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M.Sc. Thesis in Engineering PhysicS

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GAZIANTEP UNIVERSITY

GRADUATE SCHOOL OF

NATURAL & APPLIED SCIENCES

EFFECT OF TEMPERATURE ON PHOTOVOLTAIC PANEL EFFICIENCY

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ENGINEERING PHYSICS

BY

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Effect of Temperature on Photovoltaic Panels Efficiency

M.Sc. Thesis

in

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Supervisor

Prof. Dr. Zihni ÖZTÜRK

by

Adem DURDAĞI

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Adem DURDAĞI

ABSTRACT

EFFECT OF TEMPERATURE ON PHOTOVOLTAIC PANELS EFFICIENCY

DURDAĞI, Adem

M. Sc. in Engineering Physics

Supervisor: Prof. Dr. Zihni ÖZTÜRK

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Today, the needs of societies are mostly provided by technology and the new generation technology has entered every part of our lives. New generation technology has created a high level of energy requirement. Many energy sources have started to be depleted rapidly and today's society has turned to search for renewable energy sources. The sun is the basis of all energy sources, and many solar energy systems especially photovoltaic panels have been developed. Photovoltaic panels are the system that converts light from the sun into direct electrical energy. In the photovoltaic panel system, there is a high amount of energy losses during the conversion of the incoming light to electricity. In this study, the negative effect of temperature on photovoltaic panels was investigated and in order to eliminate this effect, behind the panel was applied with water cooling method. Power comparison is carried out between normal solar panel and water cooled solar panel. It was shown that the output power in the water-cooled system is higher than the normal panel.

Key word : Photovoltaics, Cell Efficiency, Solar system, Cell temperature

ÖZET

SICAKLIĞIN FOTOVOLTAİK PANEL VERİMİNE ETKİSİ

DURDAĞI, Adem

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Tez Yöneticisi: Prof. Dr. Zihni ÖZTÜRK

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40 sayfa

Günümüzde toplumların ihtiyaçları çoğunluklu olarak teknoloji ile sağlanmaktadır ve yeni nesil teknoloji hayatımızın her alanına girmiştir. Yeni nesil teknoloji beraberinde yüksek seviyede enerji ihtiyacı oluşturmuştur. Birçok enerji kaynağı hızla tükenmeye başlamış ve günümüz toplumu yenilenebilir enerji kaynaklarına yönelmiştir. Güneş tüm enerji kaynaklarının temelidir ve buna bağlı olarak başta fotovoltaik paneller olmak üzere pek çok solar enerji sistemleri geliştirilmiştir. Fotovoltaik paneller güneşten gelen ışığı direkt elektrik enerjisine dönüştüren sistemdir. Fotovoltaik panel sisteminde gelen ışığın elektriğe dönüşmesi sırasında yüksek miktarda enerji kayıplarda mevcuttur. Bu araştırma çalışmada, sıcaklığın fotovoltaik panellerde negatif etkisini incelemiştir ve bu etkiyi ortadan kaldırmak için panel arkası, su ile sogutma yöntemi uygulanmıştır. Normal güneş paneli ile su soğutmalı güneş paneli arasında güç karşılaştırması yapılmıştır. Su soğutmalı sistemdeki çıkış gücü normal panele göre daha yüksek olduğu gözlemlenmiştir.

Anahtar Kelimeler : Fotovoltaikler, Hücre verimi, Güneş sistemi, Hücre sıcaklığı

To my precious family

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LIST OF SYMBOLS/ABBREVIATIONS

K	Kelvin
^oC	Celsius
W	Watt
km	Kilometer
kcal	Kilocalories
EVA	Ethylene Vinyl Acetate
uυ	Ultraviolet
EP	Energy of Photon
I_o	Cell saturation current
I_s	Current generated by light
I_L	Battery output current
q^v	Electronic load
k_B	Boltzmann constant
T	Temperature
V_{oc}	Open-civcuit voltage
I_{sc}	Short-circuit current
FF	Fill Factor
V_{mp}	Voltage at maximum power
I_{mp}	Current at maximum power
P_{output}	Output power
STC	Standart Test Conditions

PV	Photovoltaic
PID	Potential Induced Degredation
TCO	Transparent Conductive Oxide
HIT	Heterojunction with Intrinsic Thin layer
IBC	Interdigitated Back Contact
STC	Standard Test Conditions
AM	Air Mass

CHAPTER 1

INTRODUCTION

Today, the search for new resources due to the rapid depletion of fossil energy sources has made it compulsory to investigate renewable energy sources. Solar energy is also considered as an alternative. Solar cells are produced from semiconductors that are similar to the materials used in the processors of computers. Solar cells are not systems that generate electricity by means of a generator they use solar radiation for generating electricity without using any other process. This procedure will be explained in more detail later however, it is only when photons are struck by the material in the solar cell and the electrons that are weakly attached to the material break away from their orbit and generate an electric current. [7,9]

Becquerel found the Photovoltaic event in 1839 by observing that the voltage between the electrodes immersed in the electrolyte was dependent on the light falling on the electrolyte. In solid bodies, a similar event was first shown in 1876 on the selenium crystals by G. W. Adams and R. E. Day. In 1914, the efficiency of photovoltaic cells increased to 1%, but the photovoltaic cells that actually transformed solar energy with 6% efficiency into electrical energy were first carried out on a silicon crystal in 1954. In the following years, which were accepted as the turning point for photovoltaic power systems, researches and initial designs were made for the power systems to be used in space vehicles. Photovoltaic power systems have been a reliable source of space work since the beginning of the 1960s. [9]

In the United States, Europe, Japan in the years following the 1973 Petroleum Crisis, large-scale and comprehensive research and development projects were initiated. The work for the use of solar cells as an electrical power system has also started in the 1954s. Efforts to increase the efficiency of solar cells based on proven silicon crystal in space studies and on the other hand, studies on thin-film solar cells have been accelerated, which require much less semiconductor material, which is an alternative, and which can therefore be produced cheaper.

The research and development of the production of electricity from solar energy has been a task of the universities. In the last two decades, however, the pressure of the public sector with increasing environmental awareness has forced multinational large companies to work on non-fossil-based and renewable energy sources. With the introduction of large companies technological advances in photovoltaic batteries and increasing demand for power systems and consequently growing production capacity also led to a rapid decline in costs. Photovoltaic power systems which are considered to be very expensive when compared to the previous generation of electrical energy production methods is now considered as systems that can contribute to power generation in the near future. Considering the ve social cost ”which cannot be taken into account in the production of electrical energy and which can be considered as invisible cost, photovoltaic systems can be evaluated more economically than fossil based systems. [7]

The adventure of generating electricity from solar energy began in 1873 when Willougby Smith produced a simple solar cell. In 1877, W. G. Adams and R. E. Day continued this work. In 1883, Charless Fritts produced a solar cell using selenium and produced a 1% yield. By the 1900s, the yields of the cells are around 9% and nowadays the yields of the cells are around 12-18% respectively. In the studies, 11 different cell production materials have been used and the efficiency of solar cell is increased. The yields of some cells, such as monocrystalline, polycrystalline and thin film, range from 12 to 18% as we have noted above, but the efficiency in the next generation of cell production increases. For example, the efficiency of semiconductors which generated by the III and V group elements reaches 27%. These studies are the internal factors that directly affect the panel yields. [8] Apart from these, there are also factors that indirectly affect the efficiency of the panel. Panel temperature is the leading factor. The aim of this study is to examine the effect of temperature on panel efficiency. As a result of experimental studies, the effect of temperature difference between panels on panel efficiency will be examined and what is needed to minimize the yield reduction will be discussed.

1.1 Sun

The sun is a celestial body composed of hot gases, which is the energy source of our world. It is one of the 1014 (one hundred trillion) stars in the Milky Way galaxy. It is an average of 150 million km away from the world and its diameter is 1.39 million km. The diameter of the world is 12,700 km. The temperature in the center is estimated to be 8 - 40 billion and the surface temperature of the sun is about 6000 K. Due to the high temperature in the center every second, 646 tons He occur from 650 tons H_2. The difference refers to the lost mass and this mass is converted to energy. The event is a fusion reaction. Solar energy is the energy released by the fusion process in the sun's core. It sends 175 billion MW of radiation from its surface. The annual average value of solar energy from the sun to the Earth's atmosphere is 1367 W / m² (= 1175 kcal / hm²). The amount of radiation reaching the earth is 20.000 times the energy requirement of humanity.

1.1.1 Sun Spectrum

Solar radiation diffuses at different wavelengths. The sequential appearance of these emitted wavelengths is also called the solar spectrum. To be fully stated; Emitted from the sun and total of all electromagnetic radiation in known different wavelengths is called the Electromagnetic Solar Spectrum. In this spectrum, solar radiation is ordered according to wavelengths and is expressed by the following basic groups. These;

- Gamma Ray
- X-rays
- Ultraviolet Light
- Visible Light
- Infrared Light
- Radio Waves.

As shown in the figure below, the wavelength limits of each beam may overlap with the next. There is an overlap in borders. For this reason, the boundaries are not clear with certain lines. The interactions of the different rays in the overlap areas with the substance are the same. [4]

Note: 1 nm = 10^{-9} meters.

