REPUBLIC OF TURKEY
AYDIN ADNAN MENDERES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
MECHANICAL ENGINEERING
2021-M.Sc.-007

THE EXPERIMENTAL INVESTIGATION OF PHOTOVOLTAIC SYSTEM

Ramazan Burak DOMURCUK

Supervisor:

Asst. Prof. Dr. Mustafa ASKER
Prof. Dr. Pınar DEMİRCİOĞLU

AYDIN

REPUBLIC OF TURKEY
AYDIN ADNAN MENDERES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
AYDIN

REPUBLIC OF TURKEY
AYDIN ADNAN MENDERES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
AYDIN

I hereby declare that all information and results reported in this thesis have been obtained by my part as a result of truthful experiments and observations carried out by the scientific methods, and that I referenced appropriately and completely all data, thought, result information which do not belong my part within this study by virtue of scientific ethical codes.

11/01/2021

Signature

Ramazan Burak DOMURCUK

ÖZET

FOTOVOLTAİK SİSTEMİN DENEYSEL OLARAK İNCELENMESİ

Ramazan Burak DOMURCUK

Yüksek Lisans Tezi, Makine Mühendisliği Anabilim Dalı

Tez Danışmanı: Asst. Prof. Dr. Mustafa ASKER, Prof. Dr. Pınar DEMİRCİOĞLU

2021, 85 sayfa

Günümüzde ihtiyaç duyulan enerjinin büyük bir çoğunluğu fosil yakıtlardan elde edilmektedir. Bu yakıtların gerek çevreye verdikleri zararlar gerekse kaynaklarının sınırlı oluşu, alternatif enerji kaynakları arayışına sebep olmuştur. Güneş enerjisi, dikkat çekici yenilenebilir enerji kaynaklarından biridir ve enerji ihtiyacını karşılamak ve çevreyi korumak için çözümlerden biri olarak kabul edilmektedir.

Fotovoltaik panel sistemleri, güneş enerjisini doğrudan elektrik enerjisine dönüştürmesi gibi avantajı sebebiyle hızla yaygınlaşan önemli yenilenebilir enerji kaynaklarından biridir.

Bu tezde, monokristal ve polikristal güneş panelleri gibi iki farklı tipte fotovoltaik paneller deneysel olarak incelenmiş ve bu panellerin performansı değerlendirilmiştir. Analiz Türkiye'de Aydın ili için yapılmıştır. Deneysel ölçümler, Aydın ilinin hava koşullarında Ağustos ve Eylül aylarında gerçekleştirilmiştir. Ayrıca güneş radyasyonu piranometre cihazı ile ölçülmüştür. Panel yüzey sıcaklığı ise K tipi termokupl kullanılarak ölçülmüştür. Bu çalışmanın temel amacı, elektrik enerjisi üretimi yoluyla Aydın için en uygun panel tipinin belirlenmesi ve böylelikle yatırımcılara ve şirketlere bilimsel veriler sağlamaktır. Sonuçlar, monokristal ve polikristal güneş panelleri için elde edilen maksimum gücün sırasıyla 49.74 W ve 46.13 W olduğunu göstermektedir. Ayrıca monokristal ve polikristal güneş panellerinin maksimum verimi sırasıyla %13.94 ve %12.13 olarak belirlenmiştir.

Anahtar Kelimeler: Fotovoltaik, Güneş Enerjisi, Monokristal, Polikristal.

ABSTRACT

THE EXPERIMENTAL INVESTIGATION OF PHOTOVOLTAIC SYSTEM

Ramazan Burak DOMURCUK

M. Sc. Thesis, Department of Mechanical Engineering

Supervisor: Asst. Prof. Dr. Mustafa ASKER, Prof. Dr. Pınar DEMİRCİOĞLU

2021, 85 pages

Most of the energy needed today is obtained from fossil fuels. Both the damages that these fuels cause to the environment and the limited resources have led to the search for alternative energy sources. Solar energy is one of the remarkable renewable energy sources and is considered as one of the solutions to meet the power requirements and to protect the environment.

Photovoltaic panel systems are one of the substantial renewable energy sources which are rapidly becoming widespread due to its advantage such as converting directly solar energy into electrical energy.

