Chapter

Solar Photovoltaic Principles

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Abstract

Due to the limited supply of fossil fuels in the modern era, humankind's need for new energy sources is of utmost importance. Consequently, solar energy is essential to society. Solar energy is an endless and pure source of energy. Solar energy research is being used to help solve the world's energy dilemma, safeguard the environment, and promote significant sustainable economic growth. Humans have now constructed numerous solar photovoltaic power plants to produce electricity, and many people have installed solar panels on their homes' roofs to do the same. The non-mathematical explanation of PV solar cell theory and its circuit architecture is covered in this chapter. It is written for a variety of groups, including engineers who need an introduction to the subject of photovoltaic cells, end users who require a deeper understanding of the theory to support their applications, students interested in PV science and technology, and others. The fundamentals of the individual electricity-producing solar cell—the photovoltaic cell—are discussed in this chapter. The reader is informed about the workings of PV cells. The chapter focuses on the operation and construction of PV cells. The advantages and disadvantages of the cell's potential industrial applications are discussed. Here, we go over how to ensure that the PV cells used in contemporary renewable energy systems are up to snuff.

Keywords: new energy, fossil fuels, solar power, solar photovoltaic, inexhaustible energy, clean energy

1. Introduction

When something shifts in the cosmos, it also shifts in a quantity we call energy. Although its exact definition is unknown, the term "energy" is frequently used to ability of a physical or biological system to describe the motion or change. Movement, heating, and chemical transformation are just some of the various changes that can be brought about by applying different types of energy. Energy is required for all actions, including those performed by humans. It's necessary for humans to do activities like walk, cook, heat, and light their homes, and operate motor vehicles. Mankind is a voracious energy consumer. On average, a young man's daily energy needs amount to roughly 2500 kcal (2.9 kWh) while he is actively engaged in physical activity. An annual energy cost of roughly $106 is implied. The present annual worldwide energy use is close to 20,000 kWh per person. If this trend continues, men will consume 19 times more energy than they need to maintain their current level of health and well-being. Over the past 100 years, humanity has seen a significant growth in energy use. While the annual energy consumption per resident was approximately 5800 kWh in 1890, it increased to 20,200 kWh in 1970. Since 1970, the amount of energy used per resident per year has decreased to the current level of 19,000 kWh. The evolution process that began roughly five centuries ago can be linked to the rise in energy use in the twentieth century. The eighteenth century's Enlightenment saw the development of the philosophy of human progress, which provided the framework for this procedure. The method was intended to examine the environment and how it could be modified to better meet the needs of those whose lives would become safer and more comfortable. Growing industrialisation and mass production, which required an increasing amount of energy, went hand in hand with this process. Coal was the primary energy source at the end of the nineteenth century. During this time, electricity—a brand-new and sophisticated kind of energy—was introduced in the industrialised nations. This kind of energy was quickly used extensively. In the early twentieth century, as a result of the enormous rise in electricity demand and the subsequent building of hydroelectric plants, hydropower became a significant source of energy. At the close of the twentieth century, the oil and gas industries began to play a considerable part as contributors to the world's energy supply. Present-day energy sources are dominated by coal, oil, and gas. These three forms of energy (coal, oil, and gas), generally known as fossil fuels, are referred to as "conventional energy sources." During this time, nuclear energy was introduced as a brand-new energy source. Numerous household items are inexpensive because of growing and more efficient mass production. Given the tremendous increase in product consumption, it's not surprising that we now refer to modern society as a "consuming society." The quest for and use of new, sustainable energy sources has become a major issue near the end of the twentieth century. The urgency of this problem is highlighted by the Earth's finite supply of fossil fuels and rising global demand for energy generation. The focus is shifting to renewable energy sources because of this. Every human action requires energy. When considering the production and consumption of energy by human civilization, an energy system can be used to explain it. The population, overall energy consumption, and the types and sources of energy that people consume make up the key elements of the energy system. The energy system at the beginning of the twenty-first century is characterised by the six billion people who occupy the globe and the 1,300,000,000 kW of total energy use.

Even now, the cost of producing electricity from renewable sources is higher than that of conventional ones. As a result, it is not yet economically feasible in industrialised nations to use renewable energy sources as electricity power sources on a large scale. The main driver of a developing market for renewable energy sources and favourable national regulations is certainly their positive effects on the environment. But for the two billion people who, in many parts of the world, do not have access to an electricity grid, power generated from renewable energy sources is already the option that has the lowest overall cost.

The definition of "energy transition" is the move away from carbon-based energy sources during the coming years [1]. Therefore, it is crucial to provide energy using sources that can be regenerated organically over time on a human timeline. Renewable energy is the name given to this type of energy, which is largely environmentally safe and sustainable. Recent technological advancements have made it easy to convert various types of renewable energy into other forms of energy (such as electricity and heat).