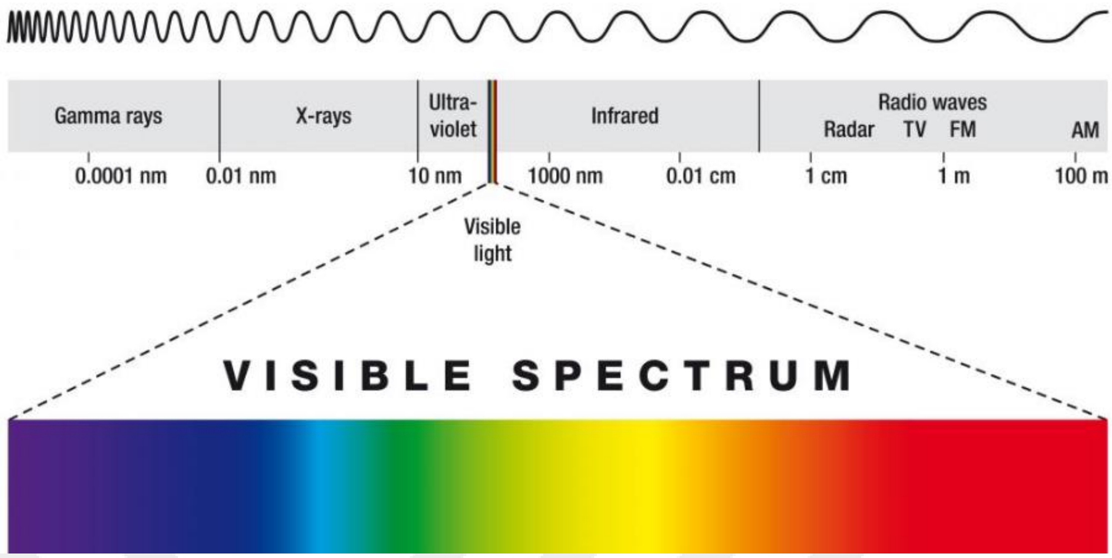

Figure 1.1 Sun Spectrum

Some of the main groups of the solar spectrum given above are also divided into subgroups. Although all electromagnetic waves are similar, they exhibit different characteristics in terms of their interaction due to the way they exist and the differences in their relationships with substances. According to the wavelengths, the energy of the light is too small, too large or between two different wavelength lights. The sequence of these electromagnetic radiation energies according to their size is called the electromagnetic spectrum. [4] Of course, there are certain frequencies and wavelengths for these energy photons (energy packs). Thus, we can consider the electromagnetic spectrum as an energy series, wavelength series or frequency series.

1.1.2 Propertios of Sun light

Solar energy is a superior energy source in many ways. The first of these advantages; This is a clean and ecological resource. Avoids air pollution, thus reducing the greenhouse effect. It works quietly and does not create noise pollution. Another feature is that it is domestic and renewable. It is economical. Unlimited and long-term use is possible. [3] Operating cost is low. There is no fuel cost. Provides a common employment opportunity. Contributes to the independence of the country in the energy sector. Finally, it can be used connected to the network and independently of the network. [1]

25% of the sun's rays are reflected back into space by multiplying the atmosphere and clouds. 25% of the light undergoes diffusion in the atmosphere. It allows the atmosphere to appear blue and shade places are illuminated. 9% of these rays are reflected back into space and 16% indirectly heats the place. 15% is absorbed by the atmosphere and clouds (absorption). When 8% hit the ground, it was reflected into space. 27% directly reach the ground and heats the place. [5]

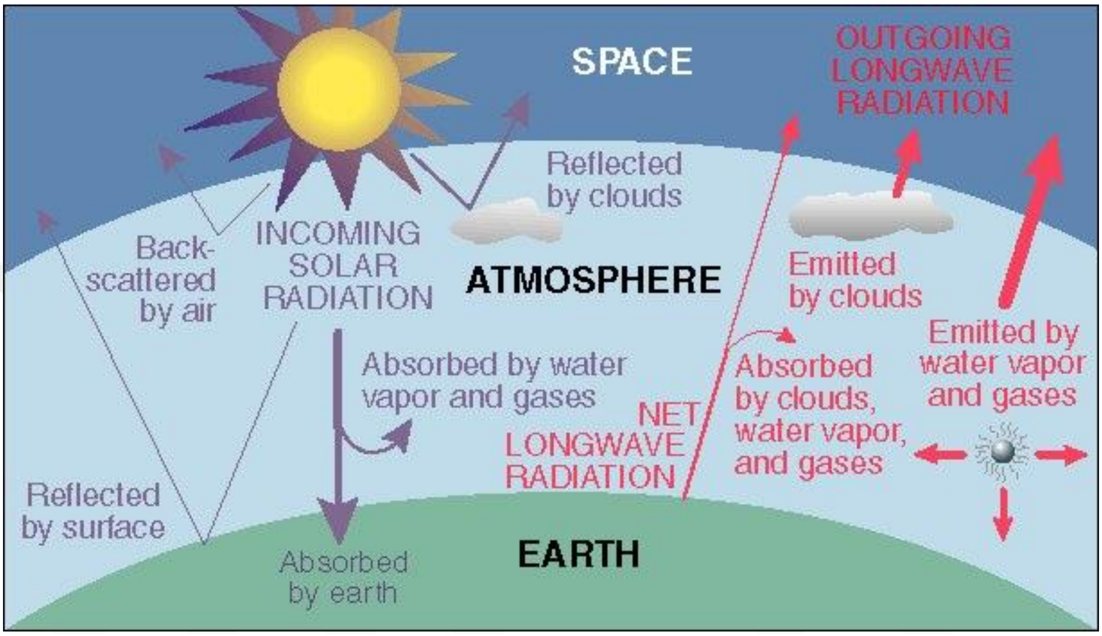

Figure 1.2 Sun rays scatter

CONCLUSION: The place is also receives the long-wave radiation from the atmosphere by 4%. The remaining energy is 39%.

1.2 Renevable Energy

Renewable Energy is the energy from the existing energy flow in the ongoing natural processes. Today, 80 percent of global energy is derived from fossil fuels. Renewable energy sources play the most important role in reducing the dependence on fossil fuels such as coal, oil and natural gas. Renewable energy sources can be listed as Solar, Wind, Biomass, Geothermal, Hydraulic, Hydrogen and Ocean Energy (Wave energy), respectively. [6]

Like sun, water, wind, wave; the sources used in the production of other energy sources before they end are simply renewable energy sources. Renewable energy sources are provided from natural resources and sustainability is possible. [1,6]

Renewable energy sources do not end over time as fossil energy sources, They are inexhaustible. Our sources such as coal, oil and natural gas are examples of non-renewable energies.

The basic classes of renewable energy sources are as follows.

- Solar energy
- Wind power
- Biomass Energy
- Geothermal energy
- Hydroelectric Energy
- Hydrogen Energy
- Wave Energy

1.3 About Solar Energy

The sun is the energy source for all the planets in the solar system. It is an indispensable resource especially for all living creatures in our world. Solar panels are among the most important renewable energy sources today due to the practicality of the use of electricity in the summer months and the big decreases in electricity bills. With the solar panels, we often encounter on the roofs of houses in cities and villages water can be heated, the home's hot water needs can be met or hot water can be used to meet the heating needs by giving the home heating system. Solar energy technologies collect heat from the sun and generate heat or electricity. Solar energy is evaluated as light, heat and electricity.

Solar energy systems convert the collected energy directly to electricity and can be placed on building roofs, devices, cars. Concentrated solar power plants can be used for the production of electricity or heat by working on the basis of reflecting solar radiation to a relatively small area with mirror and lens arrangements.

Sun in our country: According to General Directorate of State Meteorological Works measured in time sunbathing present in 1966-2012 years and the study conducted by EIE using the radiation intensity data; Turkey's average annual total sunbathing time

2640 hours (7.2 hours per day total) and average total heat-up intensity 1311 kWh / m^2-year (daily total 3.6 kWh / m^2) has been found to be. [7,9]

Sun use in the world and in our country: According to 2008 data, the installed capacity in the world's thermal systems reached 165 GW and 236 million m^2. According to 2007 data, the installed capacity is 7,105 MW thermal and 10.15 million m^2 in Turkey. [7] The most common use of solar energy per capita is Cyprus with 0.65 kW thermal / person, 0,49 kW thermal / person with israel and Austria with 0.22 kW thermal / person. The situation in our country is behind them with 0.09 kW thermal / person. [5] Countries such as Japan, Germany, China and Australia are in the same situation with Turkey in this respect. Around 100 medium and small sized companies are active in this sector and the annual production is up to 700 thousand m^2. [8]

1.4 Solar Radiation

Rays from the sun can be expressed as solar radiation. It is not possible to use all of this radiation. Nowadays, this radiation can be converted into heat or electrical energy by various methods with varying efficiency. The diversity of the yield can be caused by the team used or radiation intensity. [4]

Solar energy is an energy derived directly from the sun. The radiation of the sun reaching the earth can be used as a heat source or by converting it to electricity by means of photovoltaic devices. The strength of solar radiation depends on atmospheric conditions, time in day and geographic location. [2] The value is assumed to be 1000 W / m^2 on the surface of our planet under favorable conditions. The radiation can be used directly or as diffuse radiation or either both. direct radiation is taken directly to the surface of the power conversion from the sun without reflection and refraction. Diffuse radiation diffuses through reflection in the atmosphere, clouds and other elements during the day. Direct radiation can be reflected and concentrated to use. Diffuse rays from all directions cannot be concentrated. [3,4]

CHAPTER 2

THEORY

2.1 Semi Conductors

In nature, substances are usually found in solid form. The solids are present in amorphous form which is irregular sequence or crystalline form which is a regular array. The crystals contain crystalline structures, which are called regions within them. In the case of a crystal structure, if small regions have the same structure, they take the single crystal name. In the case that the regional structures differ, ie the crystal structures change, the structure becomes polycrystalline. Also it should be noted at this point; The structures in the single crystal may not be exactly the same and the structures in the regions may differ from each other. When solids are grouped; We can be divided into three groups according to their electrical and optical properties. These groups; conductive materials, insulating materials and semiconductor materials. In its most general terms, materials that conduct electricity directly named conductive, not conduct or conduct very little electricity materials are called insulator. Substances that do not transmit electricity up to a certain value but transmit after a certain threshold value are called semiconductors. In terms of their electrical conductivity, semiconductors are the substances that are between the conductor and the insulator. Semiconductors are present in the III-A and V-A groups in the periodic table. Today they are used in many different fields. [7,9]

First, Edmond Becquerel saw that in 1839 the light falling on one of the two electrodes immersed in the same electrolyte created a potential difference between the electrodes. Then, in 1883, Faraday discovered that the resistance of silver sulphate decreased with increasing temperature. This invention can be said to be a turning point in today's electronics industry.

2.2 Photovoltaic compenents

Photovoltaic cells and the batteries obtained by their combination have different yields and costs depending on the material used. Solar panels are composed of many different components. Basically important ones; solar cell, solar glass, EVA encapsulant, backsheet, junction box and frame. These components will be described separately. Schematic representation of the components are given in the figure.

