بسم الله الرحمن الرحيم

كلية الدراسات العليا

Sudan University of Science and Technology

College of Graduate Studies

Department of Science – Physics

Reviewing Solar Radiation and its Applications in Solar Collectors and Solar Cells

دراسة الإشعاع الشمسي وتطبيقاته على المجمعات الشمسية و الخلايا الشمسية

A Thesis submitted in partial fulfillment of the Requirements for the M.Sc. degree in Physics

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الآيــــة

بسم الله الرحمن الرحيم

قال تعالى : (اللَّهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِنْ شَجَرَةٍ مُبَارَكَةٍ زَيْتُونَةٍ لَا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُورٌ عَلَىٰ نُورٍ يهْدِي اللَّهُ لِنُورِهِ مَنْ يَشَاءُ وَيَضْرِبُ اللَّهُ الْأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ)

صدق الله العظيم

سورة النور الآية 35

Dedication

In The Name of Allah praise be to Allah and peace and blessings be upon the Rasool Allah (may Allah bless him and grant him peace) and his parents :

Dedicate This Research to The :

Abi symbol of steadfastness and pride

To The

Ami symbol of patience and affection

To The

My Dear Brothers and Sisters

To The

Everyone taught me giving

To The

Everyone who takes a path seeks knowledge

To The

My Teacher At Sudan University of Science and Technology

Acknowledgements

Praise be to Allah whose grace is righteous Allah has bestowed me on the completion of this humble search and all thanks to him and his help, and thanks first and foremost to Allah Almighty who without whom he did not intend and thanks and gratitude but he who taught me a letter to enlighten my path and special appreciation and esteem my Teacher **Dr . Ahmed ELhassan ELFaki** who supervised this research in order to establish it to safety and extend my cordial thanks to the Families Of The Department Of Physics At The University Of Sudan .

I Also thanks **My Family** for all the reverence that you made for me thanks to you I understood the meaning of life . I also thank everyone who extended his hand to help me reach my destination , Allah is the one who helps and from whom is success .

Researcher ,,,

Abstract

The aim of the study is that solar radiation can be independent in solar collectors and solar cells to obtain thermal and electrical energy.

Solar collectors are devices that collect or concentrate solar radiation mainly used for heating and allow heating water for personal use.

Solar cells through which the sun's rays are directly converted into electricity by using semiconductors such as silicon and its energy is considered a form of renewable and clean energy because it does not result in polluted waste, no noise, radiation, and does not need fuel.

The demand for energy in the world is growing rapidly due to the population explosion and technological progress for that it is important for humanity to a reliable cost-effective and durable source of energy for the growing energy demand in the future and this is what this study concluded.

المستخلص

هدفت الدراسة الى انه يمكن استقلال الإشعاع الشمسي في المجمعات الشمسية والخلايا الشمسية للحصول على الطاقة الحرارية والكهربائية.
مجمعات الطاقة الشمسية هي أجهزة تجمع أو تركز الإشعاع الشمسي تستخدم بشكل أساسي للتدفئة وتسمح بتسخين المياه للاستخدام الشخصي.
الخلايا الشمسية من خلالها يتم تحويل أشعة الشمس مباشرة الى كهرباء عن طريق استخدام أشباه الموصلات مثل السيلكون وتعتبر طاقتها شكلاً من الطاقة المتجددة والنظيفة لأنه لا يسفر عن تشغيلها نفايات ملوثة ولا ضوضاء ولا إشعاعات ولا حتى تحتاج لوقود.
أصبح الطلب على الطاقة في العالم ينمو بسرعة بسبب الانفجار السكاني والتقدم التكنولوجي لذلك من المهم للبشرية أن تتوجه لمصدر طاقة يمكن الاعتماد عليه فعال من حيث التكلفة ومصدر دائم للطاقة المتجددة للطلب المتزايد على الطاقة في المستقبل وهذا ما خلصت اليه هذه الدراسة.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

The depletion of traditional energy sources and environmental pollution can disrupt the ecosystem, therefore increasing interest in solar radiation and the advantage that it does not have any effects or residues harmful to the environment, where solar radiation is converted to electrical energy either by thermal conversion or photoelectric conversion by semiconductors and solar cell is a conductive tool turning solar energy to electrical energy, so the interest was to study collectors solar and solar cells and what they do from the production of electric energy and strive to obtain the maximum efficiency of either that these reasons in the internal structure for solar cell or which are affected by the temperature [1].

1.2 Research Importance

The use of solar radiation in solar collectors and solar energy in the production of electric energy and reduce environmental pollution resulting from other sources of energy polluting the environment, and to seek the maximum possible efficiency of the solar cell.

1.3 Research Problem

Solar radiation application, including solar collectors, as well as from them the efficiency and ability of the solar cell is affected by many factors, whether these factors arise from the Crystal structure of the cell or external factors such as the amount of radiation, temperature, humidity and humidity, and in this research we study solar radiation and its applications in solar collectors and solar cells.

1.4 Research Aims

The research presents a study on solar radiation and its applications in solar collectors and solar cells.

1.5 Previous Studies

1- Study and design of grid connected solar photovoltaic system.
2- Type of solar cells and Application.

1.6 Methodology

It was found that the depletion of traditional energy sources and environmental pollution would disrupt the ecosystem and the economic system. Therefore solar energy is considered a renewable energy source and is a source for solving problems related to the energy crisis in the future.

Therefore in order to meet the energy demand there is a solar collector is a device that collects or concentrates solar radiation. It is generally placed on the surface, it must be very strong as it is exposed to a variety of different weather condition.

A solar cell is an electronic device that converts sunlight directly into electricity. Shining light on the solar cell produces both current and voltage to generate electrical energy. Solar cells are an important source to supply spacecraft and satellites with the energy they need.

1.7 Content

The research contains four chapters:

Chapter One: Introduction, Chapter Two: Solar Radiation, Chapter Three: Solar Collectors and Chapter Four: Solar cells.

CHAPTER TWO

SOLAR RADIATION

2.1 The Sun

It is main and central component of the solar system. It is the closest star to us, as it is not far away.

About us over 150 million km. it is the one that provides the planet with the heat and light necessary for the continuation of life in all its forms and forms. From humans to animals and plants. Added to this is its role in economic life, as it is the secret of natural plant growth, the success of agriculture, and the presence of kinetic energy in coal and oil, that energy which was reduced to its existence in plants and animals before being buried in the ground and fermented.

