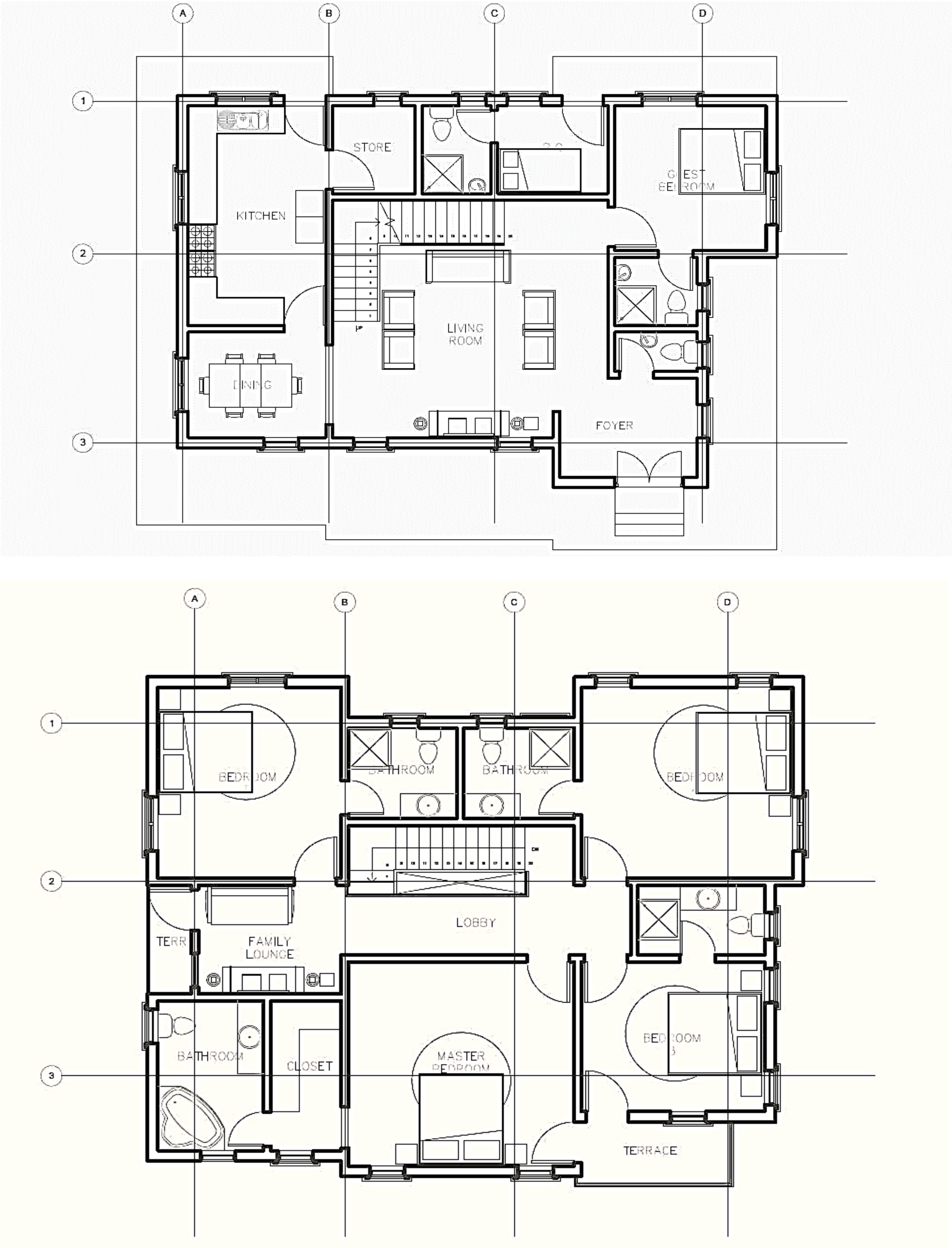


Figure 2.14. Shows the first and second floor.

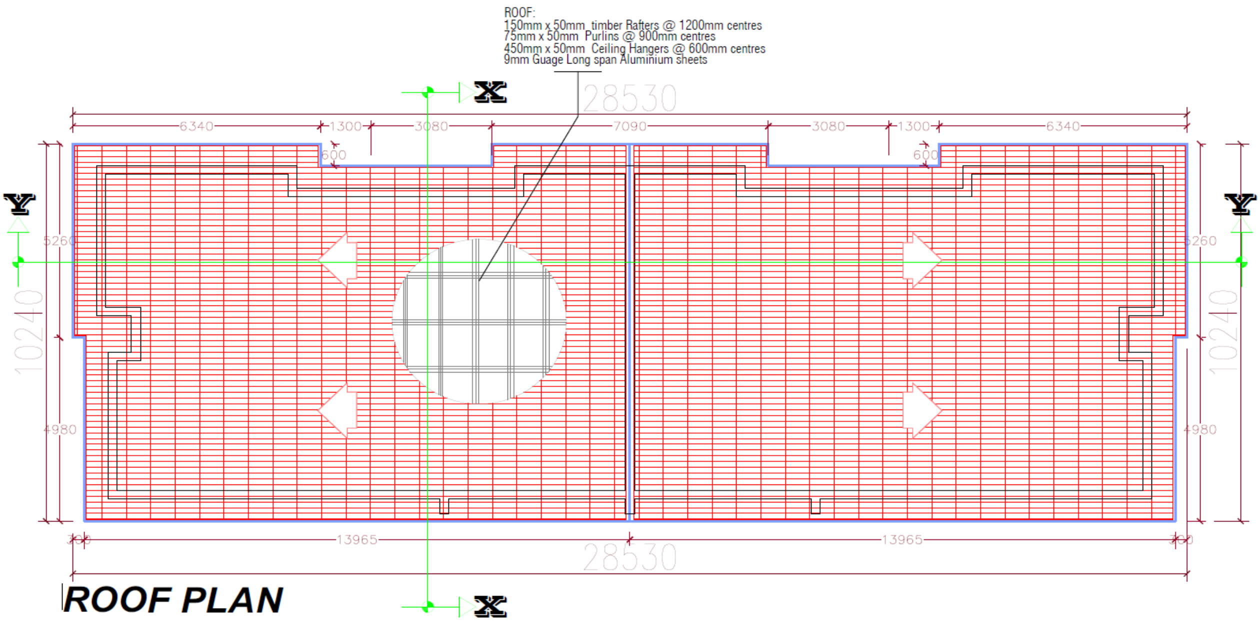
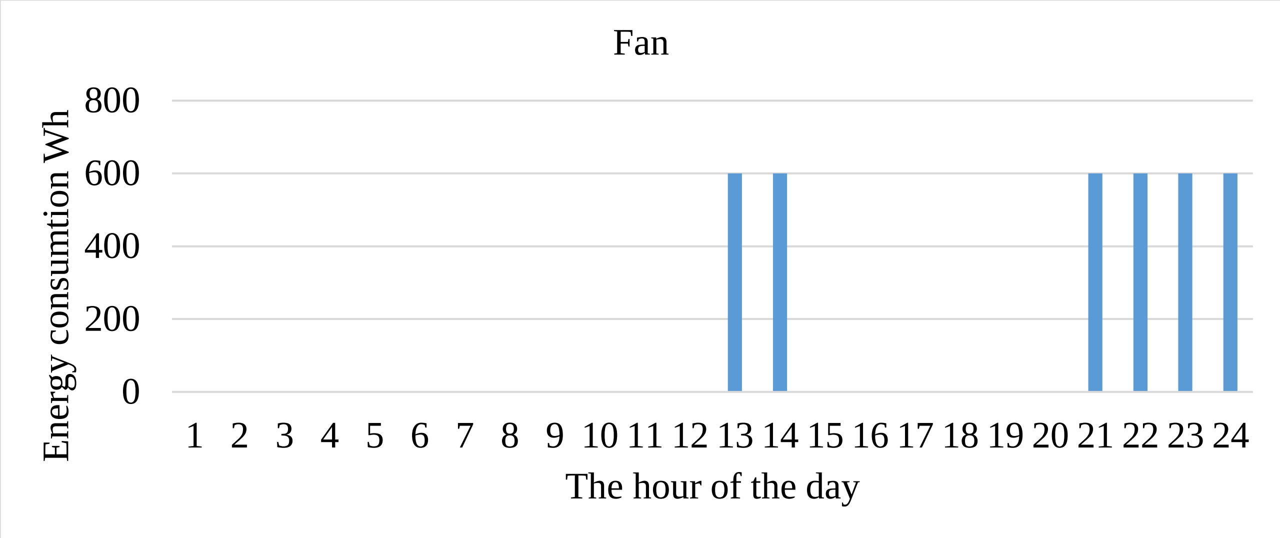


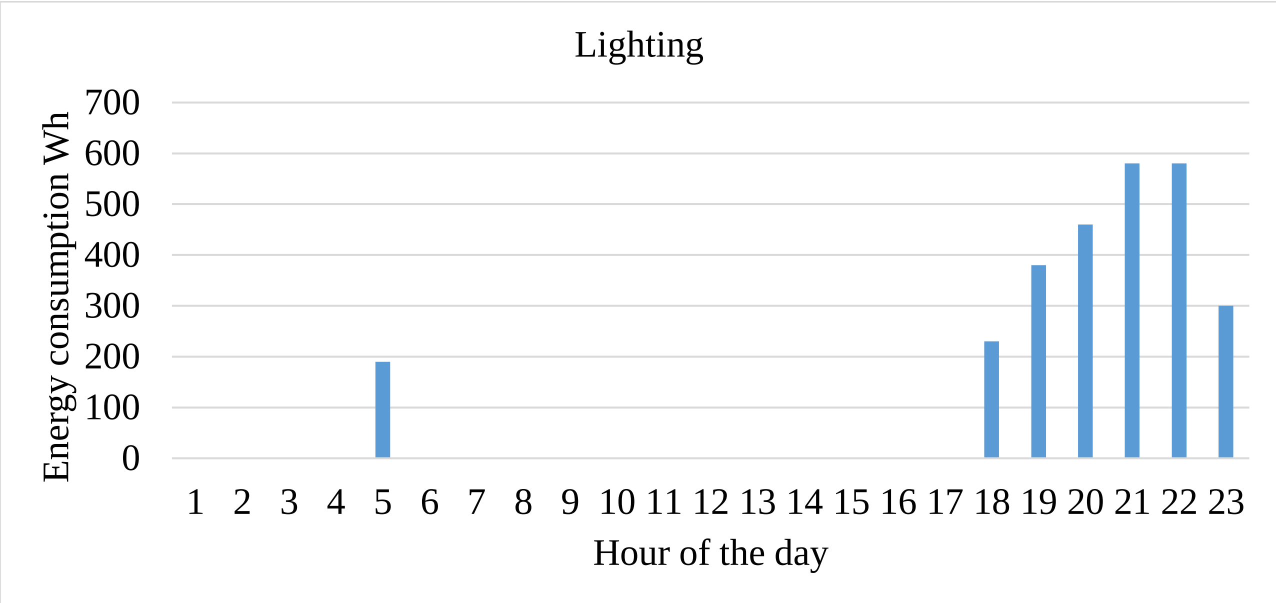
Figure 2.15. Shows the roofing pattern.