As a direct consequence of this, in 2015 the international community came together to adopt the Sustainable Development Goals (SDGs) as a component of the

United Nations 2030 Agenda for Sustainable Development [2]. The objectives promise to end malnutrition, poverty, etc. Some of the objectives specified by the world community, such as the provision of clean energy, climate protection, and others, were energy-related. The seventh goal (SDG-7) aims to raise the proportion of renewable energy in total energy by the year 2030 and to offer clean, cheap, and contemporary energy services in all parts of the world. In addition, Sustainable Development Goals—13 aims to enhance immunity either through increasing the resistance of a number of countries or by educating and raising awareness among the general public.

This is due to the fact that every nation on earth is susceptible to the repercussions of climate change. The vast majority of the energy that is required to keep things moving in the atmosphere comes from the sun. This energy is emitted in the form of electromagnetic waves, which have wavelengths ranging from 0.2 to 4 m and are invisible to the human eye. A photon is the smallest quantifiable unit of an electromagnetic field. The current definition of a photon is based on studies conducted by Albert Einstein between 1900 and 1920 (which were based on studies conducted by the German scientist Max Planck). Gilbert Lewis is credited with being the first person to use the term "photon," which was first published in Nature in 1926. Solar irradiance is the amount of energy that is received from the sun at a certain location and time in the form of electromagnetic radiation. This energy is measured in watts. It is stated as a number, and the unit of measurement used to determine it is W/m^2. One of the most important forms of renewable energy is the sun's rays, which are collectively referred to as "solar energy" by the general public. There are two primary categories of technology that exist to capture the sun's rays: active solar technologies, such as photovoltaic systems, and passive solar technologies, which encompass a wide range of practises and may include orienting a building to the sun. Active solar technologies include photovoltaic systems. Passive solar technologies include a wide range of practises. Active solar technologies include photovoltaic systems.

2. Basic operational principles

Direct use of solar energy can be performed in essentially two different ways: (1) the transformation of sunlight directly into electricity in semiconducting devices that are more popularly known as solar cells; and (2) the collection of heat in solar collectors. The transformation of solar radiation into electrical current is referred to as "photovoltaic energy conversion" (PV), and this is the meaning of the word "photovoltaic energy conversion."

The photovoltaic effect is responsible for this phenomenon. The phenomena that can cause a potential difference to occur at the interface of two materials that are not identical is referred to as the "photovoltaic effect," and it is described using the word "photovoltaic effect." As a result, the entire field that studies the conversion of solar energy into electricity is referred to as "photovoltaics," and its acronym stands for "photovoltaic electrics." The term "photovoltaics" comes from the combination of the Greek word for light ("photo") with the Italian name of an early electrical researcher, Alessandro Volta (1745–1827), which is shortened to "Volt." Since most people do not know what the word "photovoltaics" means, the term "solar electricity" has become the most frequent way of referring to PV solar energy.

Three primary processes are necessary for the photovoltaic effect to take place: (1) the generation of charge carriers as a result of photon absorption by the materials comprising a junction; (2) the subsequent separation of the photo-generated charge carriers within the junction; and (3) the collection of the photo-generated charge carriers at the terminals of the junction.

2.1 History of photovoltaic effect

The discovery of the photovoltaic phenomenon is attributed to a French physicist named Alexandre Edmond Becquerel in the year 1839. During the course of his experiments using metal electrodes and electrolyte, he noticed that the conductivity increased as the amount of light increased. Willoughby Smith made the discovery that selenium possesses photovoltaic properties in the year 1873. Actually, when a material absorbs light at a frequency over a threshold frequency that varies with the substance, electrons are released. This phenomenon is called the photoelectric effect, and it is closely related to the photovoltaic effect. Taking into account the fact that light is presumed to be made up of individual energy quanta (photons), Albert Einstein was able to explain this phenomenon in 1905. This type of photon's energy can be calculated as $E = h\nu$, where h is Planck's constant and ν is the frequency of the light.

In 1921, Albert Einstein published the paper on the photoelectric effect for which he received his sole Nobel Prize. After another decade, the first pure semiconductor was developed in 1931. Solar cells were first used for space applications in the 1950s. In a short amount of time, Hoffman Electronics was able to surpass the previous record for solar cell efficiency, achieving highs of 10 and 14% in the years 1959 and 1960, respectively. The earliest solar cells, which had an efficiency of roughly 8%, were invented in 1957. A short time after that, the first PV cell made of amorphous silicon was developed, and the capacity of PV systems reached 500 kW. This amount continued to rise, reaching its highest point of 21.3 MW in the year 1983. A high-concentrating photovoltaic (PV) facility with a capacity of 175 kilowatts (kW) was finally constructed in the state of Arizona in the United States in the year 2002. A new PV technology efficiency record of 40% was set 4 years later. In 2012, when the global PV capacity hit 100 GW, production prices dropped drastically to $1.25 per watt. The first solar-powered aircraft completed a global flight in 2016 [3]. The global PV power potential is shown in **Figure 1**. Solar photovoltaic generation will increase by 23 percent, from 156 GWh in 2015 to 821 GWh in 2020, making it the fastest-growing renewable energy source after wind and ahead of hydropower. PV capacity additions experienced an exceptional rise (a record of 134 GW) in China, the US, and Vietnam. Unquestionably, solar PV is moving toward becoming the most affordable choice for producing power globally, and in the years to come, it is anticipated to draw significant investment [4].