It is also the secret of the water cycle, which includes the whole world, because it is through it that the water turns into water vapor, and it soon becomes condensed into various forms, the most important of which is the rain and snow that result in the water necessary for the life of humans, animals and plants, in addition to the resulting flow of water.

Man used it as a motor power in which he managed the windmills, and from it generated the hydroelectric energy. Also, the difference in temperature on the surface of the earth from one place to another resulting from the difference of the inclination of sunlight falling on the surface of the earth results in differences in the amount of air pressure between one region and another Causing winds that move from the centers of heavy pressure to the centers of light pressure, can be used as a driving force of scientists are equivalent to the kinetic energy generated by burning " 1500 – 1700 " million tons of coal annually. This is in addition to what the modern science has provided us with the direct use of solar thermal energy by solar devices in the field of heating, cooking, seawater desalination, electric power generation, and the conduct of satellites, vehicles, space stations and in many other fields [2].

Finally, through scientists studying the interactions that take place in the sun and the enormous heat generated by those reactions, they came to know the secret behind all this, that it is nuclear energy [2].

The Sun is a massive natural nuclear furnace that radiates heat and light to extend to the solar system's planets and their dependencies, comets and asteroids, and that revolve in the sun's orbit are varying degrees of intensity and weakness, depending on the proximity of each of these objects to the sun or its distance from it.

2.2 Solar Radiation

The sun sometimes disappears behind the clouds at times of the day or is on the opposite side of the earth at night, but it is always there, and the fact that the sun is a flaming star in which many nuclear explosions take place continuously, it continues to spread energy to reach the Earth in the form solar radiation.

This radiation interacts with the earth in different forms starting with the atmosphere, where a portion of this radiation spreads in the atmosphere and dose not reach the Earth, a section that reaches in the form of heat contributes to heating and life on the surface of the earth, a section that spreads in the clouds and another that reaches the surface of the earth as energy, which is what matters Researchers in solar energy issues.

This radiation carries energy within an initial particle called a photon, which contributes to the process of generating electricity from solar PV cells. Solar radiation is the amount of solar radiation that falls on a given area and capable of generating electrical power. The earth affects only about a part of the two thousand million parts of the sun's rays, which is estimated at 130 megawatts per square meter of the sun's surface.

Precise measurement of solar radiation intensity is important for the design and implementation of solar energy projects. Before starting the projects, researchers seek to collect information about the state and value of solar radiation in the work area in order to successfully design the project and ensure good work for it during the future work period [4].

2.3 Sun's Radiation is Divided into Three Sections

2.3.1 Infrared

It is equivalent to 53% of the total sunlight a person cannot feel or see it the human eye cannot see most of the electromagnetic spectrum except for visible light but a person can feel its temperature, many scientists use infrared rays in various fields. Astronomers use it to study galaxies light years away from Earth.

2.3.2 Electromagnetic Radiation

It consists of visible light, Ultraviolet Rays, X-Rays, Gamma Rays, Infrared Rays and Radio Waves, all of which emit from the sun at the speed of light, at a speed of 300,000 kilometers per second interrupting the distance between the sun and the earth through 8 Minutes, and all of these types of light radiation make up 38% of all sunlight. As the color blue was the most dispersed color in the Earth's atmosphere, the color of the cover was blue. As for the Ultraviolet and Ultraviolet Rays, they constitute 9 of the total sunlight. The Ozone layer in the upper layers of the Earth's atmosphere absorbs most of the deadly violet and Ultraviolet Rays, and only a small amount of the living bodies needed for their growth and continuity of life to reach the Earth's surface.

2.3.3 Electrified Radiation

It consists of molecules that carry electrical charges, which are in the form of gaseous clouds that are charged with electricity. Scientists have estimated the amount of up to the surface of the earth from electromagnetic and infrared rays with one part of a million part of what the sun releases in the surrounding space from them, while the rest cools in that dark space between the sun and its planets [4].

2.4 Types of Solar Radiation

Solar radiation has three main types that are dealt with on a daily basis

2.4.1 Direct Radiation

It represents the direct radiation from the sun to the surface of the earth, and some call it Irradiance Direct Normal or abbreviation of DNI. DNI is the primary fuel for Concentrated Solar Power or abbreviation CSP.

It should be noted that this type of radiation is directly affected by any eyebrow located between our position on the ground and between the sun.

For example: If there are clouds between us and the sun, then direct solar radiation in this case would be zero.

2.4.2 Diffuse Radiation

This type of radiation is also from the sun, but it differs from its predecessor in that it reaches the Earth not directly from the sun, but it is reflected from other sources, where the sun's rays can reach some buildings or other sites on the earth, and then they are reflected on the clouds or any other object. Before you reach our site on Earth, some also call it the Diffuse Horizontal Irradiance or abbreviation DHI.

2.4.3 Global Radiation

As for total radiation, it is called Global Horizontal Irradiance or abbreviation GHI. It means the total solar radiation that has reached a certain point. This includes part of the Direct Solar Radiation " DNI " in addition to the Reflected Solar Radiation " DHI "

$$GHI = DHI + DNI \cdot \cos \varphi \quad [2.1]$$

Where φ is the angle of inclination of radiation from the surface of the Earth [4].