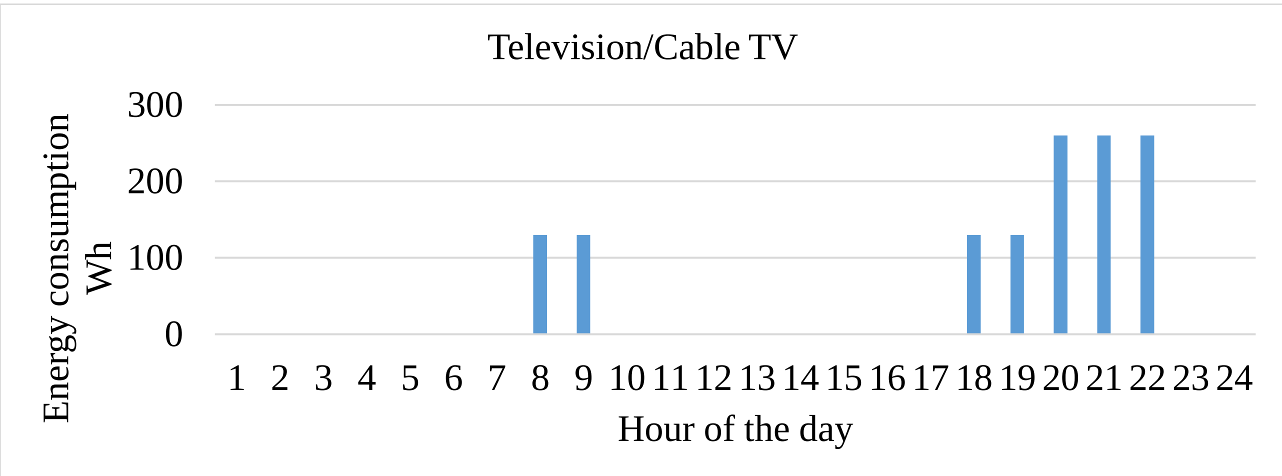
Electrical Load

Table 2.2

House Items	Quantity	Power (W)	Remarks	Hours on per day	Watt-hour per day
Fan	8	75		6	3600
LED Lamps	58	10		7	4060
Mirror light	7	5		2	70
LED TV	2	130		7	1820
Security lamps	4	20		11	880
Refrigerator	1	400		12	4800
chandelier	1	30	Intermitent use	2	60
Microwave	1	900		3	2700
Personal Computer	5	80		3	1200
Washing machine	1	500		1	500
Blender	1	300		0.5	150
printer	1	30		0.5	15
Cable TV	1	25		7	175
Total Watt-hour					**20030.00**
Inherent Efficiency Loss					**24036.00**


Fan
Energy consumtion Wh
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
The hour of the day


Lighting
Energy consumption Wh
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour of the day


Television/Cable TV
Energy consumption Wh
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of the day

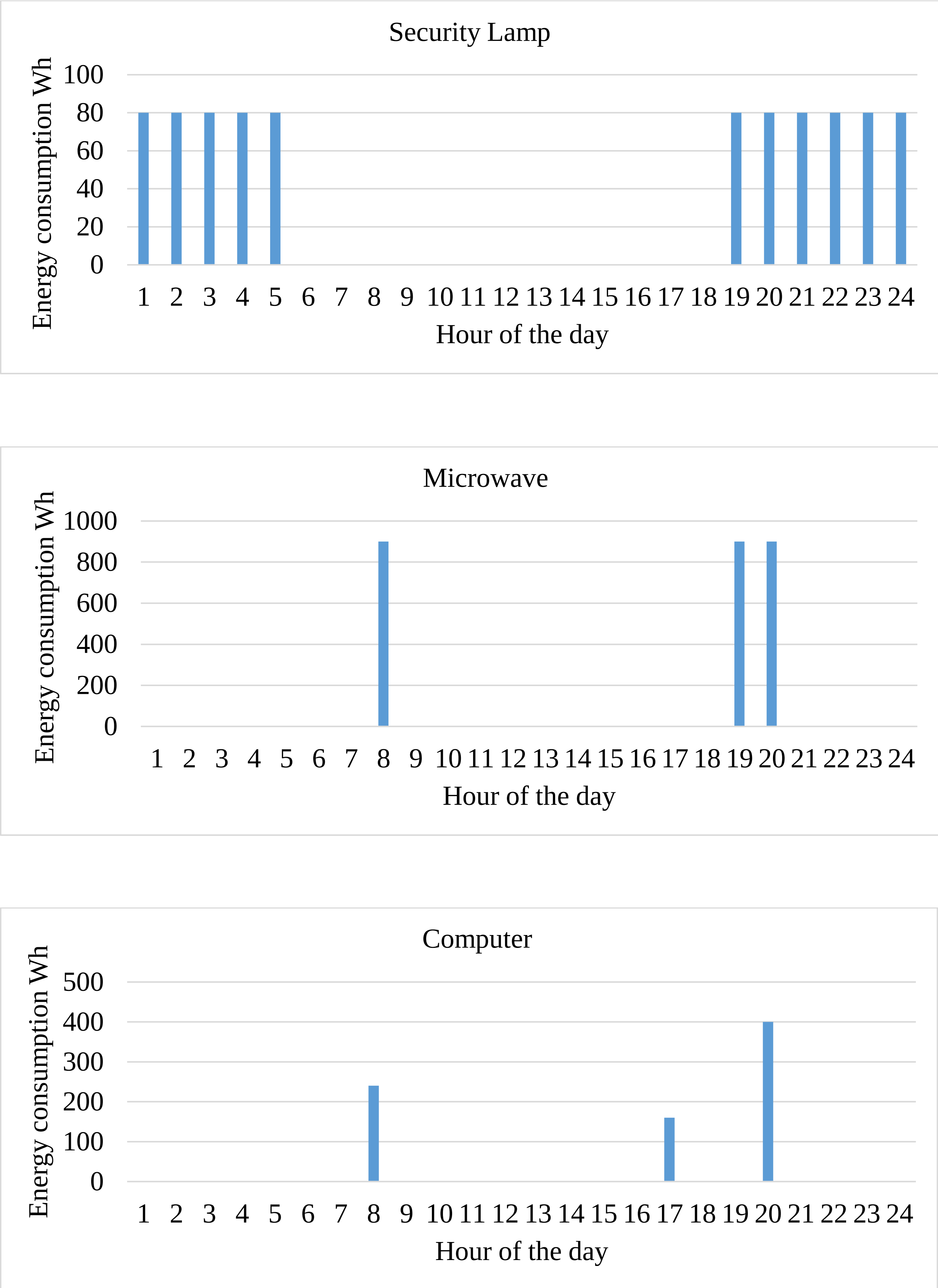


Figure 2.16. The graph of power distribution.

2.10 Conclusion to Section 2

The type and specification of the different components used in the project were detailed. A suitable charge controller is to be used to find such, solar panels should be equal to the inverter. Abuja's average daily sunshine is 7 hours. The load profile of the house must be collected since this is the first and most critical step before more measures can be taken. Determining the size of the solar array, battery size, the inverter size, and the charging controller rating was used. The solar modules are mounted to save space on the roof of the house.

SECTION 3

PROJECT DESIGNING

3.1. Calculation Of Photovoltaic Systems

The off-grid photovoltaic system is used in this project to power the building. Each part was correctly designed when designing the photovoltaic system, load power, power output from the panel, battery, and inverter, as well as how much time the device would operate to ensure optimal operation of the system. The device includes solar panels, charge controllers, battery, inverter, and insulator. The automatic temperature comprises of LCD, DS18B20, capacitor, Arduino Uno, diode relay, buzzer, and transistor.

3.1.1 PV Module Estimation and Selection

The dimensions of the solar panels you need are determined by how much energy you spend daily. The size of the bank depends on how many days the battery supplies the stored energy. The charging system is also a voltage control unit, and the battery's rating is closely linked.

The calculation of how much energy VDC is needed is based on the initial data presented below.

$$W_h = W \cdot H_d \cdot q \qquad (3.1)$$

Where;

W_h — Energy;

H_d — hours on per day;

q — quantity of appliance

The daily energy usage

Table 3.1

House Items	Quantity	Power (W)	Remarks	Hours on per day	Watt-hour per day
Fan	8	75		6	3600
LED Lamps	58	10		7	4060
Mirror light	7	5		2	70
LED TV	2	130		7	1820
Security lamps	4	20		11	880
Refrigerator	1	400		12	4800
chandelier	1	30	Intermitent use	2	60
Microwave	1	900		3	2700
Personal Computer	5	80		3	1200
Washing machine	1	500		1	500
Blender	1	300		0.5	150
printer	1	30		0.5	15
Cable TV	1	25		7	175
Total Watt-hour					**20,030**
Inefficiency Loss					**24,036**

$$D_f = P_T \cdot \eta \tag{3.2}$$

$$Df = 20,030 \cdot 1,2 = 24,036\ KWh$$

Where

D_f – Diversity factor;

P_T – Total power;

η – Efficiency.

Equation 3.3 gives the energy that is provided by the PV array,

$$E_{pv} = \frac{Wh}{\eta_{inv} \text{X} \eta_{cc} \text{X} \eta_{pv}} \tag{3.3}$$

$$E_{pv} = \frac{24036}{0,94 \cdot 0,98 \cdot 0,17} = 153,1 \text{ J}$$

Where

E_{pv} – Energy of PV array;

Wh – Watt-hour;

ηinv – Inverter efficiency;

ηcc – Charge controller;

ηpv – photovoltaic efficiency.

The PV array space would be designed according to these specifications;

$$A_{pv} = \frac{E_{pv}}{M_{sr}} \tag{3.4}$$

$$A_{pv} = \frac{153,1}{5} = 30,62\ A$$

Where

A_{pv} – Area of PV array;

E_{pv} – Energy of PV array;

M_{sr} – Minimum solar radiation.