In this thesis, two different types of photovoltaic panels such as monocrystalline and polycrystalline solar panels are examined experimentally and the performance of these panels is assessed. The analysis is carried out for the city of Aydın in Turkey. The experimental measurements are achieved under the weather condition of Aydın in August and September months. Besides, the solar radiation is measured using a pyranometer device. The panel surface temperature is measured using K type thermocouple. The main purpose of this work is to determine the most suitable panel type for the city of Aydın utilizing electric power generation and thus to provide scientific data to the investors and companies. The results indicate that for monocrystalline and polycrystalline solar panels, the obtained maximum power are 49.74 W and 46.13 W respectively. In addition, the maximum efficiency of monocrystalline and polycrystalline solar panels is determined to be 13.94% and 12.13%, respectively.

Keywords: Monocrystalline, Polycrystalline, Photovoltaic, Solar Energy

ACKNOWLEDGEMENTS

I wish to express my gratitude to my supervisor, Asst. Prof. Dr. Mustafa ASKER and Prof. Dr. Pınar DEMİRCİOĞLU who was offered invaluable support with her sincerity and belief in me. I am especially grateful to the head of Mechanical Engineering Department Prof. Dr. İsmail BÖĞREKCİ for his advices and comments.

I am grateful to my family for their supports.

I also want to express that this thesis is completed within the scope of the Department of Scientific Research Projects, Adnan Menderes University, with the same name and MF-17024 project number. I would like to give very special thanks for their support.

Ramazan Burak DOMURCUK

TABLE OF CONTENTS

LIST OF SUBSCRIPTS

W: Watt

Cd-Te: Cadmium-Telluride

m-Si: Monocrystalline Silicon

p-Si: Polycrystalline Silicon

h: Hour

E: Photon Energy

eV: Electron Volts

η: Photovoltaic Panel Efficiency

V_{max}: Maximum Voltage

P_{max}: Maximum Power

I_{max}: Maximum Current

P_{in}: Input Power

FF: Filling Factor

V_{oc}: Open Circuit Voltage

I_{sc}: Short Circuit Current

I: Load Current (A)

V: Voltage (V)

T: Absolute Temperature (K)

G: Solar Radiation (W/m^2)

LIST OF ABBREVIATIONS

PV: Photovoltaic

EU: Europe Union

STC: Standard Test Conditions

AC: Alternating Current

DC: Direct Current

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Background

Rapid population growth and industrialization in developing countries cause the demand for energy to increase rapidly. Energy is a necessary production factor in production and one of the basic indicators reflecting the economic and social development potential of a country. There is a linear relationship between energy consumption and social development, and it is observed that energy consumption increases with economic development and an increase in welfare.

Starting from the industrial age, the energy demand of developing countries is increasing rapidly. The use of renewable energy sources has gained importance in recent years due to vital reasons such as the decrease in fossil fuel reserves, environmental pollution and global warming. As it is an indispensable energy source as an alternative to fossil fuels; the renewable energy sector is the fastest-growing sector of today and the future. The potential of solar energy to become widespread is higher than other renewable energy sources due to its potential, ease of use, cleanliness, renewability and environmental friendliness. The biggest source of energy is the sun. Solar panels are the leading technologies that generate electricity from solar energy. Photovoltaic (PV) systems can convert solar energy directly into electricity, do not pollute the environment, their structure is simple and easy to implement. The photovoltaic panel converts the energy carried by sunlight directly into electrical energy by taking advantage of the internal photoelectric reaction. Electricity generation from solar energy is provided by different types of monocrystalline and polycrystalline solar panels called photovoltaic (PV). In this study, the performance of different types of solar panels will be experimentally investigated by comparing them with each other. The most important parameter that determines efficiency is the conversion of sunlight into usable electrical energy. Electricity generation from solar energy will be realized through the designed system and hourly data for August obtained from Aydın province will be presented. In this study, the effect of some design parameters such as panel surface temperature and solar radiation on the performance of different types of PV panels will be investigated experimentally. The current, voltage and power values generated from the solar panel will be recorded on the computer using the data obtained from the measuring devices used at certain time intervals, depending on the operating conditions, solar radiation, panel surface temperature. Thus, the efficiency of renewable energy sources and the potential of solar energy will be examined in order to meet the current energy needs in Aydın.

PV device manufacturers report performance values of 1000 W/m^2 radiation density and 25 °C operating temperature, which are only specified as standard test conditions in the device catalogs to be presented to the consumer. There will be significant differences between the conditions tested by the manufacturer and the actual operating conditions of the panel. There will be negative differences between the actual operating conditions and standard test conditions. These differences also affect the performance of photovoltaic panels. The actual energy production values of the photovoltaic panel can only be determined by testing with the panel in the relevant region. Thus, using the data obtained from different types of solar panels to be installed in the experiment, the relationship between them is determined by examining the solar radiation, panel surface temperature and panel output power.