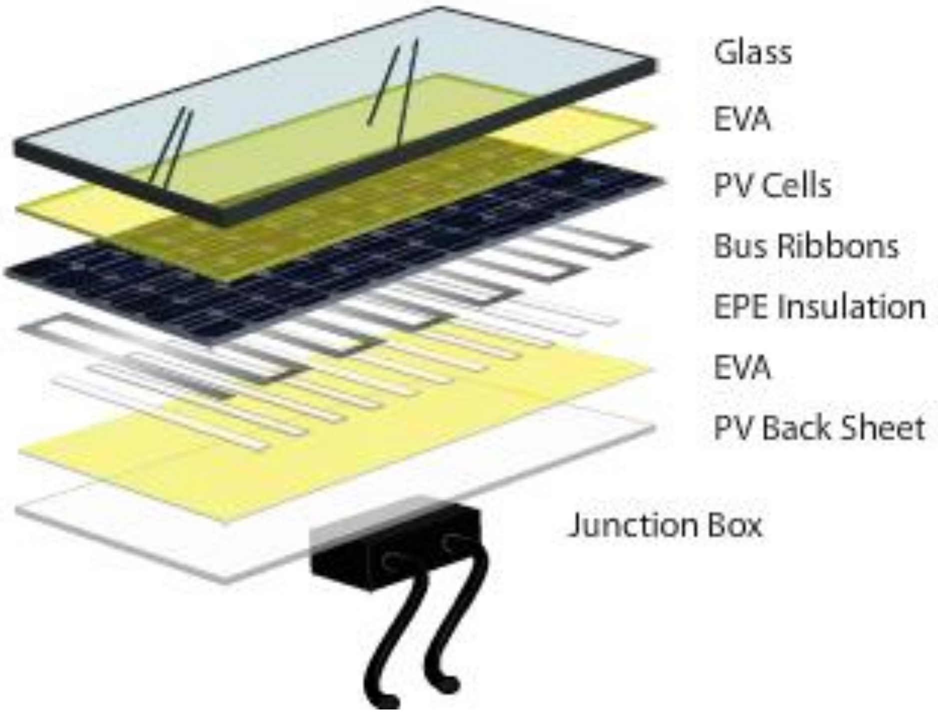

Figure 2.1 Schematic representation of solar panel components

2.2.1 Cell

Solar cells are the most important part of a solar panel. It is the part that turns sunlight directly into electrical energy. They consist of semiconductors and operate according to the photovoltaic effect. Nowadays, si-based solar cells are used. As a result of increasing needs, new researches have been made and new generation solar cells are being studied. The yield of solar cells used today is around 17%.

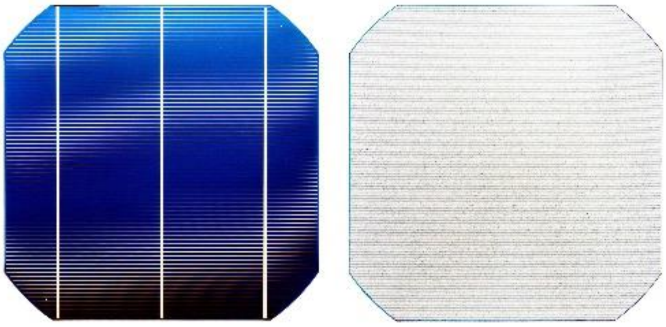

Figure 2.2 Solar cell

2.2.2 Solar Glass

The part that protects the solar panel from external influences is the protective glass. This glass is manufactured according to IP standards. In addition, it does not block the sun's rays and the heat storage is low.

2.2.3 EVA Encapsulant

In the solar industry, the most common encapsulation is with cross-linkable ethylene vinyl acetate (EVA). With the help of a lamination machine, the cells are laminated between films of EVA in a vacuum, which is under compression.

This procedure is conducted under temperatures of up to 150°C. One of the disadvantages of EVA films is that it is not UV-resistant and therefore protective front glass is required for the UV screening.

2.2.4 Backsheet

Backsheets function as electrical insulator and protect the solar cells from humidity and harsh environments. This guarantees the solar module’s durability and correct functioning over the time.

2.2.5 Junction box

The junction boxes are an important part of the kit, either in a commercial or home environment, as it protects and insulates the electrical connections. It is also an essential part of solar panels. It can also be defined as the output point of the generated electricity from the panel.

2.2.6 Frame

The frame is the pattern that holds the panel together basicly. It increases the strength of the panel and protects the panel against impacts. It also facilitates the installation of the panel.

2.3 Photovoltaic working principles

Photovoltaic cells are generally made of semiconductor material. When sunlight is absorbed by these substances, electrons begin to circulate free from the atoms to which they are attached end, and thus an electric current is generated.

In a crystal of pure silicon, the atoms form a lattice. These atoms, like any others, have nucleus which includes positive charged protons, while around the nucleus, are negatively charged electrons in layers or shells. The outer shell of electrons is not "full", so neighboring atoms share electrons and hold each other together in the crystal. These electrons are held quite firmly in place and do not readily move around.

However, the pure silicon crystal can be "doped" with a different element, ie small amounts of an "impurity" are added. If the doping is done with an element that has more electrons in it's outer shell than silicon, there will be negatively charged electrons that are free to move around, and this is called "n-type" silicon. [7] This material will conduct electricity much better than pure silicon as these spare electrons are more free to move, and we have created a semiconductor. The crystal does not have an overall negative charge however as the negative electrons are still balanced by positive protons in the nucleus.

If instead, the silicon is doped with an element having fewer electrons in it's outer shell, there will be an overall shortage of electrons, and the material will be a p-type silicon. The minute areas where electrons are effectively missing are called holes, and these holes can also freely move around.

In a solar cell, there will be both n-type and p-type silicon in contact with each other. Electrons will move across from the n-type to the p-type at their junction as they will be attracted to the nearby holes. Once this has happened at the junction, this area acts a barrier, stopping further electrons moving across and an electric field exists across the junction. [9]

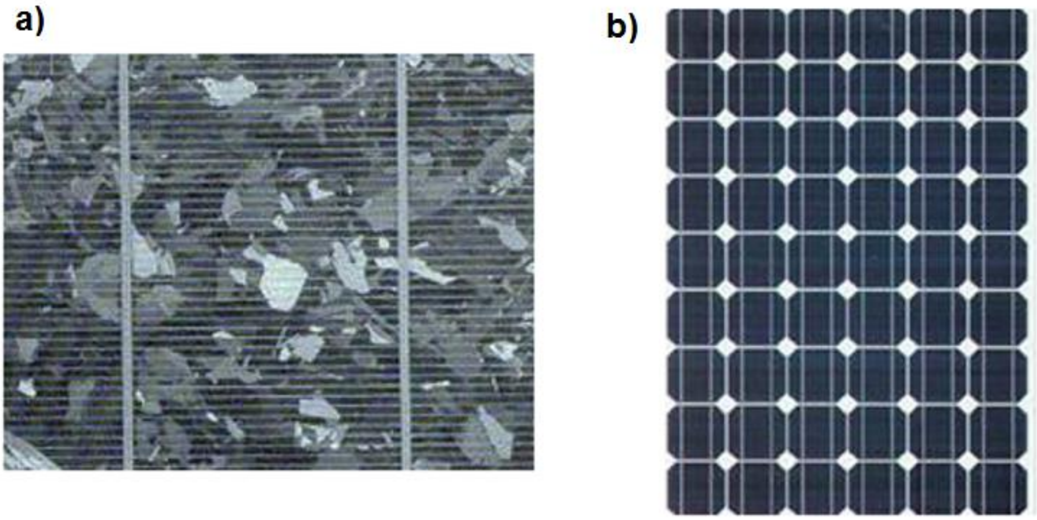

Figure 2.3 a) Solar cell close-up, b)Photovoltaik module

The performance of a solar cell is measured by its efficiency. What percentage of the energy it takes is the most important parameter that determines the efficiency. Yield can be defined as the ratio of the energy of the photons falling onto the panel to the resulting voltage. panels can be converted to electricity at certain wavelengths. Because the light beam (especially uυ) corresponding to the wavelength above a certain energy can provide the necessary energy. The large amount of the remainder is either absorbed or reflected by the cell-forming agent. Therefore, the efficiency of an ordinary solar cell is around 15%. So; it can convert about one/sixth of the energy into electricity. On the other hand, 40% efficiency is obtained in laboratory conditions. [6,7]

The electron induced in the insulated semiconductor is mainly combined with the space in the valence band and emits its excess energy as photons or phonons. Therefore, no significant electrical energy can be obtained and the efficiency of the photovoltaic battery is became low. The surface dimensions of photovoltaic batteries are generally 100 cm^2 and the thickness of the solar cells between 0.2-0.4 mm; square, rectangular, circle-shaped. The most commonly used materials in photovoltaic solar cell production are silicon (Si), gallium arsenic (GaAs), cadmium sulfide (CdS) and cadmium telluride (CdTe). [15]

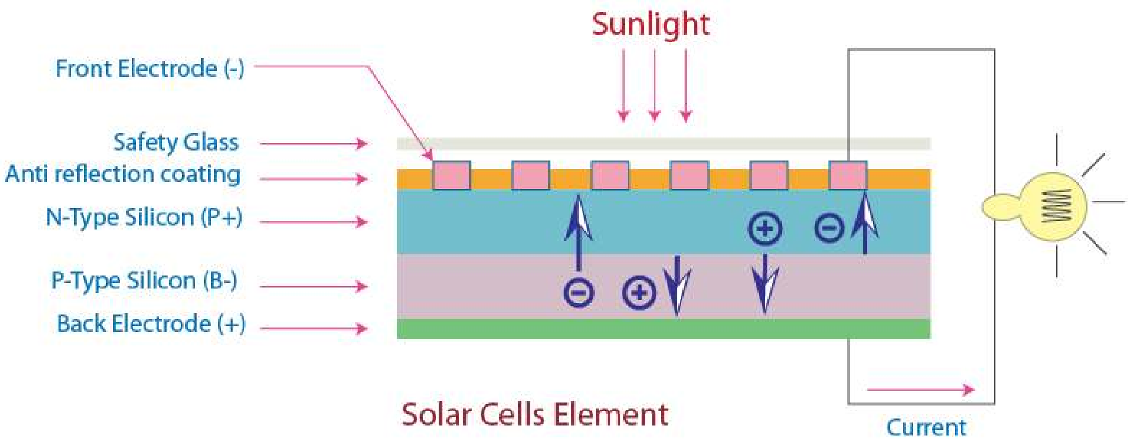

Figure 2.4 Solar cells working principles and colar cells components

The amount of solar energy in Turkey in 1 m^2 ranges from 800-2600 kWh for 1 year. Depending on the nature of the solar cell, this energy can be converted into electrical energy with a efficiency between 5% and 70%. It is possible to increase the power output by connecting multiple solar cells in parallel or in series. This system can be carried out by mounting the batteries on a surface. This structure is called the solar cell module or photovoltaic module. Depending on the power demand, the modules can be connected to each other in series or parallel; systems can be created from several Watts to MWatts. (2) These systems can be used, especially in areas away from residential areas, in non-electrical networks and where fuel is difficult and expensive to transport to the generator. It is also possible to use them in combination with diesel generators or other power systems. (16)