The output of the PV-array electrical power is influenced by;

$$PV_p = PS_{STC} \text{ x } A_{PV} \text{ x } \eta_{PV} \text{ x } SF \tag{3.5}$$

$$PV_p = 1000\ \cdot 30,62\ \cdot 0,17\ \cdot 1,2 = 6246,48\ \text{W}$$

Where

PV_p –Photovoltaic power;

PS_{STC} – Peak solar intensity in standard test condition;

A_{PV} – Area of PV array;

ηpv– Photovoltaic efficiency;

SF – Safety factor.

The number of PV modules to be connected in series can be modeled by;

$$NM_S = \frac{V_{\text{system}}}{V_{\text{module}}} \tag{3.6}$$

$$NM_S = \frac{48}{40,1} = 1,19$$

Where

NM_s – Number of panels in series;

V_{system} – The voltage of the system;

V_m – Voltage of the module.

The number of PV modules to be connected in parallel can be modeled by;

$$NM_P = \frac{PV_P}{NM_S \text{ x } P_{\text{module}}} \tag{3.7}$$

$$NM_P = \frac{6246,48}{1.19 \cdot 370} = 14,18$$

Where

NM_P – Number of panels in parallel;

PV_P – Photovoltaic power;

NM_s – Number of panels in series;

P_M – Power of module.

The total number of panels to be installed;

$$NM_{Total} = NM_P \text{ x } NM_S \tag{3.8}$$

$$NM_{Total} = 14,18 \cdot 1,19 = 16,87 \cong 17$$

Where

NM_{Total} – Total number of panels;

NM_P – Number of panels in parallel;

NM_s – Number of panels in series.

3.1.2 Determining the amperage and number of the required battery capacity

The calculation below indicates the required amount of battery to being used for just a day. The battery selected has a depth of discharge of 80%. Batteries are not rated in kWh, so we have to convert to Ah. To do this, we divide the kilowatt-hour by the intended battery used;

$$BB_C = \frac{Wh}{V_{system} \cdot \eta B \cdot DoD} \tag{3.9}$$

$$BB_C = \frac{24036}{48 \cdot 0,85 \cdot 0,8} = 736.39\ Ah$$

Where

BB_C – Battery bank capacity;

Wh – Watt-hour;

V_{system} – Voltage of the system;

ηB – Battery efficiency;

D.o.D – Depth of discharge.

The number of batteries to be connected in parallel;

$$NB_P = \frac{BB_C}{AS_B} \tag{3.10}$$

$$NB_P = \frac{736,39}{200} = 3,68$$

Where

NB_P – Number of batteries to be connected in parallel;

BB_C – Battery bank capacity;

AS_B – Amperage of a single battery.

The number of batteries to be connected in series;

$$NB_S = \frac{V_{system}}{VS_B} \tag{3.11}$$

$$NB_S = \frac{48}{12} = 4$$

Where

NB_S – Number of batteries to be connected in series;

V_{system} – Voltage of the system;

VS_B – Voltage of a single battery.

The whole number of batteries required obtained through;

$$NB_T = NB_P \cdot NB_S \tag{3.12}$$

$$NB_T = 3,68 \cdot 4 = 14.72$$

Where

NB_T – Total number of batteries;

NB_P – Number of batteries to be connected in parallel;

NB_S – Number of batteries to be connected in series.

3.1.3 Determining the appropriate inverter size

An inverter is needed to convert DC input to AC output. The critical condition to bear in mind during inverter sizing is that the input rate of the inverter is wholly and always higher than that of the load. The same nominal voltage level also refers to both the battery and the inverter. The power of the inverter size is provided;

$$R_P = 1,2 \cdot \left(L_R + \left(2 \cdot L_{IN} \right) \right) \tag{3.13}$$

$$R_P = 1,2 \cdot \left(2340 + \left(3600 \right) \right) = 7128W$$

Where

R_P – Rated power of inverter;

L_R – Resistive load;

L_{IN} – Inductive load.

3.1.4 Determining the appropriate charge controller size;

The Solar Charge Controller is responsible for maintaining the voltage between the photovoltaic array and the battery, thus ensuring that the battery bank is not overcharged and appropriately recharged. A suitable charge controller is required to manage the maximum current produced by the PV array properly. They are labeled against amperage and voltage. The allowed capacity of the load controller is modeled;

$$CC_R = 1,25 \cdot NM_P \cdot I_{SC} \tag{3.14}$$

$$CC_R = 1,25 \cdot 14,18 \cdot 9,8 = 173,71$$

Where

CC_R – Charge controller rating;

NM_P – Number of panels connected in parallel;

I_{SC} – Short circuit current.

The number of charge controllers to be connected in parallel will be the total rated amperage of the charge controller divided by a unit ampere per controller.

$$NCC = \frac{CC_R}{AS_C} \tag{3.15}$$

$$NCC = \frac{173,71}{70} = 2,48 \cong 3$$

Where

NCC – Number of charge controllers connected in parallel;

CC_R – Charge controller rating;

AS_C – Amperage of a single charge controller.

3.2 Defining the Cooling and Heating Level

The Heat Level Prototype

The cooling level of the solar panel is derived from the heat levels of the panel. The module temperature is calculated as a function time to get the heat level of the solar panel. The module temperature is, therefore, calculated using the following equation [10-13].

$$T_m = T_{amb} + (NOCT - 20)\ E / 800 \tag{3.16}$$

The temperature of the solar panel is based on the ambient condition around it, which consists of nominal operating cell temperature (NOCT), ambient temperature, and the solar irradiance. NOCT is dependent on the ambient air temperature as the sunrises. It is written in the following equation as;

$$\text{NOCT} = 20°\text{C} + \text{Trise} \tag{3.17}$$

The NOCT has a fixed value, while the ambient temperature and solar irradiance work with relation to time. In other words, the solar panel temperature will be determined by measuring the temperature between sunrise and sunset. Solar irradiance, ambient air temperature, and temperature of the panel were recorded on a day in July 2020 between sunrise and sunset. The temperature of the module was measured and using Eq. (3.16) the temperature of the module was calculated; the result is similar. The temperature of the module, as determined and analyzed, is shown in Figure. 1. The discrepancy between the recorded and estimated temperature of the module does not surpass 5%

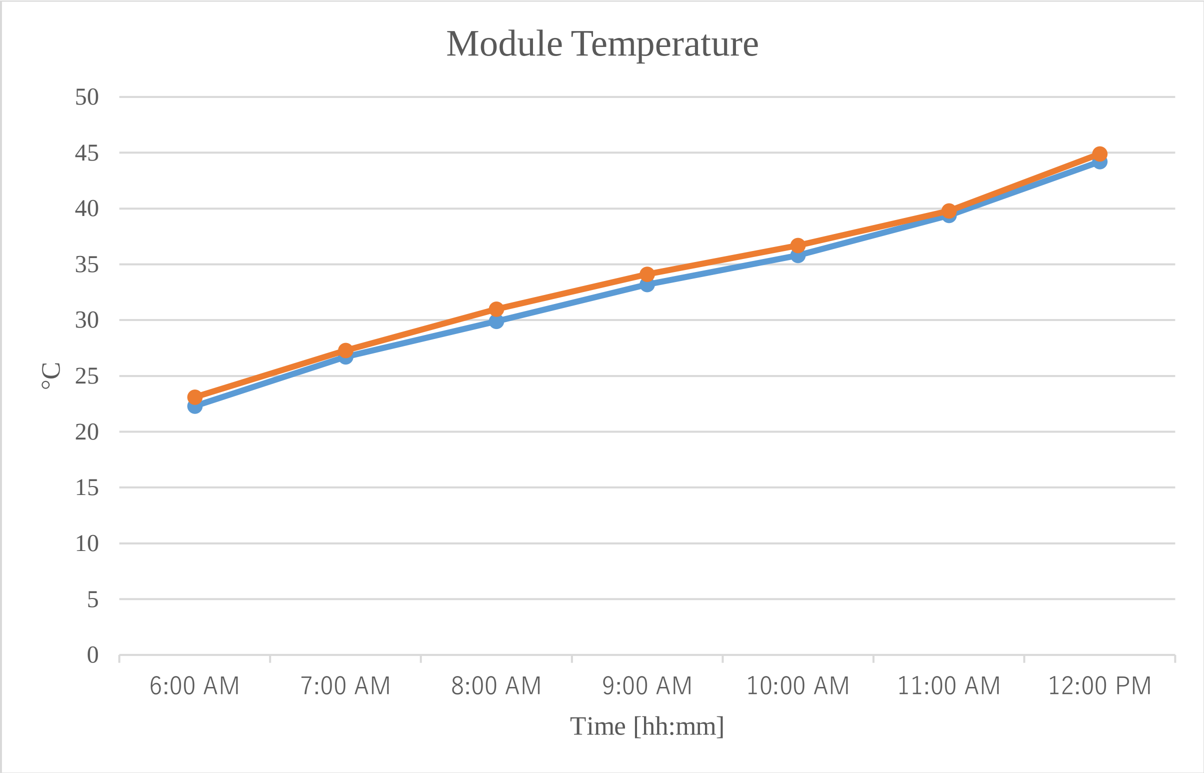


Figure 3.1. The temperature of the module as estimated and analyzed.

The Cooling Level Prototype

The period of cooling is determined by the energy balance of the system [14], $\Delta E_{system} = \Delta E_{final} - \Delta E_{initial,}$ the amount of heat energy gained by the cooling water – the heat energy gained during exposure of panels to the sunlight. The temperature of water leaving the panel is assumed to be the same as the temperature after cooling the panel. Therefore ΔT_w is the change in the temperature of the cooling water before and after cooling of the panel. It is also good to note ΔT_w is equal to the difference between the hot water coming from the panel to the storage container and the cold water leaving the storage container. From the manufacturer datasheet, it can be seen that 45° C is the allowable temperature for the panel to operate normally. The set value for this task is 40° C. Above that value; the Arduino will kick start the pump in other to cool the panels down to 30° C.