The aim of this thesis is to obtain electricity from solar panels applied in Aydın province and analyze the performance of two different solar panel systems with hourly data and compare the results with the analytical and experimental solutions. Particularly this thesis does;

1. Investigate the efficiency of monocrystalline and polycrystalline panels under Aydın conditions,
2. Examine the effect of electrical and environmental parameters affecting the performance of monocrystalline and polycrystalline solar panels on panel performance in Aydın province,
3. Compare the numerical results with the previous studies and analytical solutions,
4. Determine the most suitable panel type for Aydın region within the framework of efficiency analysis and to provide scientific data to investors.

In the “Literature Review” chapter, it has been assessed that there are the effect of electrical and environmental parameters on the performance of monocrystalline and polycrystalline solar panels. Also, it has been assessed that monocrystalline solar panels are more efficient than polycrystalline solar panels.

In the chapter “Material and Method”;

1. The materials used are described thoroughly and the measurement process are presented,
2. The details of PV solar panels and devices used in experiment and method are presented,
3. The measurement values for a monocrystalline photovoltaic solar panel at a different angle of inclination are presented.

The results of the experimental investigations were analyzed and recorded. The following steps are in the “Results and Discussion” chapter as:

1. The effect of electrical and environmental parameters affecting the performance of monocrystalline and polycrystalline solar panels in Aydın province are presented,
2. The test results of current, voltage, power, solar radiation, panel surface temperature, panel efficiency, filling factor and performance rate for the monocrystalline and polycrystalline photovoltaic solar panel are presented,
3. The results of the above mentioned are discussed.

In the last chapter “Conclusions”

1. The results of this investigation have been summarized and presented while the conclusion is studied.
2. Recommendations and suggestions for further works have been given and the benefits of this investigation are presented.

In this study, pyranometer, digital multimeter, K type thermocouple, monocrystalline and polycrystalline solar panels are used as materials. In the study, solar radiation, current, voltage and panel surface temperature values are determined and the power values of monocrystalline and polycrystalline solar panels depending on time, solar radiation and panel surface temperature are calculated. The power values generated by monocrystalline and polycrystalline photovoltaic panels under real atmospheric conditions are measured by the experimental method in Aydın during August of 2020.

This fundamental study will offer new information about solar panels applied in Aydın province and to reveal the performance of two different solar panel systems with hourly data by taking into consideration the effect of electrical and environmental parameters affecting the performance of monocrystalline and polycrystalline solar panels by test measurement.

1.2. Solar Energy and Renewable Energies

The source of solar energy is the electromagnetic and thermal energy released as a result of fusion reactions occurring in the core of the star located in the center of our solar system. The extra-atmospheric value of this energy from the sun is approximately 1367 W/m². In the atmosphere, it can take values in the range of 0-1100 W/m² at sea level as a result of reflection, dispersion, absorption and other obstacles. Photovoltaic cells are energy conversion devices consisting of semiconductor structures that can convert electromagnetic energy from the sun into electrical energy.

Earth is located in the solar system consisting of the sun and surrounding planets. The sun is a fundamental energy source for the world. It is known that the surface temperature is approximately 6000 ^{0}C. The sun is a high-temperature gas mass that radiates heat and light. Although its distance from the earth is 150 million km, the rays emitted by the sun reach the earth in 8 minutes. The nuclear reactions that take place in the center of the sun are reactions that occur by the fusion of hydrogen nuclei. As a result of these reactions, very high energy is generated. These reactions, called fusion, are called thermonuclear reactions at high temperatures and with the help of atomic nuclei. Since the amount of helium spent in the sun is less than the amount of hydrogen spent, the difference is that it gives radiation energy from the sun. (Erkul, 2010)

73% of the mass of the Sun is hydrogen, 25% helium, and 2% other elements. Some energy is produced as a result of fusion reactions (transformation of hydrogen into helium during nuclear reactions) occurring in the sun (Eren, 2019).

The properties of solar energy are listed as follows(Mutluay, 2016);

- Being a pure type of energy, solar energy does not have harmful effects such as carbon, smoke, dust or sulfur.

- Solar energy, which has high energy and effect that all countries in the world can benefit from, has made all countries of the world dependent on itself with this feature.
- Solar energy, which does not require any fee for the resource other than facility and maintenance costs, is a continuous type of energy.
- It is not a complex system with its establishment, operation and absence of waste.