2.1.1 Construction and working of photovoltaic cell

Photovoltaic cells are a type of electrical device that are capable of transforming the energy from light into electric current. The solar cell is an example of a photovoltaic cell. This type of cell is often referred to as a PV cell, which is an abbreviation for "photovoltaic cell." A solar cell is composed of its most fundamental component, a diode with a p-n junction. Photoelectric cells, of which solar cells are a type, are devices in which the presence of light causes a change in the electrical properties of the device (such as the current, the voltage, or the resistance). One sort of cell that fits within this category is the solar cell.

In the process of fabricating solar panels, modules that have been constructed from solar cells and then joined together are utilised. These modules are then

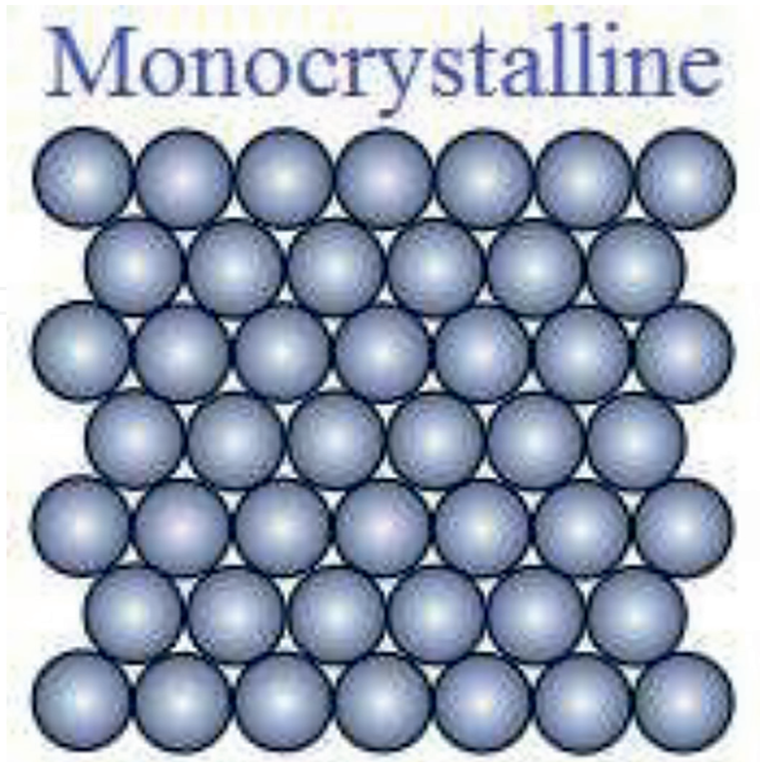

Figure 1.
Monocrystalline structure.

incorporated into panels. When producing at their best levels of efficiency, the vast majority of single-junction silicon solar cells have an open-circuit voltage that falls somewhere in the range of 0.5 to 0.6 volts on average. This occurs when the cells are functioning at their optimal levels. This by itself is not a particularly large quantity, but you need to keep in mind that these solar cells are on the diminutive side. An enormous solar panel has the potential to provide a considerable amount of energy that is kind to the environment.

2.1.1.1 Construction of a solar cell

Although solar cells differ slightly in manufacture from standard p-n junction diodes, they are essentially the same thing. On top of the far more substantial n-type semiconductor, which serves as the base for the formation of the p-type semiconductor, an extremely thin layer is added (**Figure 2**). On top of the p-type semiconductor layer, we then place a few thinner electrodes.

When these electrodes are utilised, the p-type layer does not have its accessibility to light inhibited in any way. A p-n junction can be found just beneath the p-type layer in this structure. The underside of the n-type layer is likewise equipped with an electrode for collecting current. So that the solar cell is not damaged by accidental mechanical disturbance, we enclose the whole thing in a thin glass enclosure.