3.3 Automated System Design and Description

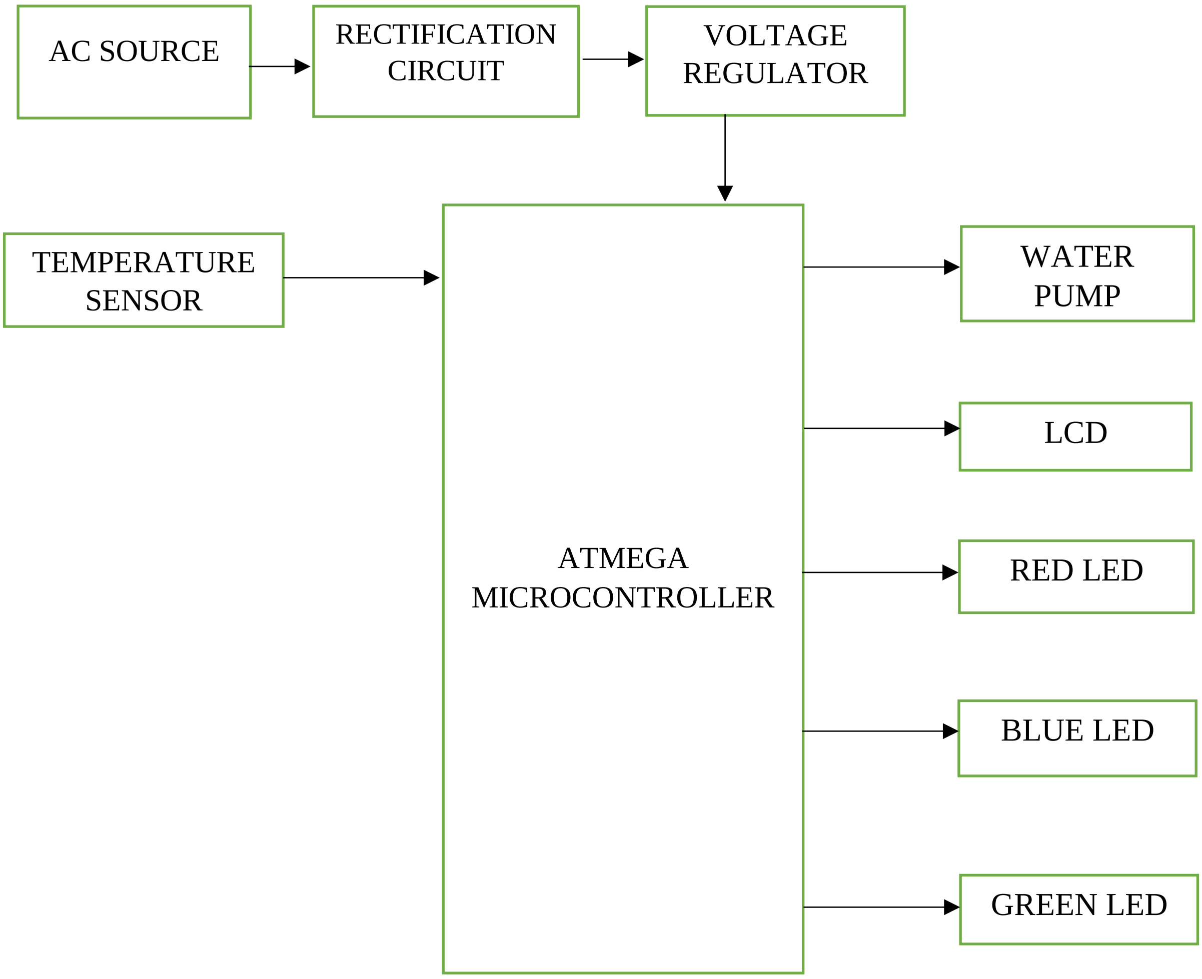


Figure. 3.2a. Circuit diagram algorithm.

System Description

The system uses an AC supply of 220V from the mains; a step-down transformer is used to decrease the voltage to 9V. Due to the ripple effects from the step down of the voltage, the output is rectified using rectifier diodes (Full bridge rectification). The output obtained then becomes more stable and smooth using the filtering capacitor. Atmega328 microcontroller, LCD, buzzer, and relay require 5V; hence the voltage regulator LM7805 is used to regulate the voltages from 9v to 5v. The Atmega328 starts running, and clocks are generated using a 16 MHz crystal. The temperature sensor needs a maximum of 5v to run. The temperature sensor is connected as an input to the microcontroller. When the temperature is above the set degree, the pump turns on until it is below the set temperature.

System Design and Circuit Interfacing

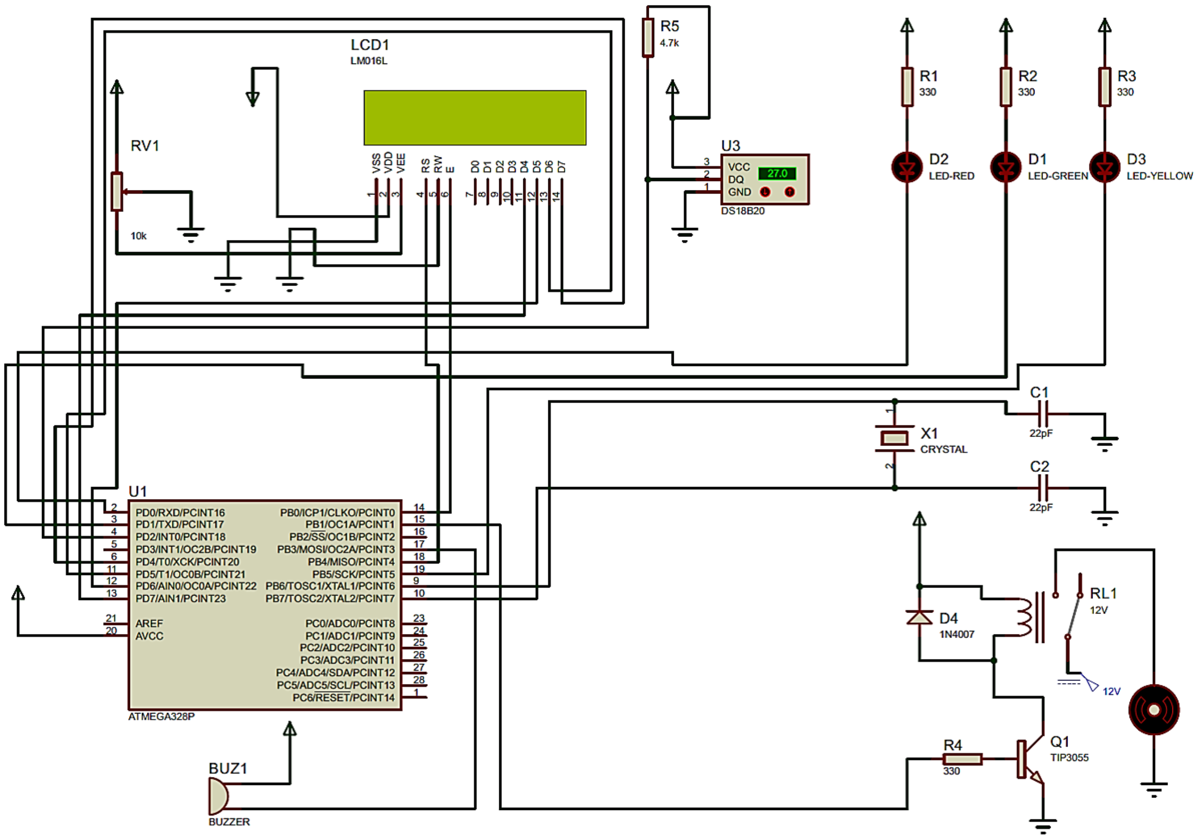


Figure 3.2b. Circuit Diagram for Water cooling system for solar panel.

ATMEGA and DS18B20 interfacing

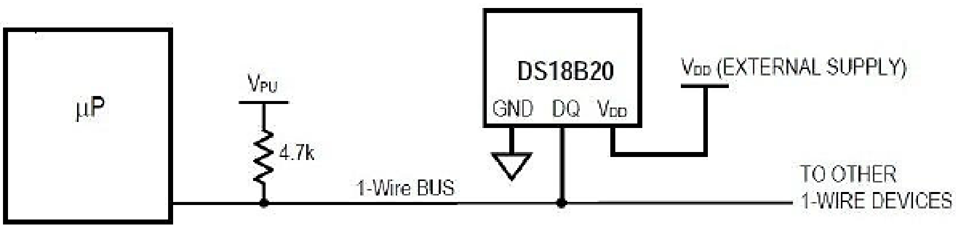


Figure 3.3. Block diagram for one wire communication between the DS18B20 and ATmega.

The mode of communication used in this project is a one-wire bus. It uses an interface, the ATmega microcontroller, and the temperature sensor. Enabling the one-wire communication in the thermometer initialization must be written to bit "0". The transmission between the master and the slave is done using 1 signal port, which is; Port D, Bit 2.

Mode of operation

The INT0/PCINT18 – Port D, Bit 2, which an external interrupt source of the microcontroller, is connected to the DQ pin of the DS18B20, This signal carries a low voltage (logic 0) which activates the DS18B20 for operation. The structure consists of a reset pulse transmitted by a microcontroller, the presence of a pulse transmitted by a thermometer in the sensor. In other words, the temperature sensor senses the ambient temperature of the environment and sends this signal to the microcontroller through the one-wire communication. The measured temperature of the PV module is transferred and stored in the EEPROM of the microcontroller. The temperature sensor contains 2 bytes of data which is stored in the EEPROM.

ATmega EEPROM

The ATmega328/P is an electrically erasable memory which can contains 1K bytes of data. It is structured as a separate data space, where a single byte can be read and written. The EEPROM has a durability of at least 100,000 write/erase cycles.

1KB = 1024 address locations

If the RFID sends identification number in 3 ½ bytes of data, E.g., 37

3	7

1 Byte = 8 bits

2 = (2 * 8)

= 16 bits

So For every transfer of data, 16 bits are received in the memory location of the EEPROM.