Areas of use and user kits research on the rapidly growing solar cells continues intensively. These batteries have a long life between the superior sides (about 20-30 years), do not create environmental pollution, does not contain the moving parts can be said. Among the weak sides, low electricity storage, textile and economic mechanisms can be counted. (9)

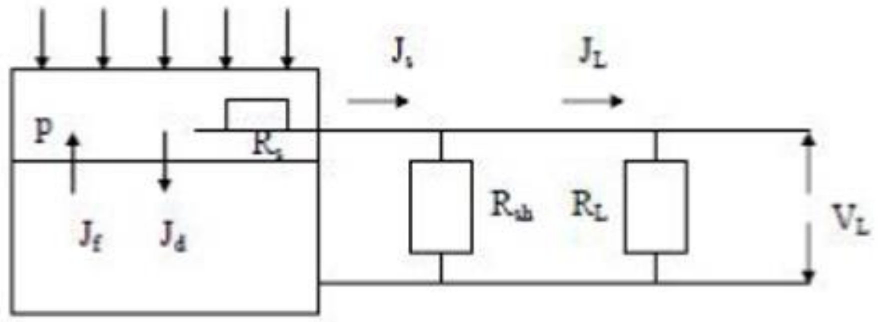

Figure 2.5 Electrical cycle of photovoltaik solar cells

In the energy cycle of photovoltaic solar cells, there are no moving parts. Solar cells, semiconductor diodes, which are used in electronic devices that can be used in every part of life today, are applied to large surface areas. The materials used and the manner of production are basically similar to the working principles of the diodes.

2.4 Photovoltaic applications

We can use solar energy for heating, cooking, cooling, lighting and energy production. Today, the most common usage is electricity generation and water heating. The schematic representation of solar energy application types are given below [17].

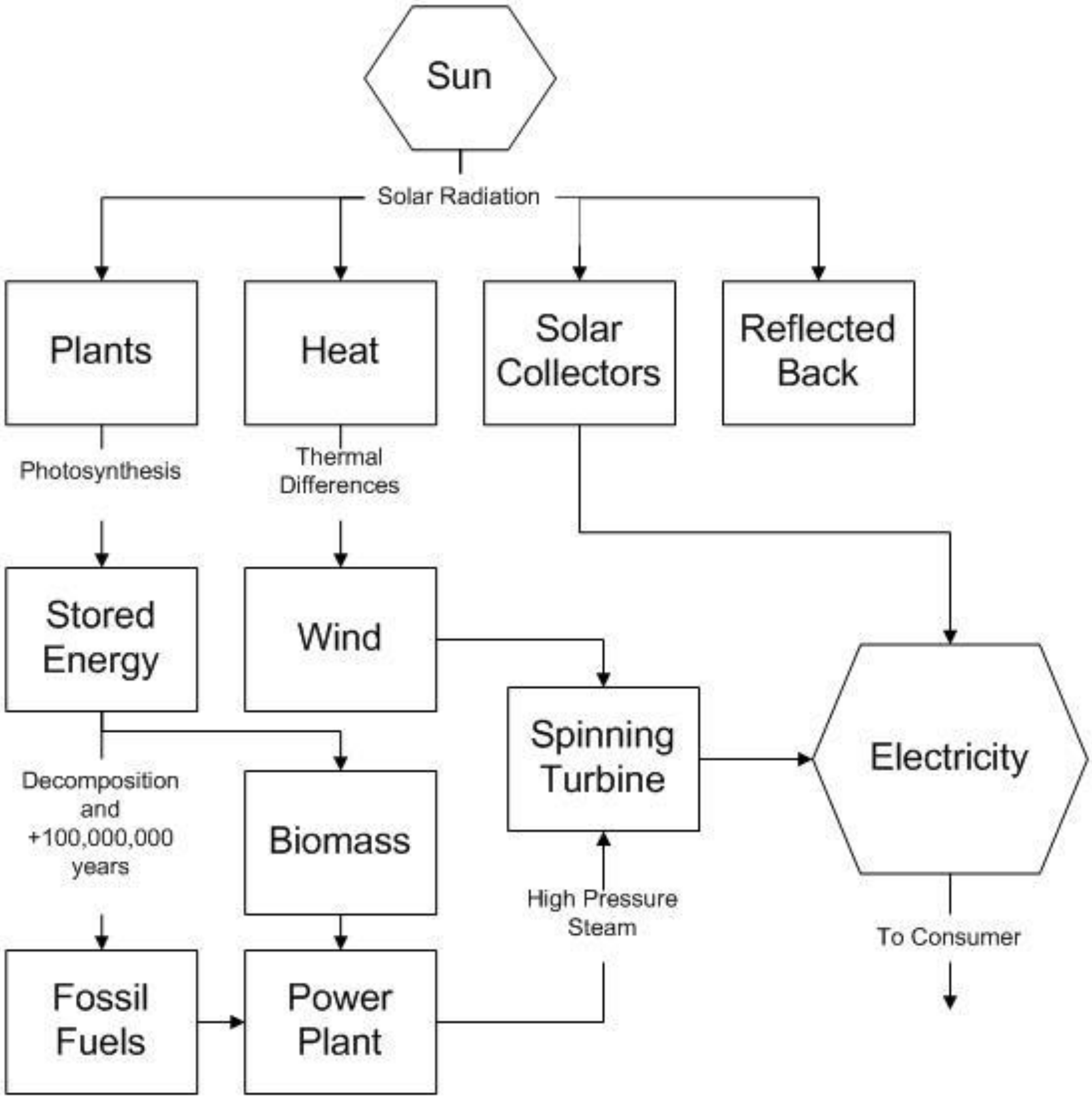

Figure 2.6 Schematik representation of solar application

Systems that will provide us with the energy we need in different ways can be designed. However, appropriate systems will be designed by calculating the load loss probability, its standard deviation, the annual system error and its standard deviation.

- Obtaining daily radiation from horizontal surface
- Obtaining daily radiation from the inclined surface
- Calculating the available energy from the daily sun
- Determination of daily energy status and energy deficit
- Determination of the probability of annual loss of load (the ratio of the energy deficit to the energy requirement) and the number of errors.

2.5 Basic Photovoltaic Formulas

The physical event when a light beam falls on the P-N junction is shown in the figure below. A beam of light is also a photon beam. Because the atomic dimensions are small, a photon may encounter a free electron or a value electron or a space. A photon confronting an electron gives her energy. A photon encounters a free electron and is unlikely to give it its energy. If a photon encounters a value electron and gives it a power equal to or greater than the forbidden bandwidth Eg, the electron that breaks off the value band leaves a gap behind the conductivity band. As indicated in Figure, if this event occurs at various points of the joint (indicated by number 1), the electric field accelerates the electron to the N-type region and the cavity to the P-type region. This load movement indicates a positive charge transition from the N-type region to the P-type region. In this transition The N-type region is loaded negative, and the P-type region is loaded positively [15].

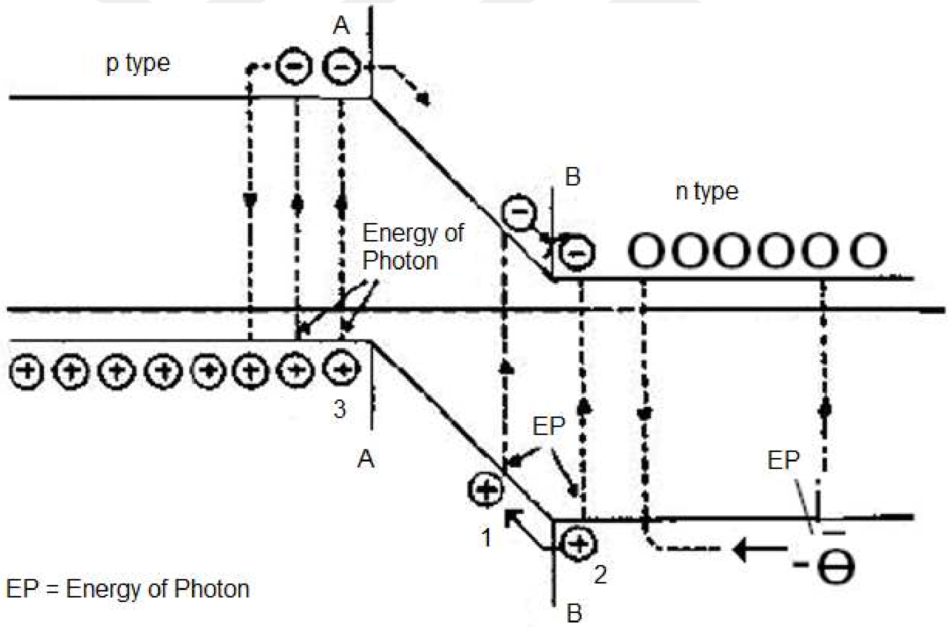

Figure 2.7 Stages of P-N junction

If the electron gap pair occurs in the N-type region (this stuation shown in Figure, number 2), the minority load carrier passes to the P-type zone. In this case, there is also a positive charge transition from the N-type region to the P-type region. The direction of movement of the load carriers in the majority is of little importance, usually their energies are not sufficient to overcome the voltage wall. If the electron-gap pair occurs in the P-type region (shown in Figure, number 3), the electron insertion moves toward and exceeds it and reaches the N-type region. In this case, there is still a positive charge transition from the N-type region to the P-type region. The electrons and cavities formed away from the joint are recombined, so that an electron-void disappears. A minority freight carrier faces multiple collisions and moves in random directions and continues until it is captured. If the load carrier is oriented toward the immediate insertion of the irregular movement, it may exceed the joint due to the content of the electric field in the joint. As the minor load carrier is located around the joint, the likelihood of crossing the joint is great. The distance of the minor load carrier from the insertion is measured by a spread distance indicating the average path of a minority load carrier prior to engagement with a major carrier. The probability of formation of the electron-gap pair from the joint N to the P region is equivalent to e = d / L. The spread distance L is the distance at which an absorbed photon is likely to be converted into an electric current passing through the joint. The L spreading distance varies between 10^{-4} m and 10^{-6} m depending on the density of the charge carriers and the shape of the crystalline formation.