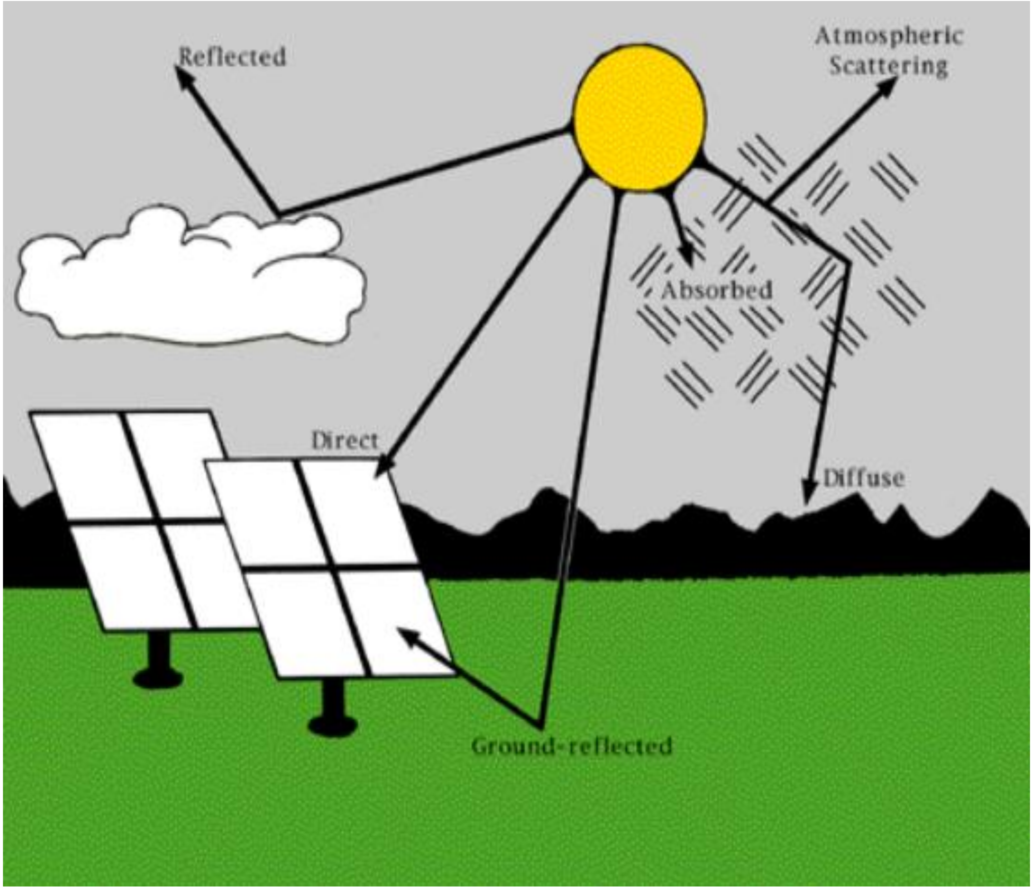


Fig (2.1) Shows Solar Radiation [8]

2.5 Angle of Solar Radiation and Temperature

The Angle of incoming solar radiation influences seasonal temperatures of locations at different latitudes. When the sun's rays strike Earth's surface near the equator, the incoming solar radiation is more direct " nearly perpendicular or closer to 90° angle ".

Therefore, the solar radiation is concentrated over a smaller surface area, causing warmer temperatures.

At higher latitudes, the angle of solar radiation is smaller, causing energy to be spread over a larger area of the surface and cooler temperatures. Because the angle of radiation varies depending on the latitude, surface temperatures on average are warmer at lower latitudes and cooler a higher latitudes " even though higher latitudes have move hours of daylight during the summer months " [4]

CHAPTER THREE

SOLAR COLLECTORS

3.1 Solar Collector

A solar collector is a device that collects or concentrates solar radiation from the sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use.

These collectors are generally mounted on the roof and must be very sturdy as they are exposed to a variety of different weather conditions.

The use of these solar collectors provides an alternative for traditional domestic water heating using a water heater, potentially reducing energy costs over time. As well as in domestic settings, a large number of these collectors can be combined in an array and used to generate electricity in solar thermal power plants.

A solar collector is basically a flat box and are composed of three main parts, a transparent cover, tubes which carry a coolant and an insulated back plate. The solar collector works on the greenhouse effect principle, solar radiation incident upon the transparent surface of the solar collector is transmitted through though this surface. The inside of the solar collector is usually evacuated, the energy contained within the solar collect is basically trapped and thus heats the coolant contained within the tubes. The tubes are usually made from copper, and the back plate is painted black to help absorb solar radiation. The solar collector is usually insulated to avoid heat losses [3].

3.2 Types of Solar Collectors

There are many different types of solar collectors, but all of them are constructed with the same basic premise in mind.

In general, there is some material that is used to collect and focus energy from the sun and use it to heat water. The simplest of these devices uses a back material surrounding pipes that water flows through. The black material absorbs the solar radiation very well, and as the material heats up the water it surrounds. This is a very simple design, but collectors can get very complex. Absorber pates can be used if a high temperature increase isn't necessary, but generally devices that use reflective materials to focus sunlight result in a greater temperature increase.

3.2.1 Flat Plate Collectors

These collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a dark colored absorber plate.

The sides and bottom of the collector are usually covered with insulation to minimize heat losses to other parts of the collector. Solar radiation passes through the absorber plate.

This plate heat up, transferring the heat to either water or air that is held between the glazing and absorber plate. Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint. These plates are usually made out of metal that is a good conductor, usually copper or aluminum.

3.2.2 Evacuated Tube Collectors

This type of solar collector uses a series of evacuated tubes to heat water for use. These tubes utilize a vacuum, or evacuated space, to capture the suns energy while minimizing the loss of heat to the surroundings.

They have an inner metal tube which acts as the absorber plate, which is connected to a heat pipe to carry the heat collected from the sun to the water. This heat pipe is essentially a pipe where the fluid contents are under a very particular pressure.

At this pressure, the hot end of the pipe has boiling liquid in it while the cold end has condensing vapor. This allows for thermal energy to move more efficiently from one end of the pipe to the other. Once the heat from the sun moves from the hot end of the heat pipe to the condensing end, the thermal energy is transported into the water being heated for use.

3.2.3 Line Focus Collectors

These collectors sometimes known as parabolic troughs, use highly reflective materials to collect and concentrate the heat energy from solar radiation [3].

These collectors are composed of parabolic shaped reflective sections connected into a long trough. A pipe that carries water is placed in the center of this trough so that sunlight collected by the reflective material is focused onto the pipe, heating the contents.

These are very high powered collectors and are thus generally used to generate steam for Solar Thermal Power Plates and are not used in residential applications. These troughs can be extremely effective in generating heat from the sun, particularly those that can pivot, tracking the sun in the sky to ensure maximum sunlight collection.

3.2.4 Point Focus Collectors

These collectors are large parabolic dishes composed of some reflective material that focus the sun's energy onto a single point. The heat from these collectors is generally used for driving Stirring engines.

Although very effective at collecting sunlight, they must actively track the sun across the sky to be of any value. These dishes can work alone or be combined into an array to gather even more energy from the sun.

Point focus collectors and similar apparatuses can also be utilized to concentrate solar energy for use with Concentrated Photovoltaic. In this case, instead of producing heat, the sun's energy is converted directly into electricity with high efficiency Photovoltaic cells designed specifically to harness concentrated solar energy [3].