Not all of the solar energy that reaches the earth as the solar energy potential of our world is transformed into usable energy. After these rays enter the atmosphere, some of them are absorbed by the clouds and the atmosphere, some of them are reflected and the rest reach the earth directly(Girgin, 2011). Figure 1.1 shows the distribution of sun rays falling on earth.

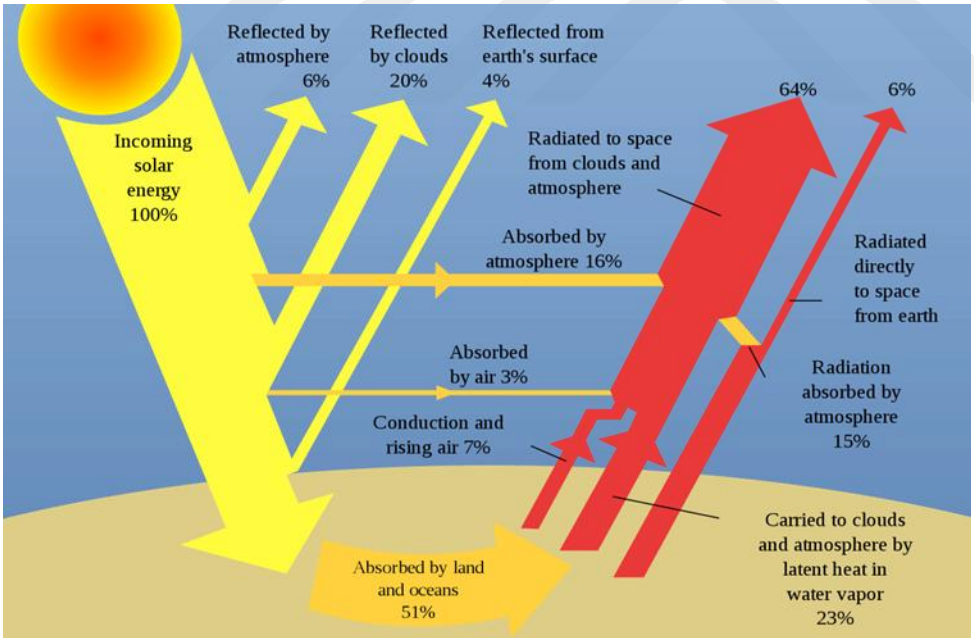


Figure 1.1. Distribution of sun rays falling on earth (Girgin, 2011)

Incoming solar energy is 100%. Reflected by the atmosphere is 6%. Reflected by clouds is 20%. Reflected from the earth's surface is 4%. Absorbed by the atmosphere is 16%. Absorbed by air is 3%. Conduction and rising air is 7%. Absorbed by land and oceans 51%. Radiated to space from clouds and atmosphere is 64%. Radiated directly to space from the earth is 6%. Radiation absorbed by the atmosphere is 15%. Carried to clouds and atmosphere by latent heat in water vapor is 23%, as shown in Figure 1.1.

1.3. Usage Areas of Solar Energy Photovoltaic System

The usage areas of solar energy photovoltaic system are as follows;

- In some wristwatches and calculators, in the form of small solar cells,
- In the electricity requirement of satellite systems sent to space,
- Electricity requirement of roadside emergency telephones,
- Traffic lights and signs,
- Recently, in the park, garden and street lighting,
- To produce hot water,
- To meet the electricity needs,
- For irrigation of agricultural lands,

Hot Water Generation: These are systems used to meet the domestic hot water need, especially in residences, by using roof collectors.

Solar Lighting: Street lamps and lightings or lighting in gardens is a type of lighting that is made by using solar panels to obtain the energy used from the sun during the day.

Electric Energy: It is the generation of electrical energy that can be used in factories, workshops, rural areas, homes and workplaces by using solar cells (Koca, 2019)

As the agricultural uses of solar energy, lighting, water extraction and drainage works, agricultural electricity generation, pump operation, etc. countable. In addition, all the electrical requirements of farm buildings, lighting of poultry and barns, incubators, egg sorting machines, air conditioners, milking facilities, milk cooling tanks, agricultural cold storage, drying facilities, electrical machines used in food production facilities and similar many solar energy can be used to support the electrical requirements of multi-agricultural systems.