As can be seen from the explanations up to here; To benefit from the current generated by the photons, the P-N joint must be illuminated first and then the resulting current must be reflected in an external circuit. The charge carriers formed by photon adsorption are often drifted towards the regions where they are. In this case, an Is current passes through the joint. Thus, the P-type region is positive and the N-type region is loaded negatively. The transition of the I_s current causes the P-N joint to be directed forward and in this case the voltage wall at the joint is lowered. If the joint does not have an external connection, it passes a I current at the front (towards P and N) due to the forward movement. Cause the passage of this I current will load the N-type region positively, the voltage wall, which prevents the passage of the majority load carriers, begins to rise. This current from P to N is continued until the voltage wall becomes a barrier to the passage of the majority charge carriers. Again the absorption of the photon happens.

The electric field present in the joint separates the existing pair of electron-gaps and allows them to cross the joint. Thus, the collapse of the tension wall, then the elevation continues, and in the event of an open circuit, the current I_s is balanced by the current I (Figure 9).

If the P-N joint is terminated with an external load resistance R1, up to I_L current of I_s current flows from the 'outer circuit', thus the P-N joint converts the light energy into electrical energy.

I_s current;

$$I_s = I + I_L \tag{2.1}$$

It is given by the equation.

$$I = I_0\left(e^{\frac{q^v}{k_B T}} - 1\right) \tag{2.2}$$

If the value of the direct current is replaced in the I_s equation, the number 3 correlation is obtained.

$$I_s = I_0\left(e^{\frac{q^v}{k_B T}} - 1\right) + I_L \tag{2.3}$$

Here; I_o cell saturation current, I_s current generated by light, I_L battery output current, q^v electronic load, k_B Boltzmann constant, T is the absolute temperature.

For a light beam which color and frequency components given, I_s flow is proportional to the light intensity.

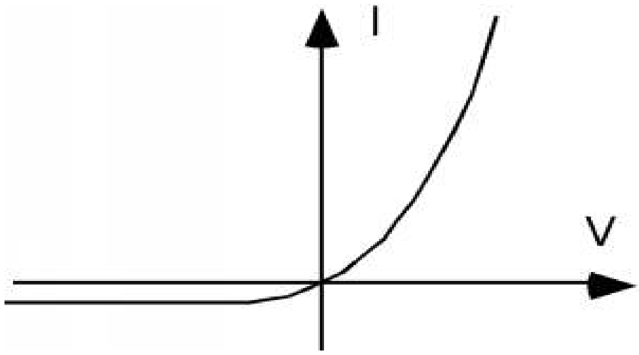

Figure 2.8 Theoretical current voltage curve

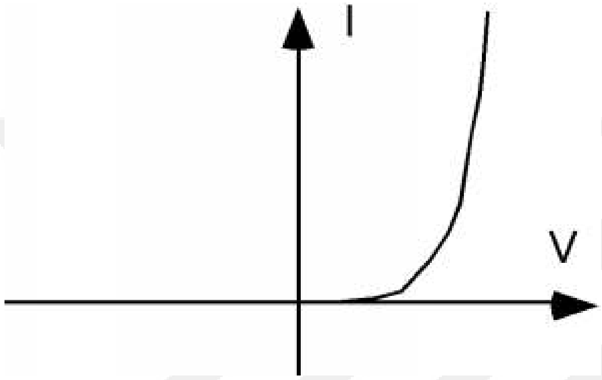

Figure 2.9 Actual current voltage curve

In order to calculate the power, in addition to the above equations, the following calculations should be made.

Open-civcuit voltage (V_{oc}): the voltage measured when the resistance between the ends of the cell is infinite, ie while the circuit is open.

Short-circuit current (I_{sc}): current measured when the resistance between the two ends of the cell is zero, ie when the circuit is closed.

Under ideal conditions, this value is equal to the current generated by the radiation.

Fill factor (FF): In the current-voltage curve under radiation, calculated in the region where the currents are negative and voltage positive, defined the ratio of the largest V_{mp} x I_{mp} to V_{oc} x I_{sc}.

FF= (V_{mp} x I_{mp}) / (V_{oc} x I_{sc}) **(2.4)**

Output power of the solar cell, output P, in terms of these variables,

$$P_{output} = V_{mp} \times I_{mp} = V_{oc} \times I_{sc} \times FF \tag{2.5}$$

Can be given in the form.

The efficiency of a solar cell is defined as the ratio of the solar radiation power falling on the photovoltaic cell to the power to be received from the cell.

$$N = (P_{output} \times I_{mp)}\ /(V_{input} \times I_{sc)} = (V_{oc} \times I_{sc} \times FF) \tag{2.6}$$

Standard Test Conditions for measuring the efficiency of solar cells which is measurement at 25^0C cell heat, under the 1000W / m^2 solar power and in the solar spectrum 1,5. This value, which can reach 1200 W / m^2 on a cloudless and sunny day, varies between 200-800W / m^2 on cloudy days. On a rainy day, the solar radiation per square meter decreases to 50W.

2.6 Useful parameters

There are a number of issues that people who want to install solar solar panel should pay attention to. It should be determined in the selection of the panel that the products should be used for the purpose. Water heating, heating, electrical energy, irrigation, lighting etc. which of the requirements should be used first. After the determination of what the panels will be used for, the calculation of the requirement must be done very well when converting the solar energy to electrical energy. After determining how much power is needed, the feasibility study of the space to be installed should be done. The area of solar solar panels should be determined by the presence of any adverse environmental conditions, the change cycle of the air in the region and the angle of arrival of the sun rays. After completion of the works, the panels to be ordered should be durable, high quality and durable. The price and price comparison of the panels with different brands of the products to be ordered is important both in terms of the product and the budget to be allocated for the order.

The purpose of this system increases of electrical efficiency at the photovoltaic panel. Basically when the radiation came from the sun and much more radiation absorbed from the panel and turning to heat. Especially while the system generate panel surface have a high temperature this be reason to decrease electrical efficiency. This mean Pmax level decrease related with panel surface temperature. So, the purpose of photovoltaic thermal system provides to decrease surface temperature and related to with this condition provide to increase electrical efficiency and compare result output power with photovoltaic thermal panel and without thermal photovoltaic.

Until now we see basic system of photovoltaic and effect of temperature to this system. With photovoltaic thermal (PVT) we purpose to increase to electric efficiency of photovoltaic and alternatively used to thermal energy with hot water that produce from to photovoltaic temperature.

2.7 Sun datas Daily, Mounthly Yearly

One of the most important points that people who want to use solar energy should pay attention to is solar data. Solar data are measured by some enterprises themselves. If it is not possible they take detailed measurement data from the general directorate of meteorology. The general directorate of meteorology makes these measurements continuously in each province. By using this data, It is possible to find the parameters like total solar radiation, daily sunshine time etc. in your current location. Using these values you can calculate what you can get from the system you want to install. Thus, it is possible to make feasibility without installing the system. This avoids damage in a possible adverse situation. [5]

2.8 Solar Efficiency

Solar panels are formed by connecting 36 or more solar cells in a series and are hermetically packaged by lamination technique so that the disruptive effects of the external environment are not affected for many years (~ 25 years). Since the life of a PV power system determines the lifetime of PV panels, solar panels should be preferred as long as possible. In general, most manufacturers guarantee 80% panel strength in the 25th year. Many have expressed the decline in power linearly, while others indicate a gradual decline of 90% in the 10th year and 80% in the 25th year. As can be clearly seen from Figure 12, linear decline should be preferred because it implies a wider range of warranty than gradual decline.

On the other hand, the power tolerance of PV panels varies between ± 2,5% and ± 5%. For example, if a 300W panel has a power tolerance of 3%, its actual power can be between 291W and 309W. This is a factor that increases the loss of incompatibility in a PV system and therefore it is appropriate to use low-tolerance panels.

A positive charge accumulation may occur in the grounded parts of the PV panels with crystal Si technology to be used with an inverter without transformer and with the so-called Potential Induced Degredation (PID), module power can be reduced by up to 30%. For this reason, it is important to choose PV panels approved by PID test in systems that will use transformer without inverter. The same effect should be considered as a result of the permanent damage to the Transparent Conductive Oxide (TCO) layer in thin film technology.