2.1.1.2 Working of a solar cell

Because the p-type layer is so thin, light photons can easily access the p-n junction. This allows light to go through the material more quickly. A sufficient quantity of energy is supplied to the circuit by the photons of light, which enables the circuit to

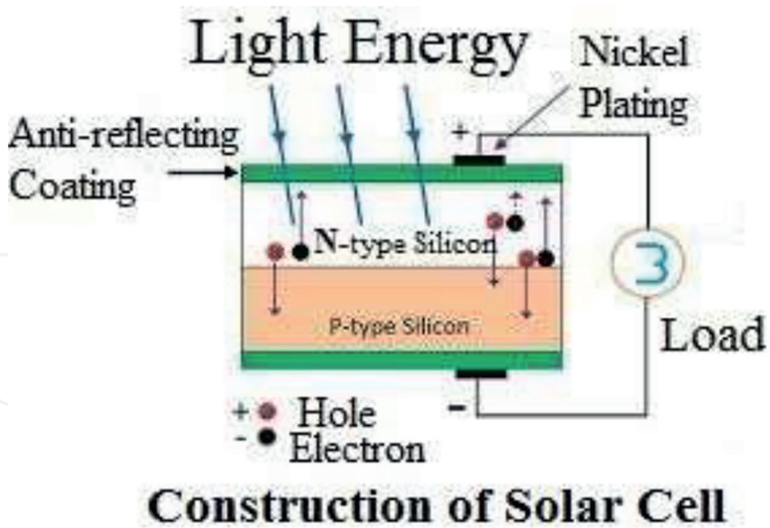

Figure 2.
Construction of solar cell.

generate a significant number of electron-hole pairs. Because of the light, the link is no longer in a condition of thermal equilibrium. This is because of the light. Free electrons have an easier time making their way to the n-type side of the junction when they are located in an area that is deficient in electrons. The depletion produces holes that have the capability of rushing to the P-type side of the link, where they can cause further damage. The barrier potential of the junction halts the freshly formed free electrons in their tracks as soon as they reach the n-type side, rendering them unable to continue crossing the junction. This occurs as soon as the electrons reach the n-type side.

Once they have reached the p-type side of the junction, newly generated holes are unable to continue crossing the junction because of the constant barrier potential that exists between the two sides of the junction. When the number of electrons on one side of a p-n junction (the n-type side) is greater than the number of holes on the opposite side of the junction, the p-n junction behaves like a small battery cell. This occurs when the number of electrons on the n-type side of the junction is greater than the number of holes on the other side of the junction (the p-type side). The voltage that is generated is known as "photovoltage," which is only another word for what it is. When there is only a light load placed across the junction, there will only be a very small amount of current flowing through it.

2.1.2 Basic structure of a photovoltaic cell

An anti-reflective coating (ARC), which is found in the vast majority of existing technologies for solar cells [5, 6], is an anti-reflective coating that is essential to the fabrication of solar cells. Because silicon has such a significant surface reflection, it is often sprayed over cells that are made entirely of silicon.

- The front contacts that is necessary to gather the current from the solar cell (**Figure 3**). They frequently construct with metal materials.

  An emitter that absorbs photons and then transfers the energy from those photons to an excited state that carries a charge after doing so. Since pentavalent-doped (n-type) silicon has a higher surface quality than trivalent-doped

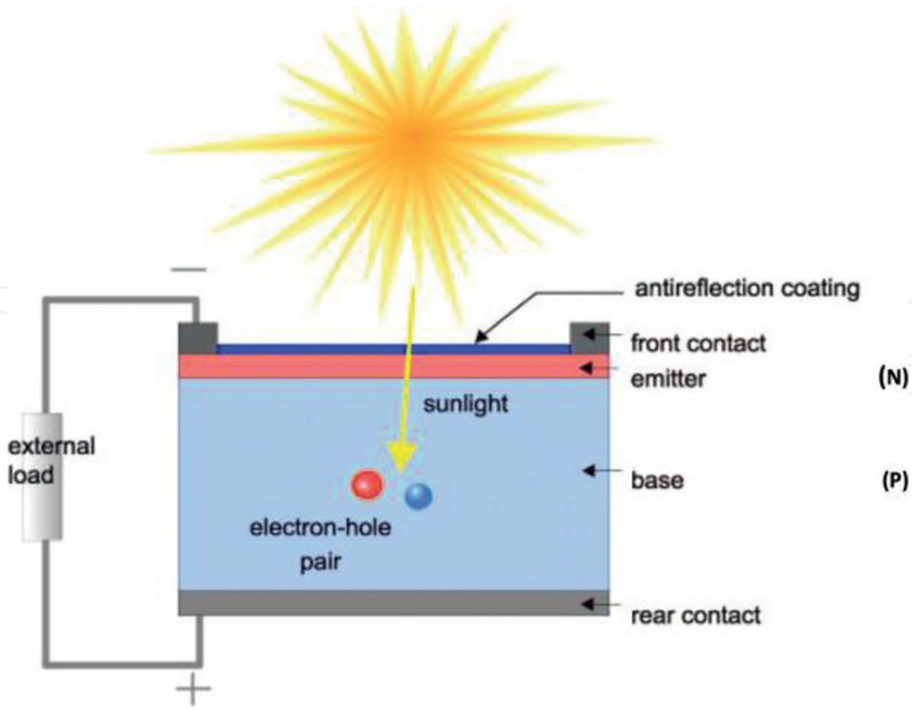

Figure 3.
Basic structure of photovoltaic cell.

(p-type) silicon, it is placed in the front of the cell, which is where the majority of the light absorption takes place. This is because pentavalent-doped (n-type) silicon is more expensive than trivalent-doped (p-type) silicon.