1.4. Solar Energy Potential In Turkey

Nowadays, when renewable energy resources have become very important for countries and states, studies on this subject have also accelerated. Especially in recent years, our country has made great strides in the energy sector and many studies have been carried out to improve the sector. Because Turkey has great potential in terms of renewable energy sources. Our country has a high solar energy potential due to its geographical location. This potential is especially prominent in solar energy. Compared to Europe and other world states, our country's annual sunshine duration is quite high.

1.5. Structure and Types of Solar Cells

The structure of the PV cell can generally be in different shapes such as square, rectangular, and circular and PV cell sizes can vary between 1 cm and 15 cm and thicknesses between 0.2-0.4 mm. Figure 1.2 shows the schematic representation of the solar cell.

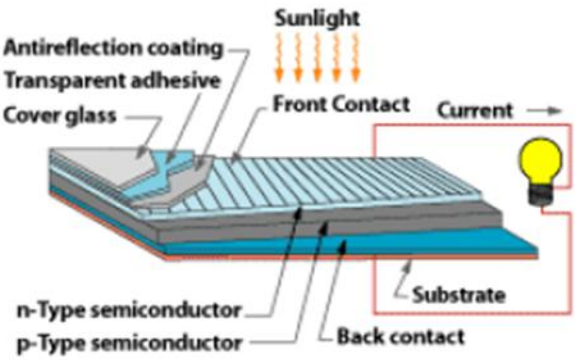


Figure 1.2. Schematic representation of the solar cell (Dişli, 2018)

The working principle of PV panels is based on semiconductor technologies. When solar radiation occurs on two P and N type semiconductor layers that make up the cell, the absorbed photons cause a potential difference between the semiconductors. This potential difference creates the electron current.

As shown in Figure 1.2 , on the upper surface of the cell, front contacts are placed to collect the current generated by the cell and whose material is usually copper. The transparent cover layer is the transparent layer that protects the semiconductor material and electrical conductors from outdoor weather conditions. Solar radiation permeability properties of this layer determine the efficiency of the collector. Electric conductors are one of the important factors that determine the quality of the cell, as the front and rear conductors on the PV cells act as a bridge in the removal of the generated energy. The rear conductor is formed as a plate under the cell. In the upper part of the cell, metal grids are used as preconductors to ensure the access of solar radiation to the semiconductor material. The grid wires should be thick enough to provide good transmission and not create much resistance, and thin enough not to prevent light from entering the semiconductor material (Mutluay, 2016).

Solar panels can be produced using many different materials. The most used ingredients today are:

- Crystalline Silicon Solar Panels
- Monocrystalline Silicon Solar Panels
- Polycrystalline Silicon Solar Panels
- Ribbon Silicon Solar Panels
- Thin Film Solar Panels
- Amorphous Silicon Solar Panels
- Cadmium Telluride Thin Film Solar Panels
- Copper indium Diselenoid Solar Panels

1.5.1. Crystalline Silicon Solar Panels

The most important material for crystalline photovoltaic cells is silicon. Silicon is the second most common element in the world, after oxygen, and is available in almost unlimited quantities. In nature, it is not pure but is found in quartz or sand bound with oxygen. Crystalline Silicon solar cells are divided into two as monocrystalline and polycrystalline.

1.5.2. Monocrystalline Silicon Solar Panels

Monocrystalline Silicon Solar Cells (m-Si) have the highest efficiency. It is seen that the property of this material is homogeneous in structural and electrical properties and that it maintains its properties for a long time. For these reasons, they are the most efficient but costly cells. Its colors are between dark blue and black. The efficiency of monocrystalline silicon batteries available in the market varies between 15% and 18%. The monocrystalline solar panel is illustrated in Figure 1.3.

Figure 1.3. Monocrystalline solar panel

1.5.3. Polycrystalline Silicon Solar Panels

Polycrystalline Silicon Solar Cells (p-Si) have less efficiency than monocrystalline due to their lower efficiency. Since they do not have a homogeneous structure like monocrystalline, they have low cost and low efficiency and they are easy to manufacture. Its colors are between blue and gray. The Polycrystalline solar panel is illustrated in Figure 1.4.

Figure 1.4. Polycrystalline solar panel

1.5.4. Ribbon Silicon Solar Panels

These cells are made of sheets of silicon in order to reduce material loss. These batteries, obtained by various methods, are still under development. Their efficiency is between 13-16% under laboratory conditions.

1.5.5. Thin Film Solar Panels

Thin-film PV devices require very little material. They have additional advantages in terms of ease of production. Thin-film solar cells consist of extremely thin layers of semiconductors superimposed. Thin-film cells can be made of many different materials. Thin-film cells, which are widely used commercially, are made of amorphous silicon. The thin-film solar cell is illustrated in Figure 1.5.