Atmega and LCD interfacing

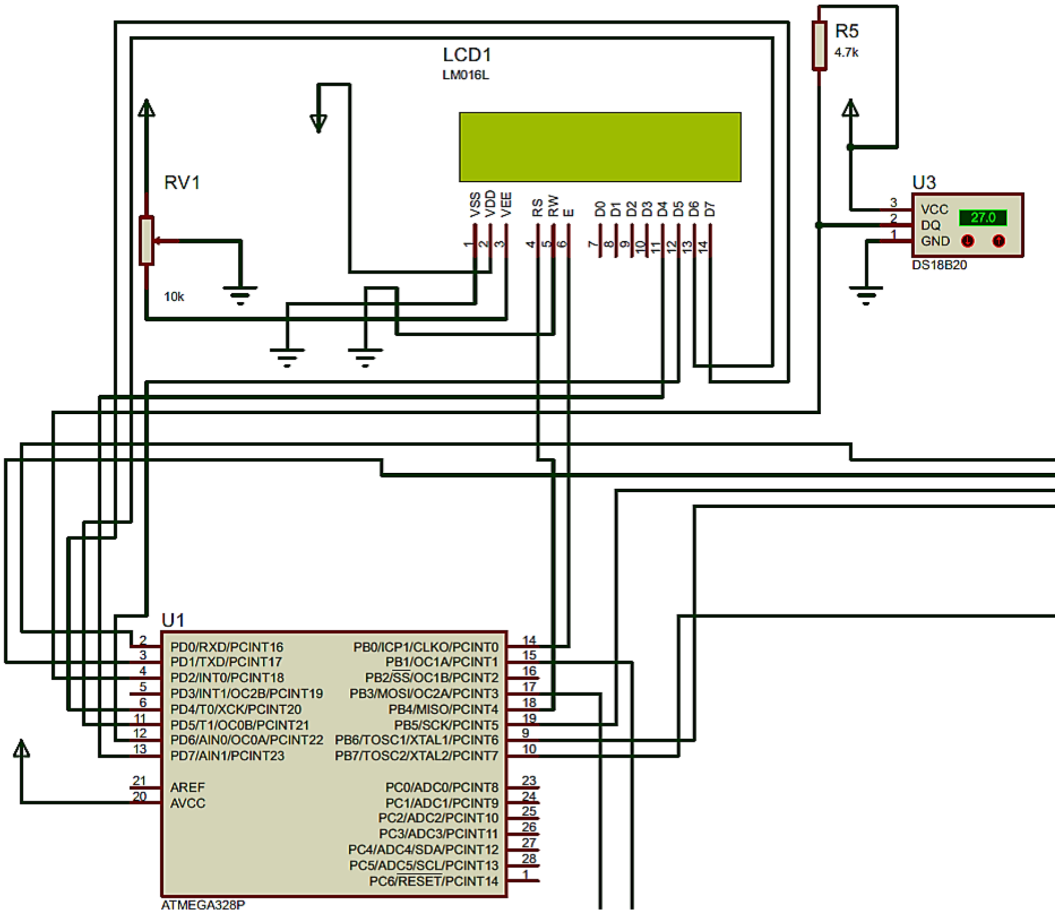


Figure 3.4. Mode of operation

The above circuit describes the connection of the LCD to the ATmega. Source voltage (V_{SS}) Connected to the ground, the Emitter voltage (V_{EE}) Connected to a variable resistor to adjust the contrast of the LCD. V_{DD} is connected to the supply 5v from the power circuit. The read and write pin is grounded, so this sets the LCD in a mode to only read data. The register select pin is connected to the microcontroller; it is configured to logic 0 to activate the command register. The enable pin is connected to the port c of the microcontroller it configured on logic 0. The data pins used in this project are limited to 4 pins (D4-D7), and they are connected to the port D of the microcontroller; hence there is a 4-bit data transfer between the LCD and microcontroller.

3.4 Object description

Specifications: SG370M Solar Panel Description [36]

Table 3.2

Performance at STC	SG370M
Nominal Max Power (Pmax)	370 watts
Max Power Voltage (Vmp)	40.1V
Max Power Current (Imp)	9.23A
Open Circuit Voltage (Voc)	48.93V
Short Circuit Current (Isc)	9.81A
Module Efficiency	19.07%
Module Fire Performance	Type 1 (UNI 9177)
Temperature Coefficient (Pmax)	-0.37%/°C
Operating Temperature	-40° to 85°C (-40° to 185°F)
Maximum System Voltage	1500V
Maximum Series Fuse Rating	15A
Cell Type	Mono 5BB Cells
Cell Arrangement	72 (6 x 12 cells)
Dimensions	77.01 x 39.06 x 1.57in (1956 x 992 x 40mm)
Weight	49.6 lbs (22.5 kg)
Connector Cables	MC4 compatible

The panels used are PEIMAR solar panels and are produced in Italy, offering a perfect combination of high efficiency and versatility [36]. Due to high-quality solar cells, these solar panels attain superior efficiency and have optimum production even under lousy lighting and environmental conditions. The firm yet ultra-light frames make it easy to install. They ensure a robust installation in residential, commercial, and large settings. The solar panels are attached to the required output power in series and parallel.

Charge Control Description

A solar charger absorbs electricity from your solar panels and stores it in your battery. Using the newest and quickest technology, Smart Solar maximizes this energy harvest and intelligently powers itself to reach full charge in the shortest time possible. Smart Solar protect and maintain the battery's health, extending its lifetime [37]. The Smart Solar charge controller can also power a heavily-depleted battery. It can work with a battery voltage as low as 0 Volts unless the cells are permanently sulfated or otherwise impaired [37].

Specifications: Smart Solar Charge Controller with screw or MC4 PV connection MPPT 250/60 up to MPPT 250/100

Table 3.3

Maximum PV input voltage	250VDC
Maximum PV operating voltage	245 VDC
Maximum PV array short circuit current	35A (max 30A per MC4 conn.)
Nominal battery voltage range	12, 24 or 48 VDC
Maximum PV array VOC	250VDC absolute maximum coldest conditions, 245V start-up and operating maximum
Float charge voltage	Its default setting: 13,8 / 27,6 / 41,4 / 55,2V
Absorption charge voltage	Its default setting: 14,4 / 28,8 / 43,2 / 57,6V
Peak and full power efficiency	99%
Protection system	over temperature, PV reverse polarity, output short circuit,
Working temperature of the module	From -30 to + 60°C (full rated output up to 40°C)

Battery

Lithium-iron-phosphate is the safest of the conventional Li-ion battery types. The standard voltage of an LFP cell is 3,2V (lead-acid: 2V/cell). A 12,8V LFP battery consists of 4 cells that are connected in series, while the 25,6V battery is made up of 8 cells connected in series [38].

SPECIFICATIONS: Victron Energy 12,8 Volt Lithium Iron Phosphate battery Smart [38]

Table 3.4

Specifications:	Lithium battery 12,8V Smart
DC Voltage Nominal	12,8V
Ampere Hours	200 Ah
Rated Wh Capacity	2560 Wh
Max Continuous Discharge Current (C/2)	400A
Max Continuous Charge Current (C/2)	400A
DC Voltage Range	12V – 14,2V
Depth of Discharge	up to 80%
Operating Efficiency	95%
Operating Temperature	Discharge: -20°C to +50°C Charge: +5°C to +50°C
Charge Temperature	-45°C to +70°C
Self-Discharge Rate	Less than 1% loss/ month
Cycle Life	2500+ (@ 80% DoD)
Protection class	IP 22
Dimensions	237 x 321 x 152
Weight	22kg

Inverter

The PV3500 series is a multifunction inverter that combines the inverter and MPPT solar charge controller, and battery charger functions for continuous portable power supply [41]. The detailed LCD monitor provides easy-to-use button activity such as battery charge current, AC/solar charger preference, and selectable input voltage depending on various applications.

Specification for PV3500

Table 3.5

<table>
<tr><th colspan="2">MODEL</th><th colspan="2">PV35 PRO-4K</th><th colspan="2">PV35 PRO-5K</th><th>PV35 PRO-6K</th><th>PV35 PRO-8K</th><th>PV35 PRO-10K</th><th>PV35 PRO-12K</th></tr>
<tr><td colspan="2">Nominal Battery System Voltage</td><td>24V</td><td>48V</td><td>24V</td><td>48V</td><td>48V</td><td>48VDC</td><td>48VDC</td><td>48VDC</td></tr>
<tr><td rowspan="10">INVERTER OUTPUT</td><td>Rated power</td><td colspan="2">4KW</td><td colspan="2">5KW</td><td>6KW</td><td>8.0KW</td><td>10.0KW</td><td>12.0KW</td></tr>
<tr><td>Surge rating(20ms)</td><td colspan="2">12KW</td><td colspan="2">15KW</td><td>18KW</td><td>24KW</td><td>30KW</td><td>36KW</td></tr>
<tr><td>Capable of starting electric motor</td><td colspan="2">2HP</td><td colspan="2">2HP</td><td>3HP</td><td>4HP</td><td>5HP</td><td>6HP</td></tr>
<tr><td>Waveform</td><td colspan="8">Pure sine wave / same as input (bypass mode)</td></tr>
<tr><td>Nominal output voltage RMS</td><td colspan="8">220V / 230V / 240VAC (+/-10%RMS)</td></tr>
<tr><td>Output frequency</td><td colspan="8">50Hz / 60Hz +/- 0.3Hz</td></tr>
<tr><td>Inverter effciency(peak)</td><td colspan="5">>85%</td><td colspan="3">>88%</td></tr>
<tr><td>Line mode efficiency</td><td colspan="8">>95%</td></tr>
<tr><td>Power factor</td><td colspan="8">1.0</td></tr>
<tr><td>Typical transfer time</td><td colspan="8">20ms(max)</td></tr>
<tr><td rowspan="3">AC INPUT</td><td>Voltage</td><td colspan="8">230VAC</td></tr>
<tr><td>Selectable voltage range</td><td colspan="8">90-280 VAC (APL)</td></tr>
<tr><td>Frequency range</td><td colspan="8">50Hz / 60Hz</td></tr>
<tr><td rowspan="5">BATTERY</td><td>Low battery voltage cutoff</td><td colspan="8">20-24VDC for 24VDC mode (40-48VDC for 48VDC mode)</td></tr>
<tr><td>Low battery voltage recover</td><td colspan="8">21-25VDC for 24VDC mode (42-50VDC for 48VDC mode)</td></tr>
<tr><td>High battery voltage cutoff</td><td colspan="8">30VDC for 24VDC mode (60VDC for 48VDC mode)</td></tr>
<tr><td>High battery voltage recover</td><td colspan="8">28.5VDC for 24VDC mode (57VDC for 48VDC mode)</td></tr>
<tr><td>Idle consumption-search mode</td><td colspan="5"><30W when power saver on</td><td colspan="3"><60W when power saver on</td></tr>
<tr><td rowspan="4">AC CHARGER</td><td>Output voltage</td><td colspan="8">Depends on battery type</td></tr>
<tr><td>Charger AC input breaker rating</td><td colspan="2">40A</td><td colspan="2">40A</td><td>50A</td><td>80A</td><td>80A</td><td>80A</td></tr>
<tr><td>Overcharge protection S.D.</td><td colspan="8">31.4VDC for 24VDC mode (62.8VDC for 48VDC mode)</td></tr>
<tr><td>Maximum charge current</td><td>80A</td><td>60A</td><td>100A</td><td>70A</td><td>80A</td><td>100A</td><td>120A</td><td>140A</td></tr>
<tr><td>BTS</td><td>Continuous output power</td><td colspan="8">Yes Variances in charging voltage & S.D. voltage base on the battery temperature</td></tr>
<tr><td rowspan="6">BYPASS & PROTECTION</td><td>Input voltage waveform</td><td colspan="8">Sine wave (grid or generator)</td></tr>
<tr><td>Nominal input frequency</td><td colspan="8">50Hz or 60Hz</td></tr>
<tr><td>Overload protection (SMPS Load)</td><td colspan="8">Circuit breaker</td></tr>
<tr><td>Output short circuit protection</td><td colspan="8">Circuit breaker</td></tr>
<tr><td>Bypass breaker rating</td><td colspan="5">40A</td><td>63A</td><td>63A</td><td>63A</td></tr>
<tr><td>Max bypass current</td><td colspan="5">40Amp</td><td colspan="3">80Amp</td></tr>
<tr><td rowspan="7">SOLAR CHARGER</td><td>Maximum PV charge current</td><td colspan="5">80A</td><td colspan="3">100A(200A optional)</td></tr>
<tr><td>DC voltage</td><td colspan="5">24V/48V Auto work</td><td colspan="3">48V</td></tr>
<tr><td>Maximim PV array power</td><td>2000W</td><td>4000W</td><td>2000W</td><td>4000W</td><td>4000W</td><td colspan="3">5000W(10000W for 200A optional)</td></tr>
<tr><td>MPPT range @ operating voltage(VDC)</td><td colspan="5">32-145VDC for 24V mode,64-147V for 48V mode</td><td colspan="3">64~147VDC</td></tr>
<tr><td>Maximum PV array open circuit voltage</td><td colspan="8">147VDC</td></tr>
<tr><td>Maximum effciency</td><td colspan="8">>98%</td></tr>
<tr><td>Standby power consumption</td><td colspan="8"><2W</td></tr>
<tr><td rowspan="5">MECHANICAL SPECIFICATIONS</td><td>Mounting</td><td colspan="8">Wall mount</td></tr>
<tr><td>Dimensions (W*H*D)</td><td colspan="5">620*385*215mm</td><td colspan="3">670*410*215mm</td></tr>
<tr><td>Net weight (solar CHG) (kg)</td><td colspan="2">36</td><td colspan="2">41</td><td>41</td><td>69+2.5</td><td>75.75+2.5</td><td>75.75+2.5</td></tr>
<tr><td>Shipping dimensions (W*H*D)</td><td colspan="5">755*515*455mm</td><td colspan="3">884*618*443mm</td></tr>
<tr><td>Shipping weight (Solar CHG) (kg)</td><td colspan="2">56</td><td colspan="2">61</td><td>64</td><td>82.5+2.5</td><td>89+2.5</td><td>92+2.5</td></tr>
<tr><td rowspan="5">OTHER</td><td>Operation temperature range</td><td colspan="8">0°C to 40°C</td></tr>
<tr><td>Storage temperature</td><td colspan="8">-15°C to 60°C</td></tr>
<tr><td>Audible noise</td><td colspan="8">60dB MAX</td></tr>
<tr><td>Display</td><td colspan="8">LED+LCD</td></tr>
<tr><td>Loading (20GP/40GP/40HQ)</td><td colspan="8">140pcs / 280pcs / 320pcs</td></tr>
</table>