- In a p-n junction, the majority of the electrons in the region of the n-type side of the junction that is closest to the junction diffuse to the p-type side, and the majority of the holes in the region of the p-type side that is closest to the junction diffuse to the n-type side.

- The front contact is more critical than the rear contact since it is closer to the junction; nevertheless, the rear contact does not need to be transparent because it is further away from the junction.

2.1.3 Different types of PV cell

Typically, there are four primary kinds of solar cells, which include the following: (1) Monocrystalline solar cells, (2) polycrystalline cells (multi-silicon cells), (3) amorphous solar cells, and (4) thin film solar cells.

(1) *Monocrystalline solar cells*, which are also known as single crystalline cells (**Figure 1**), can be differentiated from other types of solar cells by their dark black appearance. As a result of this look, monocrystalline solar cells are easily identifiable in comparison to other forms of solar cells. They are made using an incredibly pure type of silicon, which is what has driven them to the position of being the most effective material for the process of converting sunlight into electricity. As a result of this, solar panels have risen to the position of being the most effective material. Solar photovoltaic cells made from monocrystalline silicon have an efficiency of 15%*, making them the most effective but also the most expensive option. They are capable of producing up to four times as much electricity as

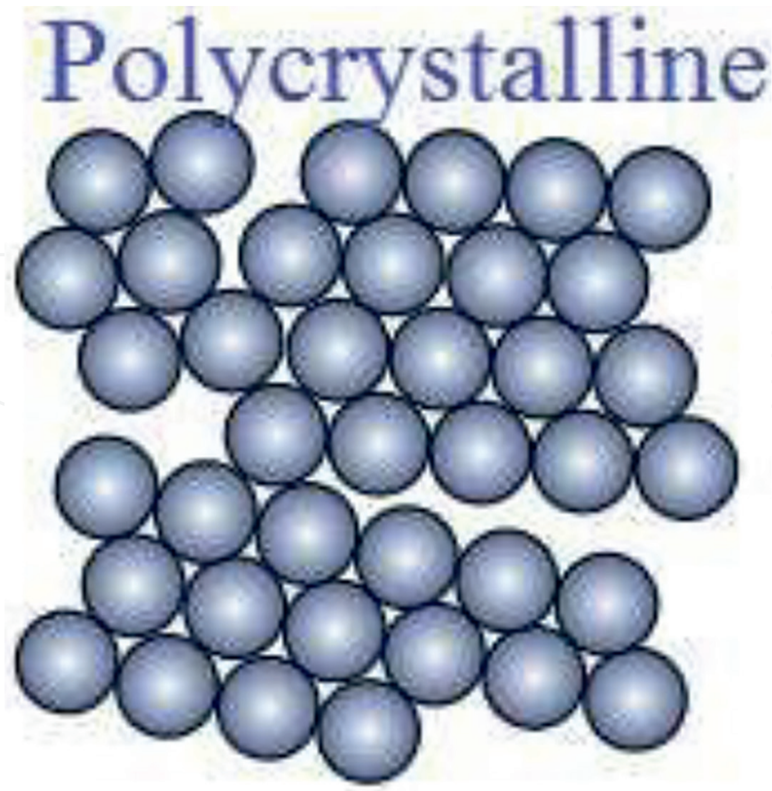

Figure 4.
Polycrystalline.

thin-film solar panels, but they only take up a small fraction of the space. In environments with low light, their performance is superior to that of other panels, and they have a longer lifespan. The most major downside of this option, as well as the primary reason why it does not enjoy more popularity among homeowners, is the high cost. In addition, dust and shadows can cause the circuit to malfunction, and the method of manufacturing that involves cutting the cells into wafers is usually regarded as being inefficient.

(2) At the very beginning of the 1980s, the solar industry developed polycrystalline cells (**Figure 4**), which are also known as *multi-silicon cells*. These cells were the very first solar cells ever made for use in commercial applications. Inside the cell, the process of synthesis can result in the formation of a number of crystalline formations. It is less difficult to put into action in a production line. It is far less expensive than monocrystalline, despite the fact that it is less effective.

(3) *Amorphous solar cells*, which are neither organised nor crystallised at the molecular level (**Figure 5**), were traditionally used for smaller-scale applications because the term "amorphous," which means "shapeless" in English, gives the impression that they are.

(4) *Thin film Solar cells*—During the manufacturing process, several layers of photovoltaic material are layered on top of one another and stacked in the form of modules that are constructed of thin film solar cells. Using this process to develop a cell (thin film) results in a lesser requirement for silicon, which in turn results in cheaper production costs. In most cases, it is less expensive, but the rate of efficiency it achieves is significantly lower [7].