Figure 1.5. Thin film solar cell

1.5.6. Amorphous Silicon Solar Panels

Amorphous structures are structures in which the cell structure is irregular. Therefore, the efficiency of amorphous solar cells is low and they are mostly used in small electronic structures in daily life.

1.5.7. Cadmium Telluride Thin-film Solar Panels

It is estimated that the cost of solar panels will be lowered with Cadmium Telluride (CdTe), which is a very crystalline material. A yield of 16% is obtained in laboratory type small cells and around 7% in commercial type modules.

1.5.8. Copper Indium Diselenoid Solar Panels

The absorption coefficients of this semiconductor are quite high. The advantage of this thin-film solar cell technology over others is its high optical absorption coefficient (Taşçıoğlu, 2015).

1.6. Solar Cell (PV) and Its Working Principle

Photovoltaic is a combination of the greek words photo, meaning light, and voltaic, which means voltage, inspired by Alessandra Volt, who designed the machine that improves the electric current. Solar cells are devices that operate according to the photovoltaic (PV) principle and can convert sunlight directly on their surfaces into electrical energy. Photons, which have an energy greater than the band gap of the semiconductor material used in the production of PV solar cells, generate photocurrent by producing electron-gap pairs in the battery. Thus, the solar cell operating as a semiconductor diode converts the energy carried by sunlight into electrical energy directly by taking advantage of the internal photoelectric reaction (Çıngı, 2019).

In order to increase the power output, many solar cells are connected to each other in parallel or series and mounted on a surface. This structure is called a solar cell module or PV module (panel). Depending on the power requirement, these modules can be connected in series or parallel to create arrays, and by combining arrays, PV systems with energy production capacities from Watt to Mega Watt can be created. When the radiation falls on the cell, the voltage at the ends is around 0.7 V and this value decreases when an electronic load is connected to the ends (Bayat, 2016). Figure 1.6 shows the PV cell, module, array and PV system, respectively.

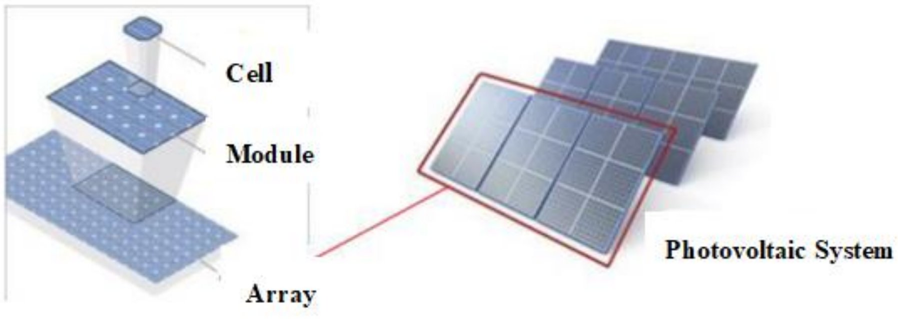


Figure 1.6. Photovoltaic cell, module, array and photovoltaic system display (Bayat, 2016)

Photoelectric effect: When sunlight falls on the semiconductor material, the energy of the radiation moves the electrons in the outermost orbit of the matter atoms. The electric current on conductors is created by the movement of these loose electrons of the atoms. Electrons do their work by leaving their energies on the barriers(resistance-charge) they encounter (Demirtaş, 2006). Figure 1.7 shows the schematic representation of the photovoltaic effect in a solar cell.

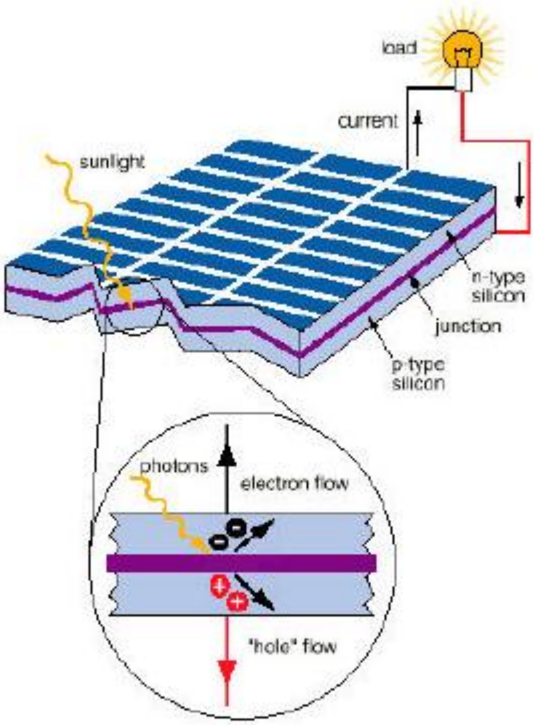


Figure 1.7. Schematic representation of the photovoltaic effect in a solar cell (Erkul, 2010)