CHAPTRE FOUR

SOLAR CELLS

4.1 Solar Cell

Photovoltaics known as solar cells or photovoltaic cells through which the sun's rays are converted directly to electricity by using semiconductors such as silicon that is extracted from pure sand.

In generally the materials of these cells are either a thick crystalline material such as crystalline silicon or a thin crystalline material such as amorphous silicon or precipitated material as layers on slices of semiconductors consisting of gallium arsenide.

Its energies are considered a form of renewable and clean energy, because it does not result in the operation of polluted waste no noise no radiation nor even needs fuel. But its starting cost is high compared to other energy sources.

Solar cells generate constant and direct electricity (as in normal dry and liquid batteries).

A solar , photovoltaic , or photovoltaic cell , and it was called a solar battery in the early days of its manufacture , but now that has a completely different meaning now , a device that converts solar energy directly into electrical energy using the photovoltaic effect , and it consists of a silicon layer that has some impurities to give it some electrical properties , so the layer the upper side facing the sun is added to the element phosphorus to give it the property of pumping photons when the photon hits it . This layer is called the N layer, while the boron element is added to the lower layer and gives it the property of absorbing photons This layer is called P, when the solar photocell is collided whit in the upper layer, photons give energy that depends on the intensity of the solar radiation, and when there is an electrical conductor between the two layer, the photons travel from the upper layer to the lower layer and thus an electric current and voltage are formed.

The solar cell is an important source for providing the spacecraft and satellites with the electrical energy they need, and they are considered alternatives help for conventional energy sources from petroleum, coal, gas and its derivatives that are limited in nature and depleted due to massive depletion of them.

Solar cells convert solar energy directly into electricity and are characterized by producing electricity without leading to environmental pollution of, aged up to 30 virtual years, the high cost of production is the main obstacle to use.

The intensity of its current depends on the time of the sun's brightness and the intensity of the sun's rays, as well as on the efficiency of the photovoltaic cell itself in converting solar energy into electrical energy. These solar cells can give hundreds of volts of DC voltage if you connect these cells, respectively. The resulting energy can also be stored in lead or base acid batteries made of nickel and cadmium. DC can be converted to AC by invertor for use and management of ordinary household and industrial electrical appliances.

Its advantage is that it has no moving parts that are damaged. for this it works on satellites with high efficiency, especially as it does not need maintenance, repairs or fuel, as it works in silence, except that the dirty photovoltaic cells as a result of pollution or dust leads to a decrease in their efficiency, which requires cleaning at intervals [5].

4.2 Solar Photovoltaic Technology

Photovoltaic offer consumers the ability to generate electricity in a clean, quiet and reliable way. photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from photo meaning light and voltaic which refers to producing electricity. Therefore, the photovoltaic process producing electricity directly from sunlight. photovoltaic are often referred to as PV [6].

4.3 Photovoltaic Cell

A device that produces an electric reaction to light. PV cells do not use the sun's heat to produce electricity. They produce electricity directly when sunlight interacts with semiconductor materials in the PV cells.

Fig (4.1) Shows Photovoltaic Cell [8]

4.4 Basic Theory of Photovoltaic Cell

Photovoltaic cells are made of silicon, and use two types of semiconductors, one P- type and other is N-type to generate electricity.

When sunlight strikes a semiconductors, it generate pairs of electrons (-) and protons (+) [6].

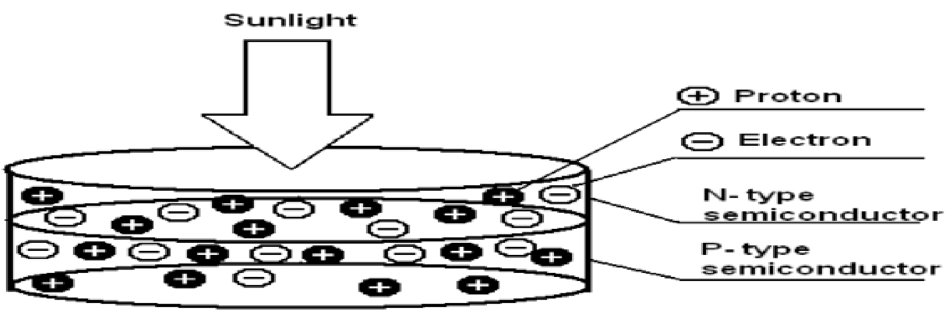


Fig (4.2) Shows Basic Theory of Photovoltaic Cell 1[9]

When an electron (-) and a proton (+) reach the joint surface between the two types of semiconductor, the former is attracted to N-type and the latter to the P-type semiconductor. Since the joint surface supports only one way traffic, they are not able to rejoin once they are drawn apart and separated.

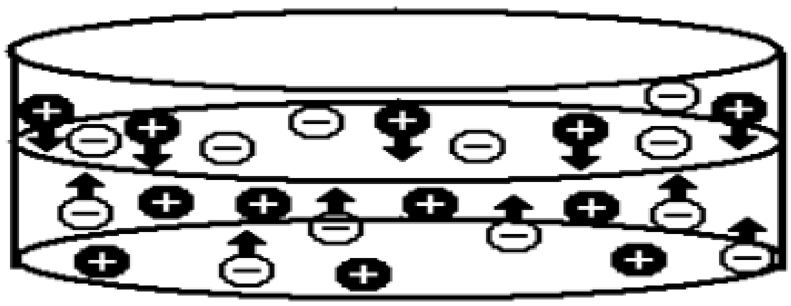


Fig (4.3) Shows Basic Theory of Photovoltaic Cell 2 [9]

Since the N-type semiconductor now contains an electron (-), and P-type semiconductor contains a proton (+), an electromotive (voltage) force is generated . Connect both electrodes with conductors and the electrons run from N-type to P-type semiconductors, and the proton from P-type to N-type semiconductors to make an electrical current [6].