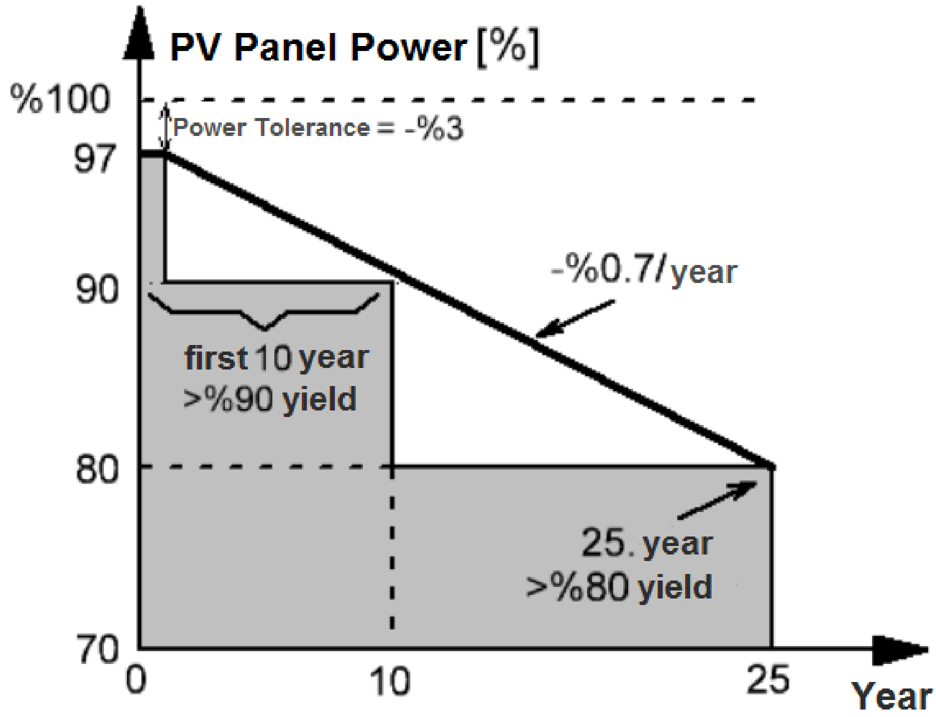

Figure 2.10 Power warranty periods of commercial panels

Panel efficiency and panel area are two parameters to consider together. If the space is limited, it is necessary to use the most efficient panels to achieve maximum installed power. Figure 12 shows the efficiency of commercial panels with different technologies [4]. Accordingly, the efficiency of Heterojunction with Intrinsic Thin layer (HIT) and Interdigitated Back Contact (IBC) technologies is considerably higher than other technologies. In addition, the high dependence coefficient of power in high-efficiency HIT and IBC technologies is lower than that of conventional technologies, and therefore the advantages are higher in places where the temperature is high throughout the year. Instead of using only the yield value as a criterion in panel selection, it would be more appropriate to consider the total energy produced by the PV system to be established by calculating with various simulation programs. Because in this case the life and aging processes of the panels are also taken into account. On the other hand, it will be possible to use> 45% efficient solar panels with the introduction of multi-joint solar cells in the future.

2.8.1 Factors of Solar Efficiency

The efficiency is the most commonly used parameter to compare the performance of one solar cell to another. Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun. In addition to reflecting the performance of the solar cell itself, the efficiency depends on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. Therefore, conditions under which efficiency is measured must be carefully controlled in order to compare the performance of one device to another. Terrestrial solar cells are measured under AM1.5 conditions and at a temperature of 25°C.

The main parameters of photovoltaics in electricity production

- Intensity of incoming solar radiation
- Sunbathing time
- Arrival angle of the sun
- Optimum efficiency temperature
- Technology selection
- Structure of the material used

Temperature and Performance of Photovoltaic Panels

Photovoltaic panels work more efficiently in situations where they receive enough solar radiation at very low temperatures rather than high temperatures. In some efficiency calculations, it was observed that the efficiency of the southern pole was higher in the sun. There is stability in these transformations at low temperatures during photon conversion to electron. When we look at the I-V curves, there is a voltage drop despite the current increase at high temperature. The resulting power is lower.

Photovoltaic panels and solar radiation density

The photon current is maximum in full sunshine conditions. At partly cloudy weather conditions, the photon current will be reduced depending on the intensity of the sun. The I-V curve will fall down at a lower solar density and will cover smaller areas. In a cloudy day, short circuit current will decrease significantly.

Productivity

In the solar photovoltaic system, the power factor (fill conversion factor) is sometimes mixed with efficiency and this leads to some difficulties. The efficiency of photovoltaic panels is the ratio of the total amount of electricity produced by the total amount of solar radiation generated. In this definition, only the electricity produced by photovoltaic batteries is taken into calculation. Cell temperature, ambient temperature and chemical components of the cell, which are the other components that affect photovoltaic panels, are not directly involved in the calculation.

Solar radiation measurements varies according to; The state of the sky, short time change (minutes, hours), long-term period of time (season, year, decades), the current point.

Sun Range Types

- Direct from the Sun (Direct radiation)

- Out of the sun from all directions (Diffuse, diffuse radiation)

- From Sky Total (Global or Total Radiation, Total Radiation = Direct + Spread)

Solar Radiation Measuring Instruments

Direct Normal Radiation: It is measured by pyrocyometers with the help of solar tracer trajectory systems.

Total (Global) Radiation coming to the horizontally: Measured with a horizontal pyranometer.

Diffuse Radiation: Measured with shaded pyranometer. There are also tracer balls.

Standard conditions are considered in the efficiency calculations for photovoltaic batteries. These conditions are total solar radiation of 1000 W / m^2, ambient temperature of 25 ° C and absence of other atmospheric effects.

The effects of atmospheric and other environmental effects on efficiency in photovoltaic batteries are taken into account with the rate reduction factor. In this factor, time, cloudiness, dust, temperature, air pollutants, amount of snow, shade etc. parameters are effective. When the effect of each parameter specified is used in efficiency calculations, the expected efficiencies will be calculated.

Solar energy and photovoltaic applications, especially in the world and the rapid production and investment process in Turkey is experiencing. Developing projects with maps in energy planning can cause big problems in terms of efficiency and investments. The baseline is to measure the solar radiation and the duration of the sunshine for at least one year. Measure the atmospheric and environmental impacts affecting photovoltaic batteries and perform feasibility studies in this direction.

Among the renewable energy technologies, solar cells are one of the major developments and applications. They will be used more in the future due to their unlimited energy supply. As it is known, as a result of our world's great environmental disasters, the interest in renewable energies has increased. Solar energy is a clean fuel. Photovoltaic Battery systems are the primary means of generating electricity directly from the solar source.

2.9 Temperature effect on Photovoltaics

The cell temperature (T_c), desired air temperature (T_a) and radiation (G) value of an PV panel can be estimated using the NOCT temperature.

$$T_c = T_a + \frac{NOCT - 20}{0.8} G(kW / m^2) \qquad \textbf{(2.7)}$$

Using the panel power together with the temperature dependency coefficient μp The temperature value found, the output power of the panel can be calculated.

$$P_m(T_c) = P_{m,STC}\left[1 - \mu_P\left(T_c - 25\right)\right] \quad \textbf{(2.8)}$$

Here, $P_{m,STC}$ is the panel power of the standard test conditions (STC). The NOCT temperature in the PV panels is between 42 and 52 ° C. This 10 ° C difference between the panels produces a power difference between 3.8-4.5% if the temperature dependency coefficient is accepted as 3.8p = 0.38-0.45% / K, which is an important amount. Therefore, in the panel selection, the temperature dependency coefficient of NOCT and power should be evaluated together and the least affected ones should be selected. Thus, the performance decrease will be reduced when the temperature is high. [11,12]

Temperature give to photovoltaic negative effect to operating performance and also to electrical efficiency. When the system generate temperature increase and efficiency decrease. The standard value that is global solar irradiation intensity unit for photovoltaic is G=1000 W/m^2. If the plane have a 20% efficiency at 20 C degree and for mono crystal semiconductor cell each increase of degree make down to efficiency 0.5 degree decrease.

CHAPTER 3

MATERIAL AND METHOD

3.1 Material

In order to observe the effect of panel temperature on efficiency, a basic set of experiments was established. In this system the solar panel is operated under cooled and normal conditions separately.

In this experiment, we can examine the materials under the system devices and measurement devices headings.

3.2 Devices for system

System components are basically composed of devices in a solar panel operating cycle. This system consists of a photovoltaic module, water pump, water flow channel, wate hose and water bucket. Information is provided below each one. Also the system image is given.

Figure 3.1 The experimental setup

3.2.1 Photovoltaic Module

20 W si based solar panel was preferred. 2 solar panels are used. One is cooled and the other is non-cooled panel. They have 5% tolerance. Panel yield is around 15%. For the cooling system, suitable channels are also installed in it. There is one water inlet and one water outlet and cooling was provided by a water pump.

3.2.2 Water Pump

The water pump is the main element that provides the water cycle in the system. A pump with 0.1 hp power was selected. The feed rate is adjusted to the optimum value for heat transfer.

3.2.3 Water Flow Channel

An important intermediate element in the refrigeration cycle is the water flow channel. The water passes through the heat transfer element in the panel with the help of the pump. During this process, water flow channel is used from pump to water bucket. Classic garden hose was used as water flow channel. It has a diameter of 10 mm.

3.2.4 Water Hose

The hose allows the water to come from the water bucket to the pump. a thicker hose was used than the water flow channel. Water speed is lower than in water flow channel speed.

3.2.5 Water Bucket

Water bucket is the main tank used in the cooling cycle. Water is sent from here and water from the cycle accumulates here.

3.3 Measuring Devices

The measurement devices are important for us to see the results of the experiment. In this system, the temperature of the solar panel is one of the most important parameters. Therefore, surface thermometer was used to monitor the panel temperature. An air thermometer was used to measure the ambient temperature. Another thermometer was used to measure the temperature of the cooling water. The last measuring device is multimeter. Multimeter is used to measure the panel output current and voltage.

3.3.1 Mutimeter

The multimeter is an important measurement tool to monitor the change of output power in the cooled and non-cooled panel. The output current and the output voltage of the solar panels at certain time intervals are measured by this instrument. Cause of multimeter can take different measurements, no need for different devices to measure current and voltage.