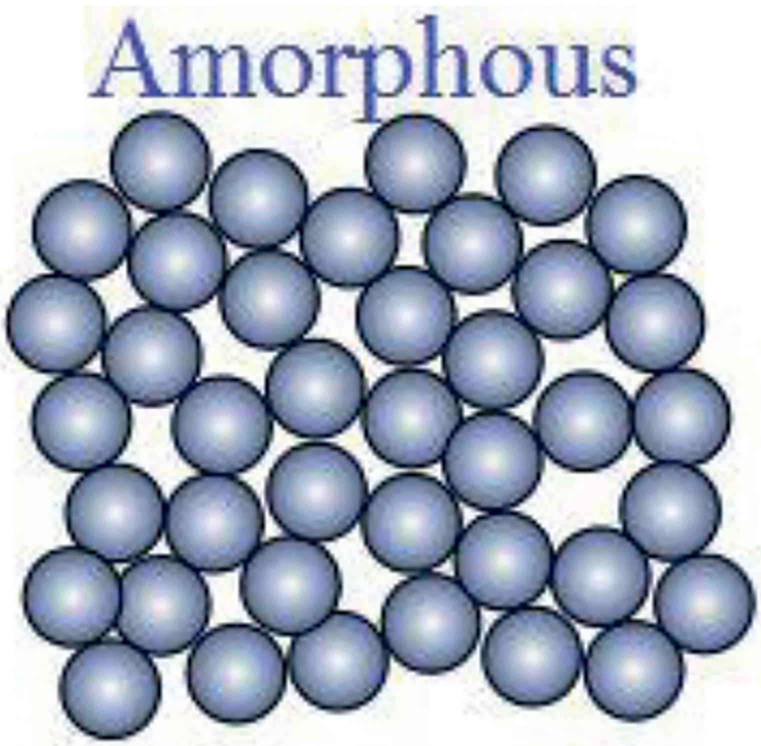

Figure 5.
Amorphous.

2.1.4 Equivalent circuit of a solar cell

In order to appreciate the electronic behaviour of a solar cell, it is helpful to construct a model that is electrically equivalent and is constructed on discrete electrical components whose behaviour is well understood. This model should be based on discrete electrical components. Because there is no such thing as a perfect solar cell in the actual world, the model incorporates both a shunt resistance component and a series resistance component (**Figure 6**). A current source that is coupled in series with a diode can successfully duplicate the characteristics of an ideal solar cell.

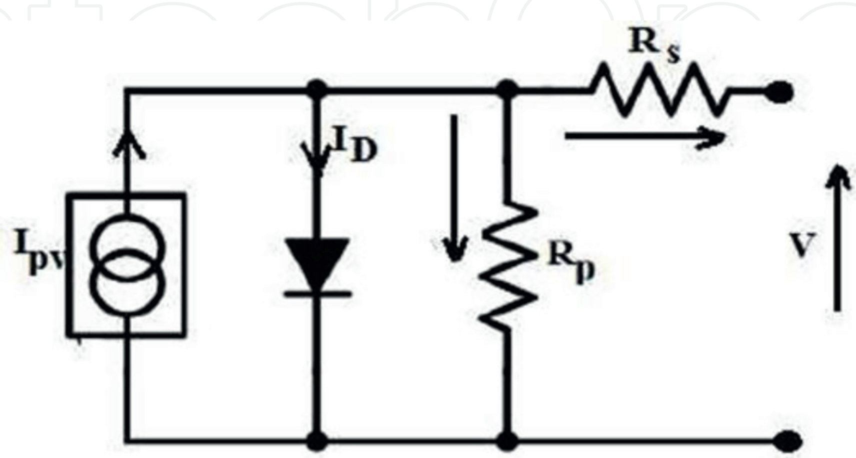

Figure 6.
The equivalent circuit of a solar cell.

2.1.5 Photovoltaic (PV) system

Solar cells are semiconducting devices that are responsible for converting solar energy into electricity. This transition takes place inside of a solar cell. A solar cell is a piece of equipment that can produce a specific amount of electrical power when exposed to sunlight. This particular kind of cell can produce both a voltage and a current as its output. A solar panel, which is also referred to as a photovoltaic module, is constructed out of a collection of solar cells and is used to generate electricity for the operation of various useful devices that require a particular voltage or current. Solar arrays are formed when individual solar panels are interconnected in order to generate huge amounts of solar-generated electricity.

The solar panels are just one component of a more extensive photovoltaic (PV) solar system. Depending on the application, the photovoltaic (PV) solar system may additionally comprise batteries for storing any excess electricity, dc/ac inverters for connecting the PV solar system to the electrical grid, as well as any additional electrical or mounting components. The balance of systems is the name given to the second component of the photovoltaic solar system, which is composed of these additional components (BOS). Last but not least, the solar system includes goods such as consumer electronics that can be powered by solar energy, such as radios and televisions. This shipment of products is the topic of our conversation.

The photovoltaic (PV) solar system is made up of a total of three components:

(I) photovoltaic cells or solar arrays, (II) the system's overall equilibrium, and (III) the load.