In atoms with more than one electron orbit, the electrons in the closest orbit to the nucleus have the least energy and need the highest amount of energy to overcome the gravitational force of the nucleus, while the electrons in the outer orbit of the nucleus have the highest energy to become free, they need the least amount of energy. Figure 1.8 shows the conductivity energy band diagram of insulator, semiconductor and conductor.

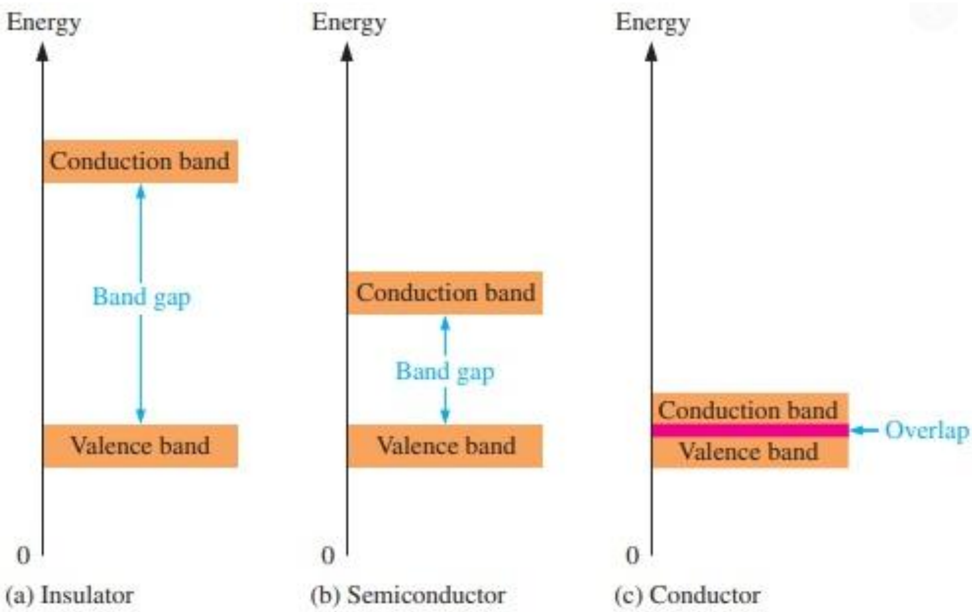


Figure 1.8. Conductivity energy band diagram of ınsulator, semiconductor and conductor (Yıldız, 2019)

The energy levels in semiconductors and insulators between the energy level of valence electrons and the next energy level where these electrons can be found are energies for which electrons are prohibited. The energy band where the valence electrons are located is called the "valence band" and the energy band starting from the first energy levels where electrons can be found after the forbidden energy range is called the "conductivity band". The size of the forbidden energy range is the measure of whether the substance is classified as a semiconductor or insulator. If the energy of photons, which we define as energy-carrying units in solar radiation, is equal to or greater than the forbidden energy range, it transfers its energy to an electron in the valence band and takes it to the conductor band. If the forbidden energy band is greater than 2.5 eV (electron volts), the substance is an insulator. The reason why the material used is semiconductor is that the forbidden energy range that absorbs sunlight can work in harmony with the solar spectrum and has a long bandwidth that allows electrical charges to diverge (Erkul, 2010).

In insulators with very few free electrons, the energy range is wide. Therefore, free electrons can not pass into the conduction band. In conductors with more free electrons than insulators, the conduction band and valence band are almost intertwined, so most valence electrons can pass to the conduction band without applying external energy. The energy range of semiconductors is wider than conductors and narrower than insulators.

1.7. System Applications of Photovoltaic Panels

There are 3 types of applications of photovoltaic systems as off-grid, grid-connected and hybrid systems.

1.7.1. Off Grid Systems of Photovoltaic Panels

These systems are used in places where access to the network is difficult. Electricity produced in these systems, which are independent of the network, is stored in batteries. These systems consist of PV panels, charging groups and batteries. If it is desired to convert direct current to alternating current, an inverter is added next to them. In other words, the system can feed both direct current (DC) loads and alternating current (AC) loads. Figure 1.9 shows the schematic of off-grid PV systems.