Atmega 328p Microcontroller

The Atmel AVR core combines a rich set of instructions with 32 general-purpose working registers [39]. It has 32 registers that are directly connected to the Arithmetic Logic Unit (ALU) so that two independent registers can be accessed in a single instruction in a single clock cycle. [39].

Pin Diagram

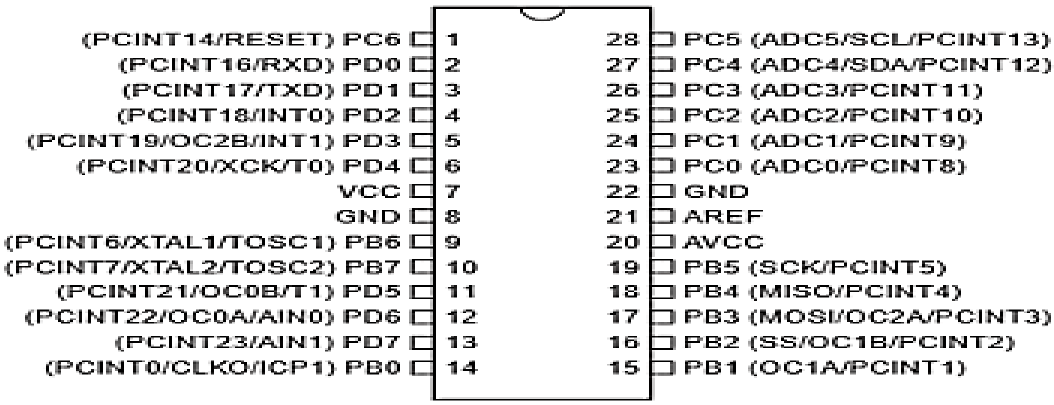


Figure 3.5. Pin Diagram of Atmega 328

The ATmega328/P provides the following features:

- 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities.
- 1Kbytes EEPROM.
- 2Kbytes SRAM.
- 23 general-purpose I/O lines.
- 32 general-purpose working registers.
- Real-Time Counter (RTC).

Summary of ATmega 328p [39]

Table 3.6

FEATURES	ATMEGA 328P
Pin count	28/32
Flash (Bytes)	32K
SRAM (Bytes)	2K
EEPROM (Bytes)	1K
General Purpose I/O Lines	23
SPI	2
TWI (I^2C)	1
USART	1
ADC	10 Bit1 5k SPS
ADC Channels	8
8-bit Timer/Counter	2
16-bit Timer/Counter	1

16 x 2 Liquid Crystal Display

The below are listed features of the LCD [40]

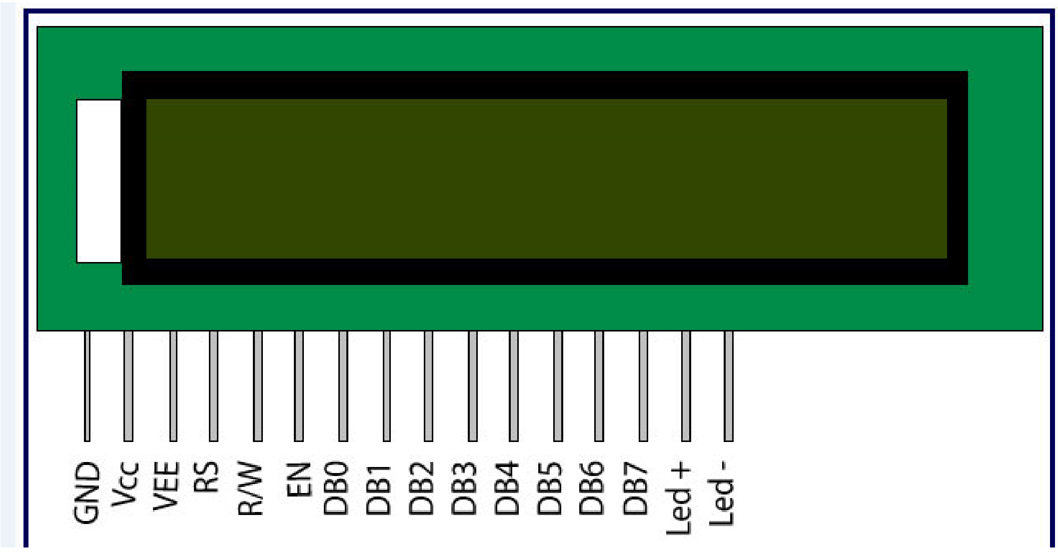


Figure 3.6. Pin Diagram of 16 X 2 LCD [40]

3.5 Scheme of the Stand-alone PV System and Equipment Being Used

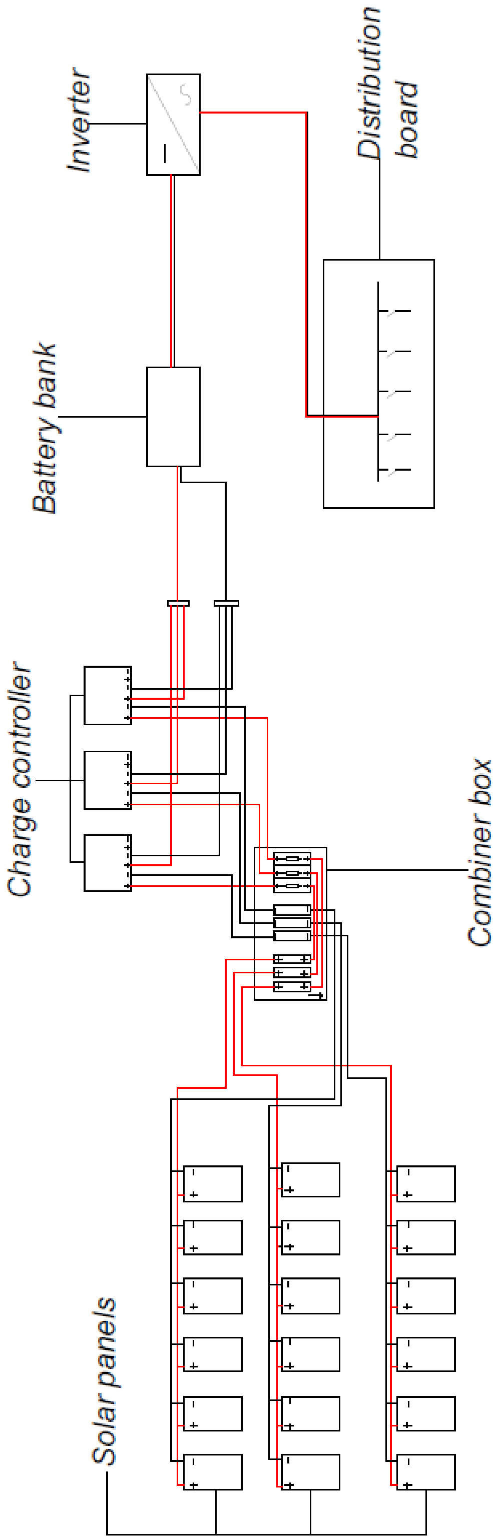


Figure 3.7. Scheme of stand-alone PV system for the house.