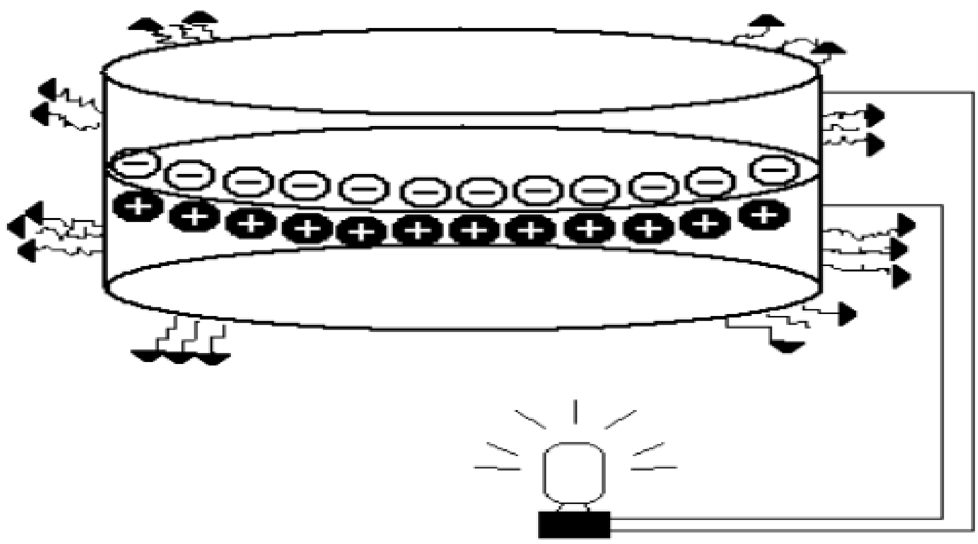
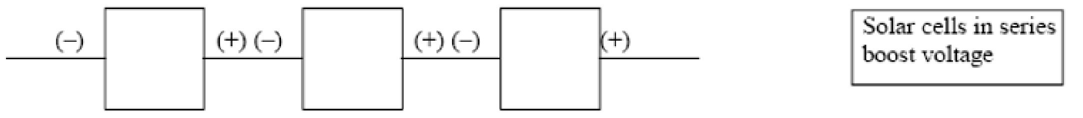


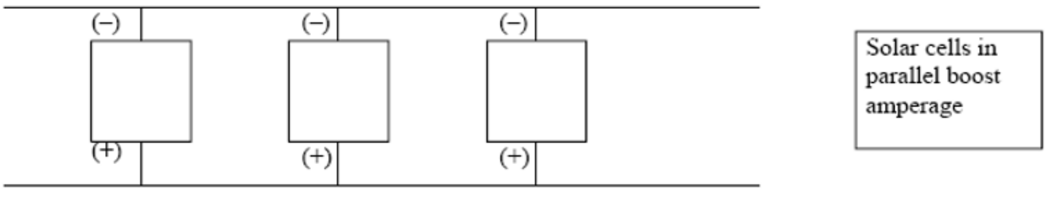
Fig (4.4) Shows Basic Theory of Photovoltaic Cell 3 [9]

4.5 Series and Parallel Connection of PV Cell

Solar cells can be thought of as solar batteries. If solar cells are connected in series, then the current stays the same and the voltage increases.



If solar cells are connected in parallel, the voltage stays the same, but the current increases.



As known those solar cells are combined to from a " module " to obtain the voltage and current and therefore power desired [6].

4.6 Types of Photovoltaic Cells

Solar cells are typically named after the semiconducting material they are made of. These materials must have certain characteristics in order to absorb sunlight. Some cells are designed to handle sunlight that reaches the Earth`s surface while others are optimized for use in space. Solar cells can be made of only one single layer of light-absorbing material single-junction or use multiple physical configurations multi-junction to take advantage of various absorption and charge separation mechanisms. Solar cells can be classified into first, second and third generation cells.

The first generation cells also called conventional, traditional or wafer-based cells are made of crystalline silicon, the commercially predominant PV technology, that includes materials such as polysilicon and monocrystalline silicon.

Second generation cells are thin film solar cells, that include amorphous silicon, and are commercially significant in utility scale photovoltaic power stations, building integrated photovoltaics or in small standalone power system.

The third generation of solar cells includes a number of thin film technologies often described as emerging photovoltaics most of them have not yet been commercially applied and are still in the research or development phase.

Many use organic materials, often organometallic compounds as well as inorganic substances. Despite the fact that their efficiencies had been low and the stability of the absorber material was often too short for commercial applications, there is a lot of research invested into these technologies as they promise to achieve the goal of producing low cost, high efficient solar cells.

First generation panels include silicon solar cells. They are made from a single silicon crystal mono-crystalline or cut from a block of silicon that is made up of many crystals multi-crystalline shown at right.

Second generation thin film solar cells are less expensive to produce than traditional silicon solar cells as they require a decreased amount of materials for construction. The thin film PV cells are just as the name implies to physically thin technology that has been applied to photovoltaic. They are only slightly less efficient than other types but do require more surface to generate the same amount of power [7]

The following are the different types of solar cells, some of which was mentioned.

4.6.1 Monocrystalline Solar Cell " Mono-Si "

Monocrystalline silicon or single crystal silicon Si, Mono-Si or just Mono-Si is the base material for silicon chips used in virtually all electronic equipment today.

Mono-Si also serves as photovoltaic, light-absorbing material in the manufacture of solar cells. It consists of silicon in which the crystal lattice of the entire solid is continuous, unbroken to its edges, and free of any grain boundaries. Mono-Si can be prepared intrinsic, consisting only of exceedingly pure silicon, or doped, consisting very small quantities of other elements added to change its semiconducting properties. Most silicon mono crystals are grown by the Gzochralski process into ingots of up to 2 meters in length and weighing several hundred kilogram. These cylinder are then sliced into thin wafers of a few hundred microns for further processing.

Single crystal silicon is perhaps the most important technological material of the last few decades the silicon era. Because its availability at an affordable cost has been essential for the development of the electronic devices on which the present day electronic and information revolution is based. Monocrystalline silicon differs from other allotropic forms, such as the non-crystalline amorphous silicon used in thin-film solar cells, and polycrystalline silicon, that consists of small crystals, also known as crystallites. Extraction from these photons. The lowest band gap of a MJ cell will be lower than of a typical SJ band gap. Therefore, the MJ cell can absorb extra photons that possess less energy than the SJ band gap but greater than its own lowest band gap. The MJ cell will absorb the same photons more efficiently since having band gaps closer to the photon energy will reduce the lizard losses [7].

4.6.2 Polycrystalline Solar Cell " Multi-Si "

Polycrystalline silicon also called polysilicon or Poly-Si, is a high purity, polycrystalline from of silicon, used as a raw material by the solar photovoltaic and electronics industry.