2.2 Advantages of solar photovoltaic cells

1. Installing photovoltaic panels, which give clean, green electricity, is one of the most important advantages because it offers significant cost savings. As a result of the fact that there is no emission of potentially damaging greenhouse gases during the process of generating power using PV panels, solar PV is good for the environment.

2. Because solar energy is derived directly from the sun, it is an environmentally friendly, non-depletable, and economical source of energy. Solar power may be generated virtually wherever that there is access to sunlight. The power grid of the future will be a distributed power generation (DPG) system, and solar electricity is an excellent fuel source for this type of grid.

3. As a result of the rapid decline in the price of solar panels, which is forecast to continue over the next several years, the future of solar photovoltaic panels appears to be unusually promising in terms of both their economic viability and their environmental sustainability. Photovoltaic panels are a type of direct electricity generation that get their name from the fact that they generate power through photoelectric processes and are referred to as such.

4. When compared to the expenses of other types of renewable energy, it is often believed that the costs of operation and maintenance associated with photovoltaic panels are extremely cheap or nearly non-existent. Solar photovoltaic (PV) panels, with the exception of sun-tracking mechanical bases, do not contain

any mechanically moving elements. As a result, they break significantly less frequently and require much less maintenance than other energy sources that are in direct competition with them. Other energy sources include: (e.g., wind turbines).

5. Solar photovoltaic panels are perfect for usage in residential and urban areas because they do not produce any audible noise (see solar panels for homes).

6. Solar photovoltaic panels are an efficient approach for managing spikes in energy use, particularly during the scorching summer months, when the need for air conditioning is at its highest point. This is the time of year when energy consumption spikes the most.

7. Solar photovoltaic panels are one of the major renewable energy systems that are promoted through government subsidy funding (FITs, tax credits, etc.). As a consequence, the financial incentive for PV panels makes solar energy panels an attractive investment alternative, in spite of the fact that their prices have seen a significant reduction in recent years and are continuing to fall. In addition, the financial incentive for PV panels makes solar energy panels an attractive investment alternative.

8. Solar panels for residences may be installed on rooftops or in the ground in a rapid and easy manner, with no interference to regular activities.

2.3 Disadvantages of Solar photovoltaic cells

1. Solar energy, like other forms of renewable energy, has the potential to be unreliable due to factors such as the sun's inability to shine at night and the chance of cloudy or rainy skies during the day. Other forms of renewable energy do not have these limitations.

2. As a direct result, solar panels are not as reliable of a solution as other options due to the unpredictability and intermittent nature of solar energy.

3. An additional piece of hardware known as an inverter is required in order to connect solar panels to the power grid. This inverter is responsible for transforming the electricity from its direct current (DC) form into its alternating current (AC) form. This is important in order for the grid to be able to consume the electricity that has been generated.

4. In order to keep a consistent supply of electric power, solar panels require not only inverters but also storage batteries, particularly when they are connected to the grid. This is especially true when the grid is the source of the electric power. Investing in photovoltaic panels will therefore be more expensive as a result of this factor.

5. The installation of land-based PV panel systems necessitates the use of enormous tracts of land; in most cases, the land must be set aside for this purpose for a period of 15–20 years, and in some cases much longer.

6. When compared to the efficiency of other forms of renewable energy technology, solar panels' efficiency ranges from 14 to 25%, which is quite a bit lower than those other forms.

7. PV panels, despite the fact that they do not require much in the way of upkeep or operating costs, are nonetheless fragile and can be damaged with relative ease. Due to this fact, the additional insurance premiums that must be paid in order to safeguard a financial investment in photovoltaics (PV) are of the utmost significance.

2.4 Challenges and future perspectives

There are a number of problems that have a major impact on how well the PV system works. To start, there may be issues with data management during the PV system implementation. The proliferation of solar power plants has resulted in an explosion of data that is beyond the capacity of current technologies to manage. For this reason, the creation of a robust system capable of real-time monitoring of massive amounts of data is essential. The second crucial feature of a wireless monitoring system is its safety. The integrity of a system may be jeopardised due to inadequate security. Security measures must be followed to guarantee safety, privacy, and secrecy. Interference with the signals is a potential third issue. This can make it difficult to keep tabs on the solar PV system's statistics. As a result of signal interference, data transfer rates, module functionality, signal strength, and connectivity might all suffer. All of this results in lower service standards and greater revenue loss. In the fourth place, the node battery's lifespan determines the PV-overall system's energy efficiency. To be more specific, the PV network includes a number of different transmitter nodes. The longevity of the PV-network decreases with each failed node battery. To conclude, the programming language and operating system must be intuitive to use. Sixth, the data transfer range needs to be adequate for the specific PV system in question. Given that the distance between the furthest two PV panels in such a system can be measured in kilometres, this is of paramount importance. Data transmission speeds should not be an issue for a long-distance platform. Seventh, the dust, temperature, radiation, and humidity in the surrounding environment have a significant impact on the performance of the PV system. When installing PV panels in the open, special care must be taken to prevent damage. For instance, dust accumulation on a PV panel can lessen the amount of sunlight that is absorbed by the panel's solar cells. To add insult to injury (number eight), various electromagnetic and radio frequencies can impact the transmission module's accuracy. Thus, there is a need for shield-modules that are compatible with data transmission boards. The ninth problem is that the effectiveness of various solar cell methods varies substantially from one another and is extremely sensitive to the composition of the material from which the cells are made (e.g. mono-crystalline silicon, poly-crystalline silicon, amorphous silicon, thin-film copper indium disulfide, heterojunction incorporating thin film). As a result, picking the right solar cell technology is crucial for maximising output [8].