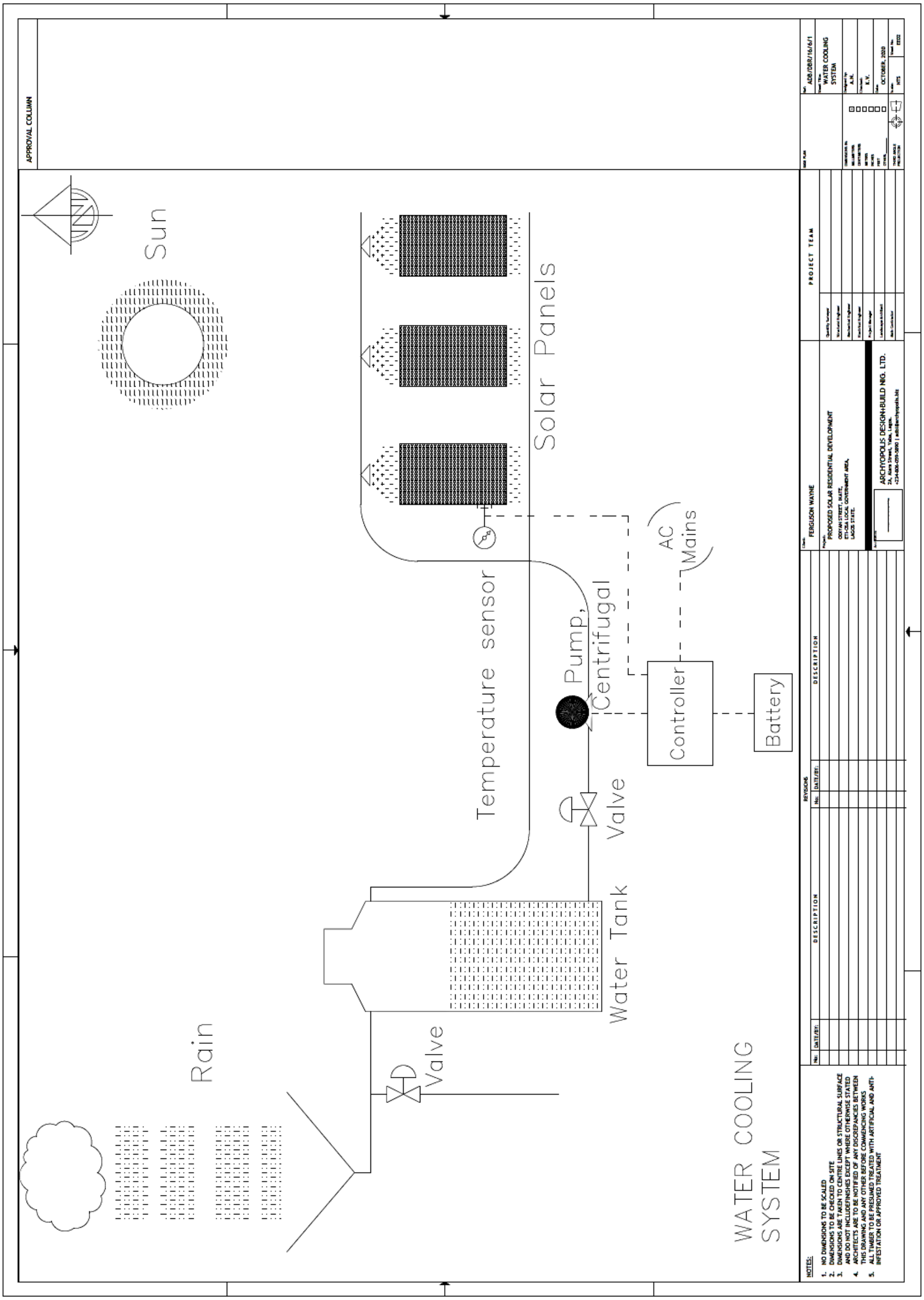
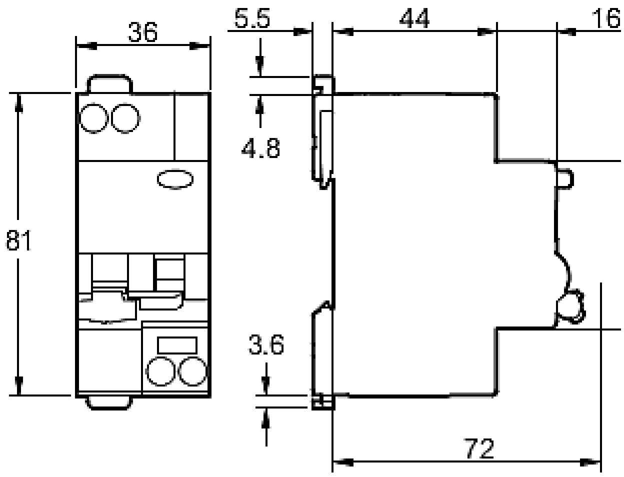


Figure 3.8. Scheme of water cooling system for the house.

a)



b)

c)

d)

Figure. 3.9. Shows the DPN N vigi series by Schneider electric,

a) Residual current circuit breaker A9N19661, b) Front and side dimensions of the A9N19661, c) C60, C120 for DC or PV, and

d) Residual current circuit breaker A9D49616

3.6. Installation of photovoltaic panels

Photovoltaic systems need a sufficient level of technical knowledge to be built. The task with the program can, therefore, only be performed by qualified individuals with the required level of expertise. Read the installation instructions before building, commissioning, or managing photovoltaic systems. Failure to meet safety standards could lead to injury or damage to equipment. Technical changes to the panels are illegal.

The construction on the roof will impact the building's fire protection. Incorrectly configured module may be a much more significant fire threat. The panel will then be mounted on the roof above the surface, which is fire resistant.

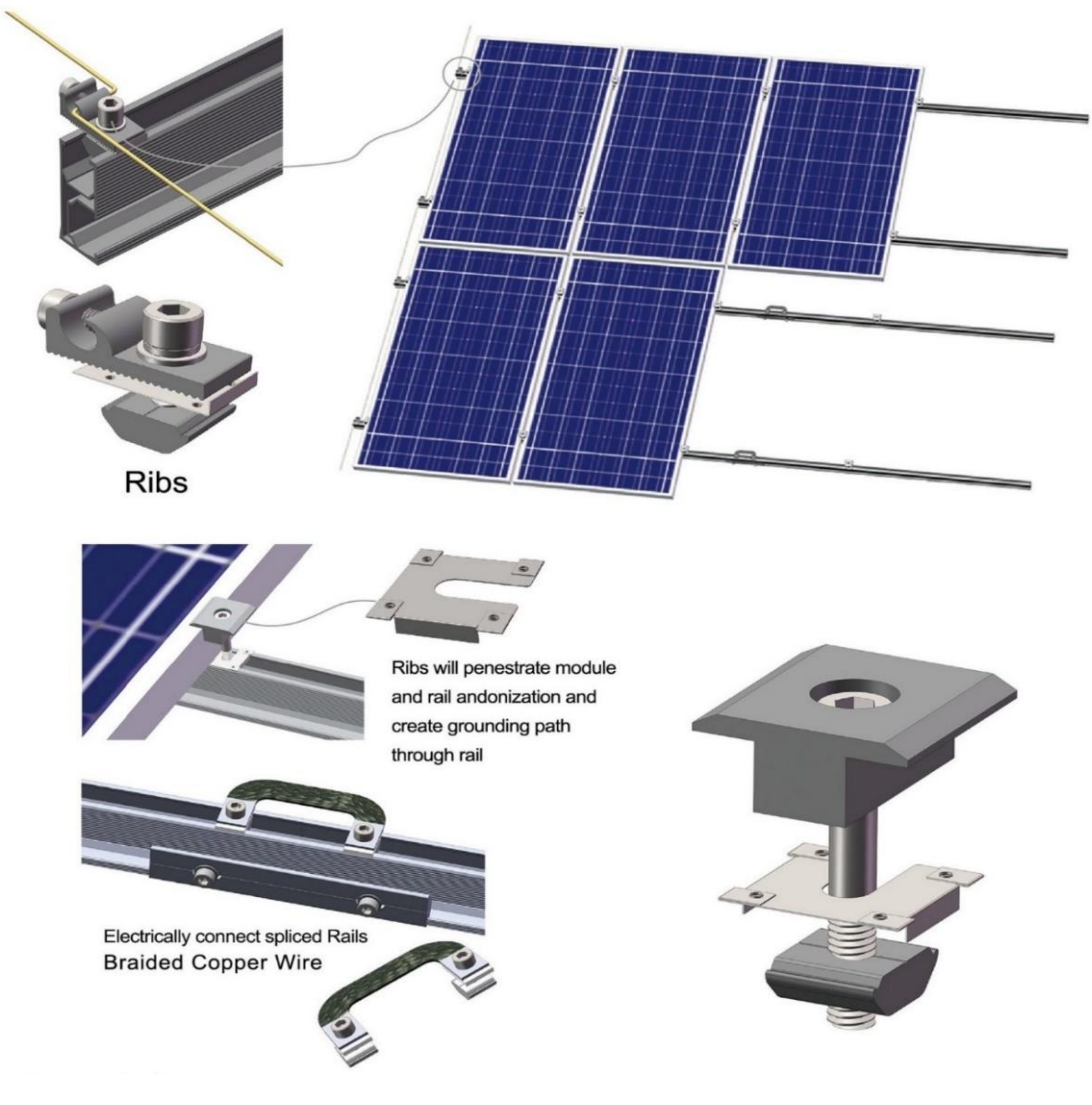


Figure. 3.10. Installation of grounding clips and wire on the panels

To maximize power output, the optimal position and angle to mount the panels is determined. Ideal conditions are achieved as the sun's rays are perpendicular to the surface of the plate. If connected in series, the output of all panels should be equal in the circle. Once the panels are mounted, it is crucial to avoid shading. Just a minor shade impacts solar panels' power production. An array of solar panels would also be mounted in places not expected to be shaded. The lower surface panels must be adequately ventilated. The lower surface panels provide adequate ventilation to dissipate excess heat, thus increasing the efficiency of the panels.