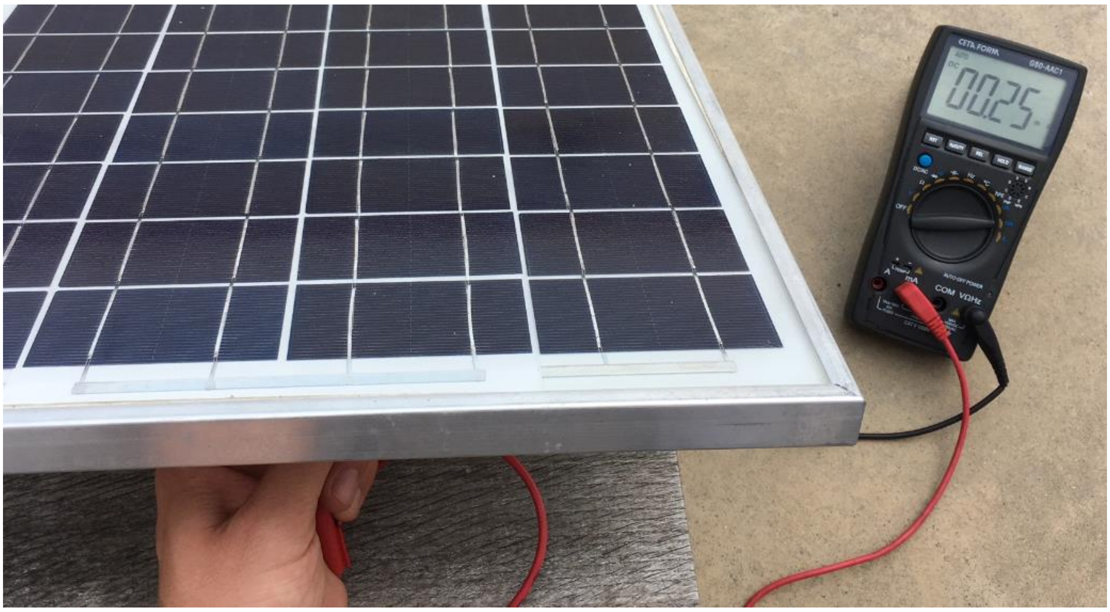

Figure 3.2 Used multimeter in experiment

3.3.2 Surface Thermometer

The most important parameter to be measured in this study is panel temperature. panel temperature was also measured by surface thermometer. infrared thermometer was used as surface thermometer. The panel surface temperature is measured with this thermometer at certain time intervals in the cooled and non-cooled cycle.

Figure 3.3 Used surface thermometer in experiment

3.3.3 Air Thermometer

Ambient temperature is an important parameter for determining the test conditions. Air temperature is a parameter that affects the system. The air thermometer was also used to measure the ambient temperature.

Figure 3.4 Used air thermometer in experiment

3.3.4 Liquid Thermometer

The last parameter measured is the coolant temperature. It is an important measurement for obtaining cooling data. This measurement was done with liquid thermometer.

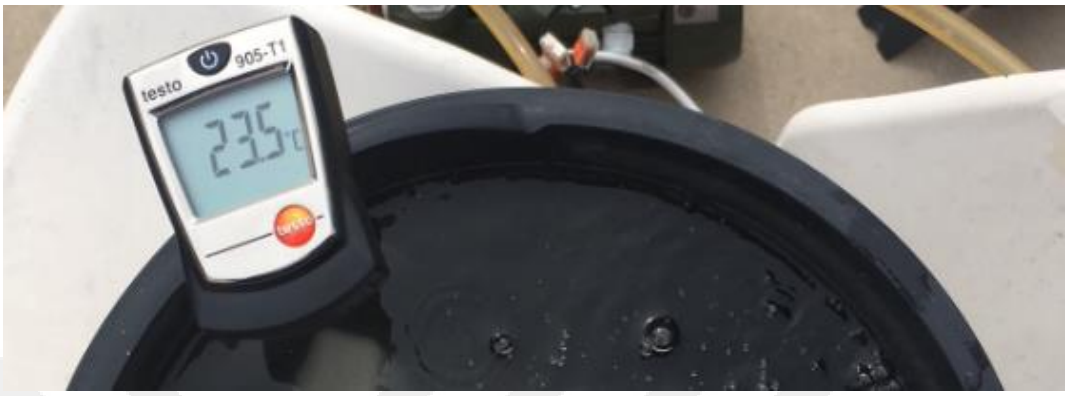

Figure 3.5 Used liquid thermometer in experiment

3.4 Method

At this study is examined the temperature effect on photovoltaic module. There have designed experimental setup which is suitable for this purpose. There are used two pieces photovoltaic module, one pieces water pump, plate with water channel. To get experiemnt datas, there are used one pieces voltmeter, one pieces surface temperature meter, one pieces ambience temperature meter, one pieces water temeperature meter. Two pieces photovoltaic modules have same characteristics values, For one of them we put the aluminum plate with water channel to the backside of module during the flow water inside of channel. Then water temperature tranfer to backside of module. In this case there occur different temperature depent to water temperature and get a volt amper datas and analysis efficiency values.

Figure 3.6 Experimental setup with components names

In this study, the cooling channel is designed to cool one of the solar panels. The cooling channels are placed on the aluminum plate. This plate is mounted behind the panel. Water passes through the plate to reduce the temperature in the panel. Aluminum plate cooling channel drawing is given in the figure.

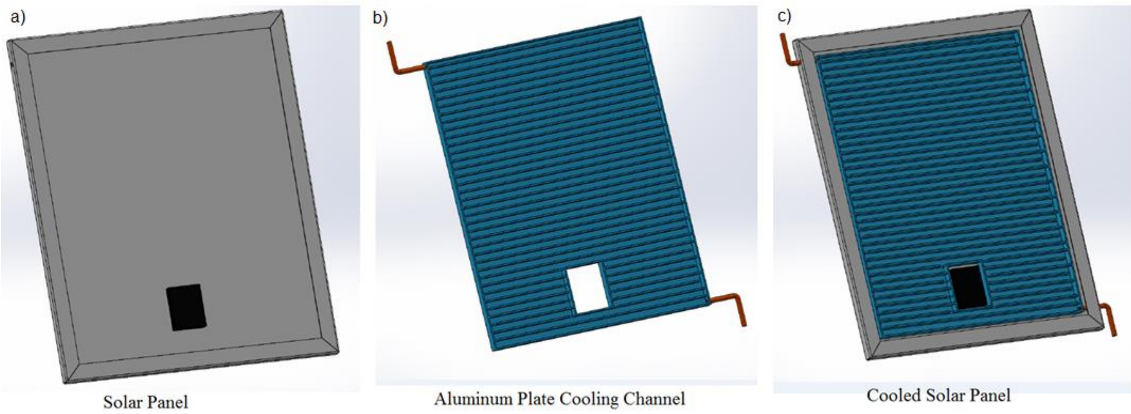

Figure 3.7 a) Solar panel, b) Designed cooler plate, c) The combined system

CHAPTER 4

RESULT AND DISCUSS

In this study, the experiment was repeated on 5 different days. Measurements were taken at different time intervals every day. The measurements were taken separately for the cooled and uncooled panels, also for two panels at the same time. The data obtained as a result of measurements are given in tables.

Table 4.1 First experiment results

Date 01.09.18	Cooled Panel Test Result	Non-cooled Panel Test Result			
Time	**Panel Surface Temperature :** 48.7 C°	**Panel Surface Temperature :** 50.3 C°	Air Temperature	Water Temperature	When the cooling system Disable
13:25	4.7 mV	10.53 V			
	0.25 mA	0.24 mA	37.2 C°	27.8 C°	
13:40	**Panel Surface Temperature :** 36.2 C°	**Panel Surface Temperature :** 43.7 C°	Air Temperature	Water Temperature	When the cooling system enable first measurement
	20.28 V	17.14 V			
	0.25 mA	0.24 mA	-	34.6 C°	
14:40	**Panel Surface Temperature :** 47.9 C°	**Panel Surface Temperature :** 52.9 C°	Air Temperature	Water Temperature	When the cooling system enable second measurement
	19.73 V	19.27 V			
	0.24 mA	0.26 mA	40.6 C°	44.7 C°	

If we take the values in the table with the basic physics formula (P = VxI); we can compare panel output powers. Below, panel powers are given according to the measurement times.

Table 4.2 Produced power according to the first experiment results

	Power of Cooled Panel (W)	Power of Non-cooled Panel (W)
13:25	1,18E-06	2,53E-03
13:40	5,07E-03	4,11E-03
14:40	4,74E-03	5,01E-03

In this table, high values are green, low values are marked in red. Out of the measurement in 13.25, the cooled panel power was higher. When paired with the panel temperatures table, we can say that the high temperature decreases the panel power (ie efficiency). 13.25 measurement is thought to be a technical failure. In the case where a measurement at mV level is obtained, it can be foreseen that the panel is unable to receive the sun's rays. On the other hand there may also have been a problem with the measuring devices.

The other measurement results and the power tables resulting from these results are given below.

Table 4.3 Second experiment results

Date 04.09.18	Cooled Panel Test Result	Non-cooled Panel Test Result			
Time	Panel Surface Temperature : 43.1 C°	Panel Surface Temperature : 50.1 C°	Air Temperature	Water Temperature	When the cooling system Disable
14:20	20.06 V	19.32 V			
	0.25 mA	0.24 mA	37 C°	30 C°	
14:40	Panel Surface Temperature : 38.6 C°	Panel Surface Temperature : 47.4 C°	Air Temperature	Water Temperature	When the cooling system enable first measurement
	20.31 V	19.56 V			
	0.25 mA	0.24 mA	41.8 C°	32.4 C°	

Table 4.4 Produced power according to the second experiment results

	Power of Cooled Panel (W)	Power of Non-cooled Panel (W)
14:20	5,02E-03	4,64E-03
14:40	5,08E-03	4,69E-03

Table 4.5 Third experiment results

Date 05.09.18	Cooled Panel Test Result	Non-cooled Panel Test Result			
Time	Panel Surface Temperature : 35.8 C°	Panel Surface Temperature : 41.5 C°	Air Temperature	Water Temperature	When the cooling system Disable
14:05	20.48 V	20.15 V			
	0.25 mA	0.25 mA	30.5 C°	27.6 C°	
14:30	Panel Surface Temperature : 34.2 C°	Panel Surface Temperature : 42.2 C°	Air Temperature	Water Temperature	When the cooling system enable first measurement
	20.94 V	18.78 V			
	0.26 mA	0.24 mA	34.5 C°	30.4 C°	
14:55	Panel Surface Temperature : 34.6 C°	Panel Surface Temperature : 40.0 C°	Air Temperature	Water Temperature	When the cooling system enable second measurement
	20.72 V	19.98 V			
	0.26 mA	0.24 mA	34.8 C°	33.1 C°	

Table 4.6 Produced power according to the third experiment results

	Power of Cooled Panel (W)	Power of Non-cooled Panel (W)
14:05	5,12E-03	5,04E-03
14:30	5,44E-03	4,51E-03
14:55	5,39E-03	4,80E-03