As solar photovoltaic (PV) systems grow in scale and area of use, future research should concentrate on improving data handling, boosting efficiency, increasing security, and expanding transmission range, and reducing signal interference. Specifically, you should avoid the nine issues we just went over. In reality, going forward, it will be necessary to create a trustworthy, cutting-edge method of monitoring wireless networks [8].

2.5 Application of Solar photovoltaic cell

Even though fossil fuels are still in high demand for automotive uses [9], photovoltaic systems have found their place in the market. A photovoltaic cell is a type of solar cell that generates electricity solely from the energy of incident light. A solar cell, also known as a photovoltaic cell, is a device that can convert light into electricity. Since PV cells may generate anywhere from a few kilowatts (KW) to enormous megawatts (MW), they have a much broader range of potential uses than traditional power plants. Only a select few will be explored briefly here:

1. It has been demonstrated that solar-powered water pumps are more effective in rural regions for the purpose of agricultural irrigation. Solar panels are used to generate electricity, which is then used to power a pump that moves water from a lower level to a higher level. One graphical representation of this idea is shown in the following figure for your perusal.

2. With regards to food preparation, solar cookers are currently all the rage. Solar cookers are readily available for purchase and use, with few maintenance requirements. The world's largest solar kitchen may be found at Taleti, which is located in the Indian state of Rajasthan at an elevation of 1219 m above sea level. It utilises solar steam cooking on six distinct modules and has 84 parabolic dish concentrators and shell-type receivers. Additionally, it has a total of 168 parabolic dishes [10].

3. Solar water and air heaters have been widely used for decades, long before PV cells were ever a possibility. The use of solar water heaters alone can significantly cut down on energy costs. These are effective in capturing the sun's rays, allowing us to use that heat to keep water at a comfortable temperature.

4. Solar panels are an easy way to power traffic lights in any location. The absence of shadows is the only real issue here.

5. Solar power can be utilised not only for conventional air conditioning systems but also for cold storage facilities. For these objectives, a vapour compressor system that makes use of solar photovoltaic panels and a vapour absorption system that makes use of thermal collectors are both viable options [11].

6. The Solar Photovoltaic (PV) System aboard the International Space Station Solar panels attached to the International Space Station provide an excess of electricity compared to what is needed to run the station [12]. The batteries of the space station are charged with around 60% of the power produced by the solar arrays when the station is exposed to sunlight. Solar panels on spacecraft offer power for two principal applications: [13] first, power to drive the sensors, active heating and cooling, and telemetry [14]. Solar panels on spacecraft also provide power for active heating and cooling [14]. Secondly, power for heating and cooling that is actively used. Then there is the power that is used for the propulsion of spacecraft, and that power is electric propulsion, which is also sometimes referred to as solar-electric propulsion. Solar panels made specifically for use in space are not the same as solar panels made specifically for use on Earth. They do not require any form of glass lamination, which means that they are resistant to moisture

even without it. The material that is used is distinct from other materials since it is required that the components be able to withstand high temperatures.

3. Conclusion

Damage to ecosystems and the natural equilibrium results from the use of fossil fuels. For the following reasons, solar energy may be the greatest long-term option: it is a huge and infinite energy source, its management has no negative effects on the environment, and it can be easily implemented in a variety of settings (from rural to urban to industrial). Thus, photovoltaic technology, which directly transforms sunshine into power, is incredibly practical. Especially considering how light and simple these gadgets are to operate. The photovoltaic system converts solar energy into usable electricity by activating electrons upon exposure to light. The PV-system has a long lifespan, functioning at 80% efficiency for 25 years and at 90% efficiency for 10 years. By allowing the PV panel's displacement to be adjusted in response to the sun's movement, efficiency can be increased. The PV system can be combined with both renewable (such as wind) and non-renewable (such as diesel) energy sources to provide reliable power. They are examples of what are known as hybrid systems. Although there are many positive aspects of solar energy production, there are also some disadvantages to consider. These include the upfront cost, the need for regular maintenance (which can have an environmental impact), and the challenge of raising consumer awareness. Nonetheless, we must be conscious of the fact that solving these issues is the path to environmental conservation around the world.

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Conflict of interest

The authors declare no conflict of interest.

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