Figure 3.11. Correct installation of panels

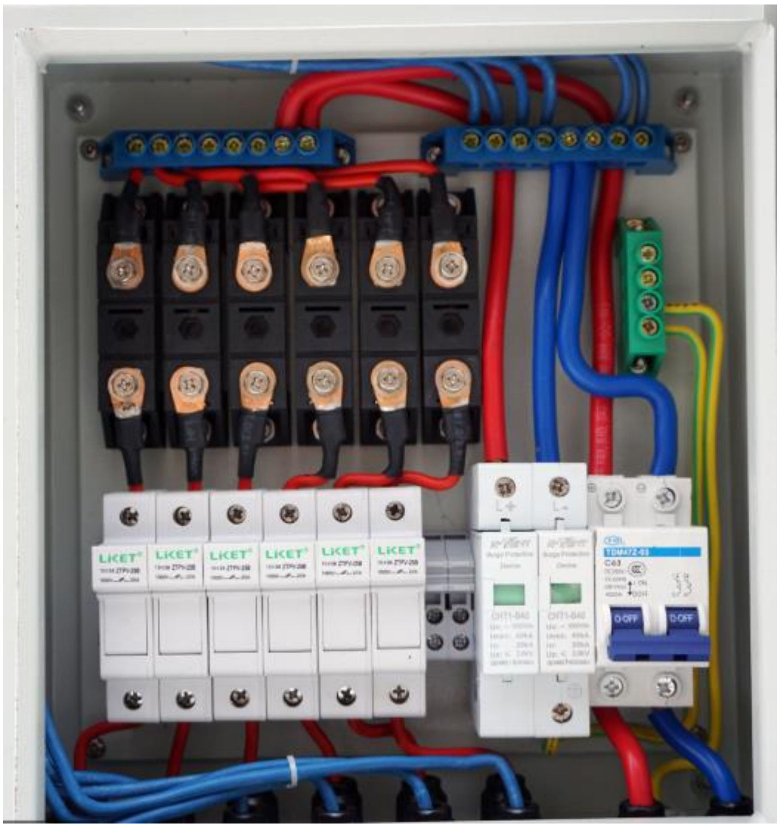


Figure 3.12. Combiner box

Installation of panel on the rooftop view

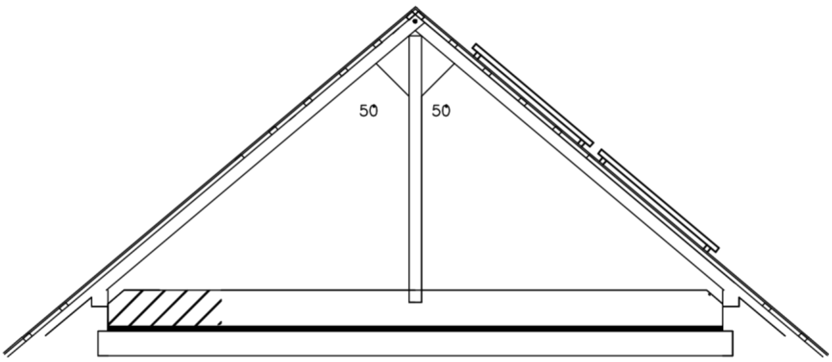


Figure 3.13. Side view of the panel installation

3.7 Conclusions to section 3

Based on the initial data provided, the parameters of the inverter type and characteristics of the photovoltaic batteries and accumulators were calculated. The MPPT charge control is a perfect charge controller as it charges the batteries and prevent them from discharging. It also charges the boosted power by increasing the amperage; only qualified persons can install the system to avoid electric shocks. Efficiency has increased due to the modernized system improved the quality of electricity.

SECTION 4

LABOUR OCCUPATIONAL SAFETY AND SECURITY IN EMERGENCY SITUATION

4.1 Safety procedures for installing solar panels

Safety precautions when conducting a solar power project are just as relevant as any other subject addressed by this study. It is worth remembering when operating on solar energy systems that the project consists of equipment capable of generating very high watts of electricity. It is, therefore, essential to familiarize yourself with the universal photovoltaic safety rules to decrease the risk of harm due to unintended electric shock or other bodily damage. Solar systems construction is a dangerous task. The lifting and organization of solar panels, the potentials for falls from building rooftops, heating panels as soon as they are exposed, are some of the severe dangers faced by solar employees. They also face the danger of conventional hazards in the construction industry. The OSHA necessitates companies to perform safety training for their workers. Numerous solar energy installation firms have taken a step further by developing their manuals outlining the special precautions for the effective management and installation of solar energy. Although safety concerns are prevalent in solar plants, protective measures can help reduce accidents in the workplace proactively.

Every Occupation Have Different Risks

All construction sites are not similar. Until a solar project starts, the developer must evaluate the site, identify safety hazards, and establish detailed measures to resolve them. Plans must cover:

- Tools for safe solar panel raising and handling.
- Specific ladders and scaffold used.
- Fall protection from the rooftop.
- Any installer should wear protective equipment.

The equipment used for the work must be tested and reviewed before it is put on site.

Safety procedures for workers:

- ❖ Any solar panel should be lifted by two persons, using secure lifting techniques.
- ❖ Transportation of PV modules to and from the workplace by pushcarts or forklift.
- ❖ Do not climb ladders with solar panels. Using correctly examined cranes and lifts to move PV modules to the rooftops.
- ❖ When unpacked, cover the PV modules with an impenetrable sheet to avoid the absorption of heat.
- ❖ Wear gloves always when the panels are handled.
- ❖ Pick the most suitable ladder – be it a portable ladder, conventional ladder or expansion ladder. Conventional or expanded ladders can reach at least some feet higher than the working area.
- ❖ It is ideal to use a ladder made of fiberglass when working close to power sources, utilizing insulating side rails.

Ladder Safety

Also, solar construction involves operating on roofs and with ladders. It is important to pick the precise ladder and use it correctly.

4.2 Solar Power Safety

Solar electrical (photovoltaic) systems require many electrical components: the PV modules, an inverter that transforms the panel's DC power to AC power, and other necessary system components. When all components are "live" with electricity produced by energy from the sun, they can because accidents are associated with electrocution and arc-flashes. And low-light conditions will produce enough voltage to cause damage. It is also necessary to note that energy is supplied from both the utility power provider and the PV modules that consume sunlight. And if a building's main Circuit-breaker is turned off, the PV system would continue to generate electricity. This makes it harder to separate the energy supply, and the worker needs to be extra careful.

Safety procedures for solar workers:

- ❖ Shield the PV module array to "turn off" the light of the sun with an impenetrable film.
- ❖ The cable coming from the PV module array is energized. Apply utmost caution. Use a multi-meter to checking the system to de-energize all circuits before operating on them.
- ❖ Shut out the electricity on lockable modules—Mark all loops at points where the device or system can be energized.
- ❖ Never, when under load, detach PV module connections or other linked PV cables.

Personal Protective Equipment (PPE)

Personal safety gear is an integral feature of all solar installations. It is the responsibility of the employer to evaluate the site for the dangers and to include the PPE, which is deemed essential for the welfare of the employee. Strong helmets, gloves, and steel shoes are among the most common PPE for PV projects. Employees are, in turn, responsible for using, managing, and demanding replacements in a secure and effective environment accordingly to their employer's orders. Risk is part of all companies, but danger should be minimized at all costs when it comes to the protection and health of an employee. Proactive safety preparation and practical work execution will help prevent accidents.

4.3 Types of Fault in Electrical System.

The electricity we use every day is provided along with current and voltage. Any electric current which exceeds the circuit rating is an overcurrent. If the current reaches the cable's rated current capacity, it produces excess heat, affecting the insulation. If the insulation is impaired, workers may sustain severe injury, and equipment or facilities may be affected or lost. The overcurrent can be split between overloads and short circuits.

Overcurrent Protective Devices

Overcurrent safety systems (fuses and circuit breaches) are used to avoid overload and breakdown of circuits and facilities. The features, architecture, and operation of these devices differ. Fuses and circuit breakers have been designed to feel irregular overloads and short circuits and to open the circuit before disastrous accidents take place. However, each device has different time characteristics and must be used and configured for the application conferring to relevant specifications and guidelines of the manufacturer.

Fuses

A fuse is a purposely poor connection in a circuit. It is a thermally, sensitive system that provides overcurrent protection. The primary purpose of a fuse is to shield conductors and appliances from overcurrent and to de-energize faulty circuits to reduce staff risks.

Fuses can be graded as rapid or delayed, as limiting or non-current limiting. Fast-acting fuses are designed to react rapidly to overload currents, while a delayed fuse is necessary for a specified period to hold an overload current. This helps time-delay fuses to bear current and other transient overloads. Fuses that restrict the maximum potential current (Ip), which can flow during the short circuit, are limiting current fuses. If the fuse is labeled as fast-acting or time-delay, fuses that limit current open rapidly under short-circuit conditions.

Circuit Breakers

They are shaped like fuses to protect circuits from overload and short circuit conditions when implemented in their ratings. Circuit breakers mainly use a mechanical latching, spring-assisted switching mechanism, and a heat, thermal, hydraulic, or electronic current sensing device which unloads and open the circuit. Current limiting is not traditional circuit breakers. In specific ratings, however, current limiting breakers are available at a higher cost.

With current ratings of up to 6300A and voltage ratings up to 1000V, regular breakers are available. With increasing amounts, the form of breakers will range from Molded Circuit Breakers (MCCBs) to Shielded- Case Circuit Breakers (ICCBs) to Low-Voltage Power Circuit Breakers (LVPCBs). Few circuit breakers have magnetic trip units only or electronic travel sensors and can be calibrated for long, quick, or instant delays. In both cases, the sensing circuit allows the switching circuit to work (open).

4.4 CONCLUSION

The introduction and rapid expansion of solar technology has brought with it several occupational hazards for workers responsible for panel installation. These hazards need to be addressed to ensure that workers are protected while we reap the benefits of this technology. Guidelines for safe solar panel installation exist. However, the injuries related to panel installation are poorly quantified. There is concern for long term health effects acquired from prolonged ultraviolet radiation and from lifting heavy panels. The lack of data regarding these concerns makes increasing awareness for worker safety more challenging. This chapter has explained the occupational concerns, including hazardous exposures to workers, accompanying health effects, the limitations of photovoltaic (PV) panels, challenges associated with this growing industry, as well as current and future directions for policy and safety procedures to be taken to ensure a safe installation.

GENERAL CONCLUSION

1. For a house located in Abuja Nigeria, considering the warm environment and the high sunshine where the house is located, this already gives high utilization of the solar irradiance of that area
2. Based on the initial data the parameters of the inverter type and characteristics of the photovoltaic accumulators were selected. After all devices needed were chosen for the setup of the whole system, calculations were made according to the amount of energy being consumed in the house, so by this point the amount of PV modules was calculated.
3. The modernization of the electrical scheme, building-based photovoltaic cells, the scheme of installation of photovoltaic panels, and especially their mounting, commissioning and maintenance.
4. After all analysis were made the project proved that Water is very effective owing to the fact that water specific heat is higher than the specific heat of air, low viscosity and cost, which led to increase in efficiency.
5. The automated system helps in increasing efficiency by operating the pump automatically to spray water on the panel which will yield optimum efficiency.

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