Table 4.7 Fourth experiment results

Date 07.09.18	Cooled Panel Test Result	Non-cooled Panel Test Result			
Time	Panel Surface Temperature : 28.8 C°	Panel Surface Temperature : 28 C°	Air Temperature	Water Temperature	When the cooling system Disable
14:25	20.14 V	19.69 V			
	0.25 mA	0.25 mA	27.1 C°	25.2 C°	
	Panel Surface Temperature : 29 C°	Panel Surface Temperature : 30.9 C°	Air Temperature	Water Temperature	When the cooling system enable first measurement
14:30	21.22 V	19.74 V			
	0.25 mA	0.25 mA	30.0 C°	26.2 C°	
	Panel Surface Temperature : 27.1 C°	Panel Surface Temperature : 28.6 C°	Air Temperature	Water Temperature	When the cooling system enable second measurement
14:55	21.05 V	20.54 V			
	0.25 mA	0.25 mA	29.3 C°	32.1 C°	

Table 4.8 Produced power according to the fourth experiment results

	Power of Cooled Panel (W)	Power of Non-cooled Panel (W)
14:25	5,04E-03	4,92E-03
14:30	5,31E-03	4,94E-03
14:55	5,26E-03	5,14E-03

Table 4.9 Fifth experiment results

Date 13.09.18	Cooled Panel Test Result	Non-cooled Panel Test Result			
Time	Panel Surface Temperature : 31.9 C°	Panel Surface Temperature : 33.0 C°	Air Temperature	Water Temperature	When the cooling system Disable
14:25	20.03 V	19.55 V			
	0.25 mA	0.24 mA	28.9 C°	23.5 C°	
	Panel Surface Temperature : 27.6 C°	Panel Surface Temperature : 33.4 C°	Air Temperature	Water Temperature	When the cooling system enable first measurement
15:10	20.24 V	19.48 V			
	0.25 mA	0.24 mA	30.3 C°	29.1 C°	
	Panel Surface Temperature : 26.7 C°	Panel Surface Temperature : 27.1 C°	Air Temperature	Water Temperature	When the cooling system enable second measurement
15:50	19.86 V	19.31 V			
	0.25 mA	0.24 mA	27.8 C°	33.5 C°	

Table 4.10 Produced power according to the fifth experiment results

	Power of Cooled Panel (W)	Power of Non-cooled Panel (W)
14:25	5,01E-03	4,69E-03
15:10	5,06E-03	4,68E-03
15:50	4,97E-03	4,63E-03

In all measurement results, it is seen that the efficiency of the cooled panel is increased. As the cooling water temperature increases, the effect of cooling on the panel is reduced. In addition to the system, cooling of the cooling water can further increase the efficiency.

CHAPTER 5

CONCLUSIONS

In this study, the effect of panel temperature on yield was investigated. As a result of the results of the experiments, it was observed that the temperature was reflected negatively in the solar panel. The yield decreased as the panel temperature increased. With the cooling ducts added to the panel, this decrease in efficiency is prevented. If we conclude that the results of the study are combined with the results of the other study; Solar panels are tested at an ideal temperature of 25 ºC, 1,000 W / m^2 solar radiation and 1.5 AM (Air Mass). According to this environment, the yields and the effects of the panels are calculated. When the panel receives the sun's rays, electricity production starts, but cause of the yields are not 100%, some of the energy coming from the sun is converted into electrical energy, and some of it comes out as heat energy. This causes the panels to warm up, the voltage (V, Volt) decreases as the current (I) increases with the warming of the solar cells. Because of the high decrease in voltage, the output power also decreases and this causes loss of efficiency.

A module with polycrystalline cells and a 280 W power output operates in 14.5% efficiency (1,95 m^2 module area). In the given values; Operating temperature: 45 ºC The effect of the temperature on the current (I_{sc}): + 0.0006 1 / ºC The effect of the temperature on the voltage (V_{oc}): - 0.0037 1 / ºC The effect of the temperature on the output power ((P_m): -0 , 0045 1 / ºC Panel gives 280W for 25 ºC ambient temperature, panel temperature is 45 ºC in 25 ºC environment, so panel output power x (1 - (panel temperature - 25) x P_m) 280 x (1 - (45-25) x 0.0045) = 254.8 W our output power and efficiency will decrease to 13%. Of course, if the ambient temperature is 30 ºC on hot summer days, the panel temperature will increase further and the efficiency will decrease below 13%. The same calculation can be made for voltage and current. In the same case, if the temperature is low, the result is an increase in the efficiency of the panel and, in the case of solar radiation at 1,000 ° C / m^2 in winter - 10 ºC. For this reason, solar panels need a sunny but cold place.

Another solution may be to use a cooled panel. As a result, the effect of temperature on the panel should be evaluated when selecting the panel.

The results of our study showed that the efficiency of the panel in cooling with a cooler increased. Although the efficiency of the panel increases, the heat drawn from the panel cannot be evaluated. In order to evaluate this heat, it may be an efficient work to use the peltier effect on solar panels.

The Peltier

The Peltier is the element that is formed by the serial connection of P and N ends and produces a physical effect known as the Peltier effect when the current flows through it. With this effect, one side of the material heats and the other side cools.

Peltier element technology is interpreted by Russian scientists as the invention that the heated surface of the spacecraft was invented to make the air conditioning effect in the interior spaces of the spacecraft. Americans provided the use of these elements in the commercial world. Peltier elements have anode and cathode ends. When a voltage is applied to the elements in the correct polarization, a surface is heated and the other surface cools. The direction of polarization varies when heated and cooled. In addition, they can produce electricity from heat. This can be used to assess the excess heat in the solar panels. In medical device technologies, CPU cooling processes, Auto refrigerators etc. are a common use.

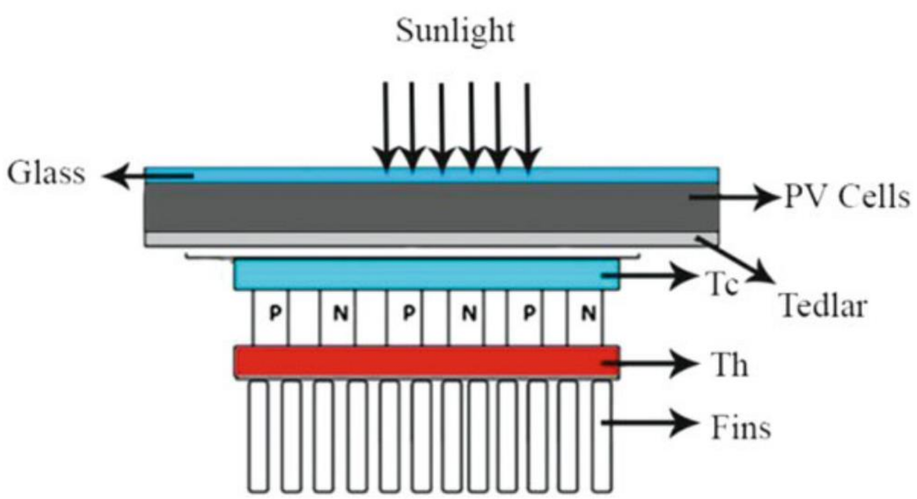

Figure 5.1 A schematic of hybrid PV cells combined with Peltier modules

The Peltier Effect

Thermoelectric coolers operate according to the Peltier effect. The effect creates a temperature difference by transferring heat between two electrical junctions. A voltage is applied across joined conductors to create an electric current. When the current flows through the junctions of the two conductors, heat is removed at one junction and cooling occurs. Heat is deposited at the other junction.

The main application of the Peltier effect is cooling. However the Peltier effect can also be used for heating or control of temperature. In every case, a DC voltage is required.

Elements of a Thermoelectric Cooler

Thermoelectric coolers from II-IV Marlow act as a solid-state heat pump. Each features an array of alternating n- and p- type semiconductors. The semiconductors of different type have complementary Peltier coefficients. The array of elements is soldered between two ceramic plates, electrically in series and thermally in parallel. Solid solutions of bismuth telluride, antimony telluride, and bismuth selenide are the preferred materials for Peltier effect devices because they provide the best performance from 180 to 400 K and can be made both n-type and p-type.

The cooling effect of any unit using thermoelectric coolers is proportional to the number of coolers used. Typically multiple thermoelectric coolers are connected side by side and then placed between two metal plates. . II-VI Marlow features three different types of thermoelectric coolers including: Thermocyclers, Single Stage, and Multi-Stage.

Heat Absorption

Cooling occurs when a current passes through one or more pairs of elements from n- to p-type; there is a decrease in temperature at the junction ("cold side"), resulting in the absorption of heat from the environment. The heat is carried along the elements by electron transport and released on the opposite ("hot") side as the electrons move from a high- to low-energy state.

The Peltier heat absorption is given by Q = P (Peltier Coefficient) I (current) t (time). A single stage thermoelectric cooler can produce a maximum temperature difference of about 70 degrees Celsius. However, II-VI Marlow’s Triton ICE Thermoelectric

Cooler will chill electronics as much as 2 degrees Celsius below current market offerings.

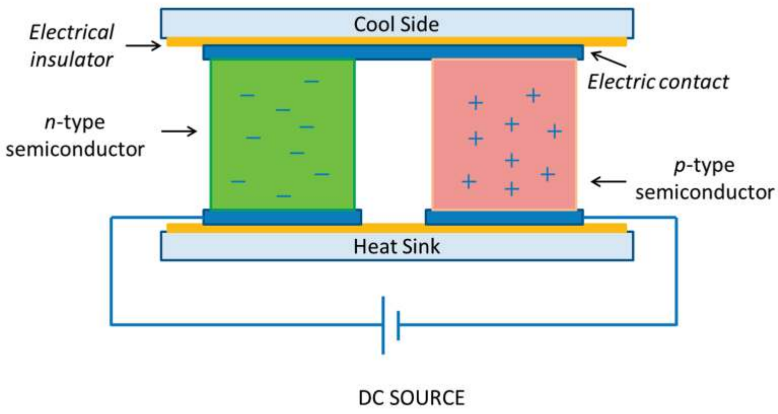

Figure 5.2 Schematic of a thermoelectric couple

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