Polycrystalline is produced from metallurgical grade silicon by a chemical purification process, called sienna process. The process involves distillation of volatile silicon compounds, and their decomposition into silicon at high temperatures. An emerging alternative process of refinement uses a fluidized bed reactor.

The photovoltaic industry also produces upgraded metallurgical grade silicon using metallurgical instead of chemical purification processes. When produced for the electronics industry, polysilicon contains impurity levels of less than one part per billion, while polycrystalline solar grade silicon is generally less pure.

The polysilicon feedstock, large rods, usually broken into chunks of specific sizes and packaged in clean rooms before shipment, is directly cast into multi crystalline ingots or submitted to a recrystallization process to grow single crystalline boules. The products are then sliced into thin silicon wafers and used for the production of solar cells, integrated circuits and other semiconductor devices. polysilicon consists of small crystals, also known as crystallites, giving the material its typical metal flake effect. While polysilicon and multi silicon are often used as synonyms, multi crystalline usually refers to crystalline larger than 1 mm. Multi crystalline solar cells are the most common type of solar cells in the fast growing PV market and consume most of the worldwide produced polysilicon. About 5 tons of polysilicon is required to manufacture 1 megawatt of conventional solar modules. Polysilicon is distinct from monocrystalline silicon and amorphous silicon [7].

4.6.3 Amorphous Silicon Solar Cell " A-Si "

Amorphous silicon A-Si is the non-crystalline from of silicon. It is the most well develop of the thin film technologies having been on the market for more than 15 years.

It is the widely used in pocket calculators, but it also powers some private home, building and remote facilities. United solar systems Corp pioneered amorphous silicon solar cells and remains a major maker today, as dose Sharp and Sanyo. Amorphous silicon panels are formed by vapor depositing a thin layer of silicon material about 1 micrometer thick on a substrate material such as glass or metal. Amorphous silicon can also be deposited at very low temperatures, as low as 75 degrees Celsius, which allows for deposition on plastic as well. In its simplest from, the cell structure has a single sequence of layers. However, single layer cells suffer from significant degradation in their power output (in the range 15-35%) when exposed to the sun. The mechanism of degradation is called the Staebler-Wronski Effect, after its discoverers. Better stability requires the use of a thinner layers in order to increase the electric field strength across the material. However, this reduces light absorption, hence cell efficiency.

This has led the industry to develop tandem and even triple layer devices that contain cells stacked one on top of the other. One of the pioneer of developing solar cells using amorphous silicon is Uni-Solar. They use a triple layer system that is optimized to capture light from the full solar spectrum. As you can see from the illustration, the thickness of the solar cell is just 1 micron, or about 1/300 the size of mono-crystalline silicon solar cell. While crystalline silicon achieves a yield of about 18 percent, amorphous solar cells yield remains at around 7 percent. The low efficiency rate is partly due to the Staebler-Wronski effect, which manifests itself in the first hours when the panels are exposed to sunlight, and results in a decrease in the energy yield of an amorphous silicon panel from 10 percent to around 7 percent. The principal advantage of amorphous silicon solar cells is their lower manufacturing costs, which makes these cells very cost competitive [7].

4.7 Photovoltaic Module

PV cells are the basic building blocks of PV modules. For almost all applications, the one-half volt produced by a single cell is inadequate. Therefor cells are connected together in series to increase the voltage. Several of these series string of cells may be connected together in parallel to increase the current as well.

These interconnected cells and their electrical connection are then sandwiched between a top layer of glass or clear plastic and lower level of plastic or plastic and metal. An outer frame is attached to increase mechanical strength and to provide a way to mount the unit. This package is called a module or panel. Typically, a module is the basic building block of photovoltaic systems. PV module consist of PV cells connected in series to increase the voltage and in parallel to increase the current, so that the output of a PV system can match the requirements of the load to be powered. The PV cells in a module can be wired to any desired voltage and current.

The amount of current produced is directly proportional to the cells size, conversion efficiency, and the intensity of light. Groups of 36 series connected PV cells are packaged together into standard modules that provide a nominal 12 volt or 18 volt peak power. PV modules were originally configured in this manner to charge 12 volt batteries [8].

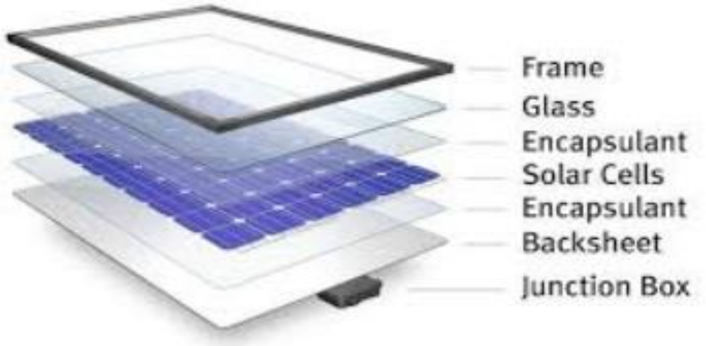


Fig (4.5) Shows Photovoltaic Module [8]

4.8 Photovoltaic Array

Desired power voltage and current can be obtained by connecting individual PV modules in series and parallel combinations in much the same way as batteries. When modules are fixed together in a single mount they are called a panel and when two or more panels are used together, they are called an array. Single panels are also called arrays, when circuits are wired in series positive to negative. The voltage of each panel is added together but the amperage remains the same. When circuits are wired in parallel " positive to positive, negative to negative " the voltage of each panel remains the same and the amperage of each panel is added. This wiring principle is used to build photovoltaic modules. Photovoltaic module can then be wired together to create PV arrays [8].

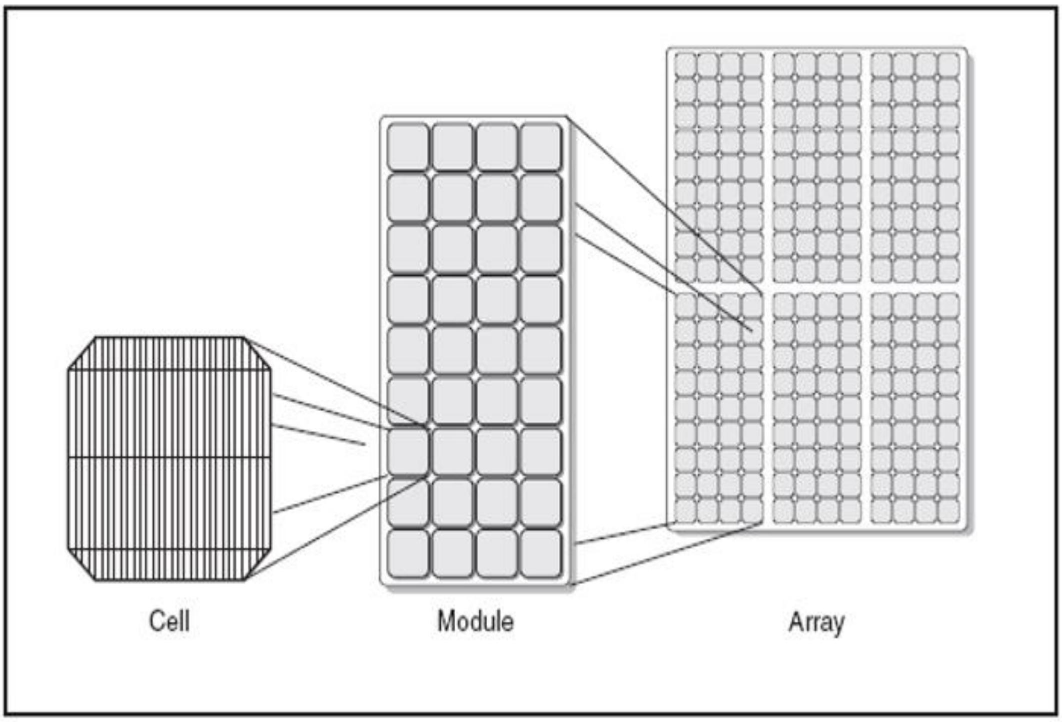


Fig (4.6) Shows Photovoltaic Array [9]

4.9 Components for Solar Panel System

Solar electric system is a popular choice among renewable energy options due to the relatively low maintenance requirements and the long lifetime of many of the system components.

Because there are no moving parts, and thus little chance of mechanical failure, most solar electric systems will continue to produce power for 30 years or more.

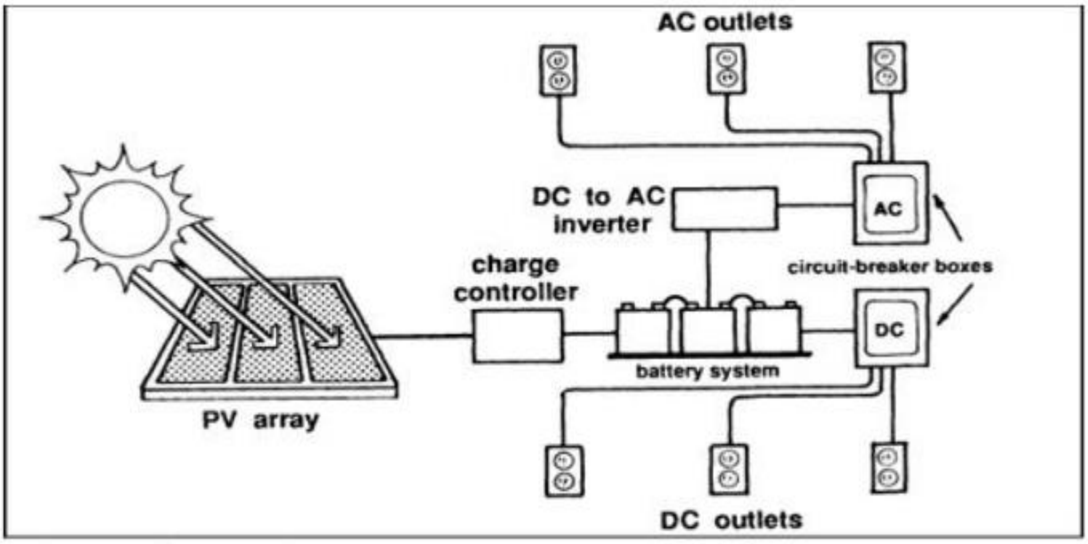


Fig (4.7) Shows Components for Solar Panel System [9]

4.10 Solar PV System

PV modules are known as solar panels or solar electric panels.

Solar panels provide electricity from sunlight, they are typically made of silicon crystal slices called cells. Glass a polymer backing and aluminum framing.

Solar panels can vary in type size shape, and color. In most cases the size of a PV module refers to the panels rated output wattage or electricity generating potential [8].

Solar panels also have voltage ratings, those with of 12 or 24 volts are generally preferred for off-grids system with battery banks.

Other solar panels come in less common nominal voltages such as 18, 42 and even 60 volts.

Those modules are typically used in grid-tied application to accommodate the working of grid-tied inverters.

Solar panels can be used alone or combined into arrays by wiring them in or into achieve the needed.

Mounting systems include hardware to permanently affix the array to either a roof, a pole or the ground. These systems are typically made of aluminum and are selected based on the specific model and number of modules in the array as well as the desired physical configuration.

Solar panels work best at cooler temperatures, and proper mounting allows for cooling airflow around the modules.

For locations wind loading is an installation factor, and it is extremely important to design and pour the cement foundation properly for any pole mount, are a pole mount option to increase energy production by moving the array to face it into the sunlight as the sun moves across the sky.

A solar array on a tacker will produce more energy than a fixed array. Trackers are often used in water pumping applications. The cost of tacker can be significant, and due to the possibility of breakdown, they are best recommended to the mechanically inclined. The cost of a mounting system varies based on the number of modules and type of mount.

In PV system terminology everything besides the PV modules themselves is called " **balance of system** " or **BOS**. We`ll go over the main BOS components below, one at a time in the direction of electricity flow through a typical system [8].

4.10.1 Solar Charge Controllers

Energy solar electric system with batteries should have a solar charge controller. A charge controller regulates the amount of current the PV modules feed into a battery bank. Their main function is to prevent over charging of the batteries, but charge controllers also block battery bank current from leaking back into the photovoltaic array at night or on cloudy days, draining the battery bank.

4.10.2 Batteries for Solar Electric Systems

Batteries chemically store electrical energy in renewable energy systems. They come in several voltages, but the most common varieties are 6 volt and 12 volt. The three types of batteries that are most common to RE systems are

- Flooded lead-Acid Batteries " FLA ".
- Sealed Absorbed Glass Mat Batteries " AGM ".
- Sealed Gel Cell Batteries.

Flooded Lead-acid batteries are the most cost-effective variety.

The require maintenance that involves monitoring voltage, adding water and occasional. Additionally FLA batteries vent hydrogen under heavy charging so they must be stored in a ventilated enclosure.

Because of the maintenance issues of FLAs, some people prefer sealed batteries, which don`t require maintenance, since they are sealed they do not require watering, nor do they typically vent any gasses.

AGM batteries cost more and are more sensitive to over charging that FLAs.

Gel cell batteries are similar to AGMs in that they are also sealed and therefore do not require maintenance, but tend to be the most expensive of the three types [8].

The useful life of all battery types is measured in rather than units of time. Is directly you drain batteries to number of charge cycles possible the deeper you drain batteries each time you use them, the fewer charge cycles you will get from them. Sealed batteries tend not to last as long as flooded batteries. Well-maintained FLAs can last as long as ten years, with sealed batteries lasting closer to five years.

Other factors to keep in mind are that some of these batteries weigh over 200 pounds and depending upon capacity, can cost anywhere from 820 to $ 1200 each.

So given the maintenance issues, weight and expense, consider your energy storage needs very carefully.

Planning for five days of battery storage for your system may not be your best option.

4.10.3 Solar Inverters

An inverter takes DC from batteries and turns it into AC which is used to run most common electrical loads. There are two main closes of inverters, or grid capable and standalone units. Off-grid inverters require batteries for storage, straight grid-tied inverters don`t use batteries and grid capable inverters can work either with or without batteries depending on system design, There is a wide range of available inverter features suited to differing system needs and situations. Some inverters have integrated AC chargers so that they can use AC power from the grid to charge the batteries during periods of low sun.

Inverters with integrated AC charges can also be used in conjunction with fossil fuel based generators for battery charging or running very large loads. Off grid inverters meant for whole home usage must have appropriate conduit boxes and accessories that enclose all live wiring. Usually whole home inverters are rated to produce 2000 watts continuous power or more.

Off grid inverters come in tow flavor : those producing current and those producing current. Some appliances " compressors or other inductive loads " and many sensitive electronics (cordless battery chargers, computers, stereos, etc) will not function properly on modified sine wave power [8].

A straight grid-tied inverter connects directly to the utility grid without the use of batteries. With these inverters, when the grid goes down the PV system also goes down to protect service linemen from injury due to unexpected live lines during outages. A grid capable inverter can both connect to the grid and use batteries, which allows for the possibility of backup power during outages. Grid connected inverters also generally produce 2000 watts or more [9].

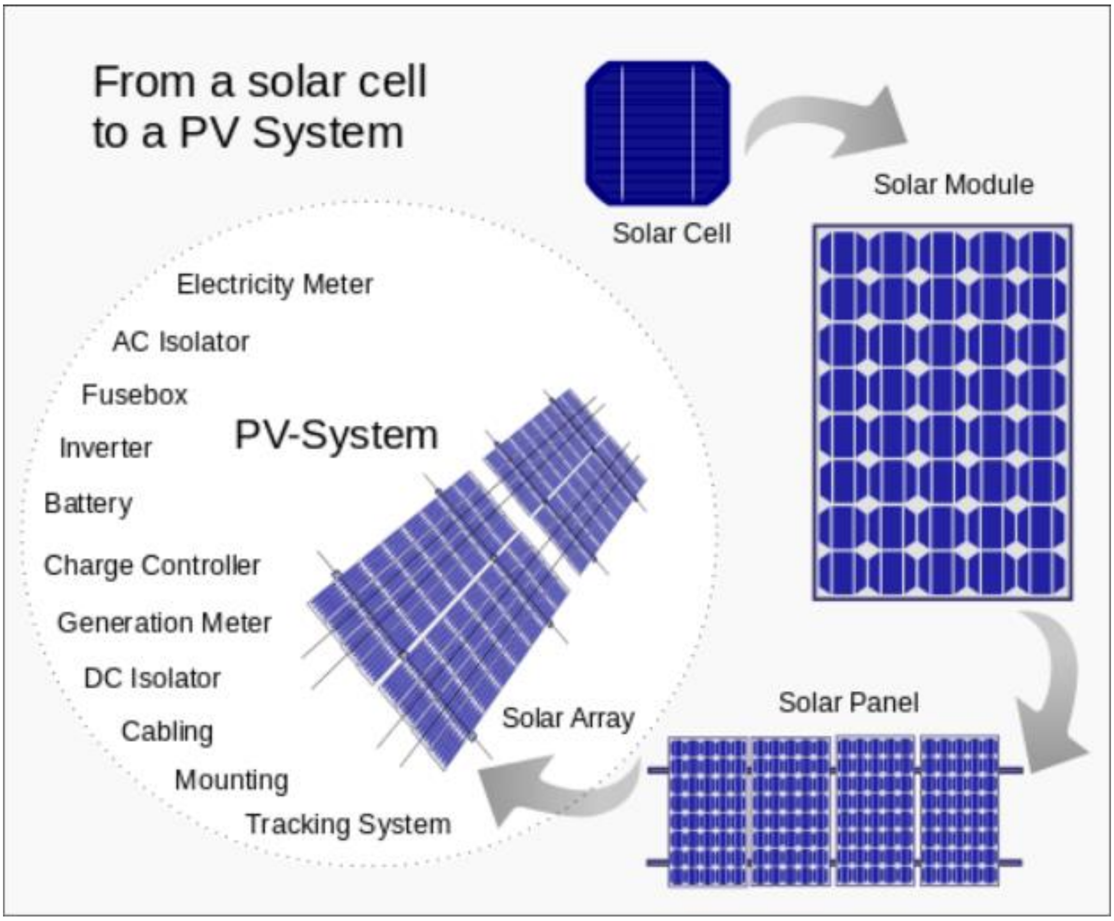


Fig (4.8) Shows From A Solar cell To a PV System [9]

4.11 Conclusion

People was dazzled since ancient times by the sun and its large and continuous energy. It was the subject of concern and the independence of the energy resulting from it. People are always searching for new sources of energy to cover their growing needs in the applications of advanced life.

The study concluded that solar radiation can be independent in solar collectors and solar cells to obtain Thermal and Electrical Energy.

4.12 Recommendations

1- Conducting a study on the properties of the cell and its dependence on the radiation intensity.
2- Study of dye solar cells.
3- Study solar cells to generate kinetic energy in electric cars.
4- Conducting a study on the economics and policies of renewable energy.

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