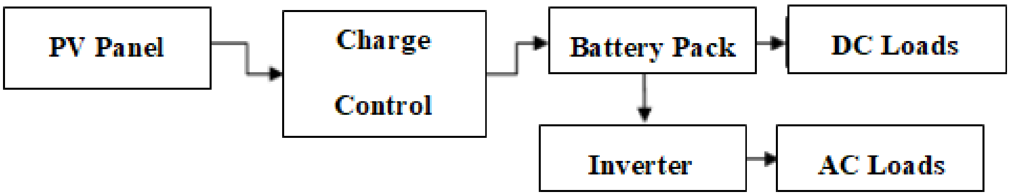


Figure 1.9. Schematic of off-grid pv systems

1.7.2. Grid-Connected Systems of Photovoltaic Panels

Grid-connected PV systems can be designed in 2 ways. The first of these can feed the grid directly by converting the generated direct current to alternating current through an inverter. The schema of PV systems directly connected to the grid is given in the figure. The other is grid-connected PV systems used in domestic applications. In these systems, it is the use of a bidirectional counter after the inverter. Thus, various loads can be fed and excess energy is supplied to the network. In case of insufficient sunlight, energy is provided from the grid. Figure 1.10 shows the schematic of PV systems connected directly to the grid.

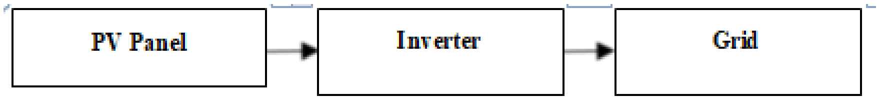


Figure 1.10. Schematic of pv systems connected directly to the grid

Figure 1.11 shows the schematic of grid-connected PV system used in domestic applications.

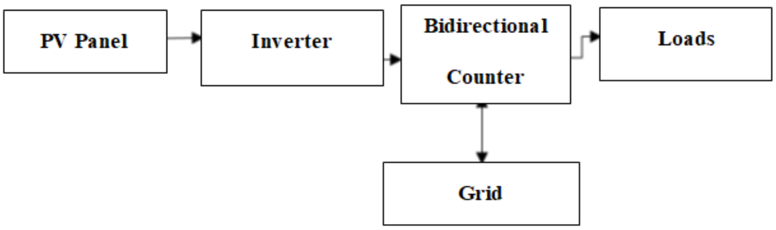


Figure 1.11. Schematic of grid connected pv system used in domestic applications

1.7.3. Hybrid Systems of Photovoltaic Panels

In hybrid systems, a different source is used next to solar panels. This source can be a renewable energy source such as a wind turbine or a non-renewable energy source such as a diesel generator. This system aims to generate more electricity. Figure 1.12 shows the schematic of the PV system connected to the hybrid system.

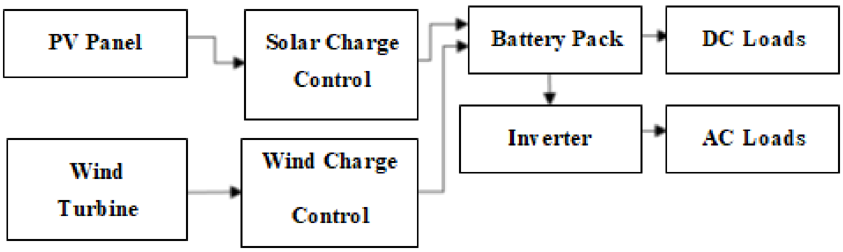


Figure 1.12. Schematic of the pv system connected to hybrid system (Eren, 2019)

1.8. Advantages and Disadvantages of Solar Cells (Photovoltaic Panels)

Advantages of PV electricity generation (Taşçıoğlu, 2015);

- Can be installed where you need it.
- Quick and easy to install. Its capacity can be easily increased or decreased according to the needs.
- It is very long-lived (20-25 years on average, although theoretically infinite).
- It is quiet and clean. It does not cause environmental pollution.
- Suitable for mass production.
- Its raw material, silicon, is one of the most abundant materials in the world. It does not use consumable materials such as petrol, coal, copper.
- They do not limit the building design.

Disadvantages of PV electricity generation (Taşçıoğlu, 2015);

- Its initial investment is high.
- Since it cannot produce continuously, the energy produced must be stored with a battery.
- Areas rich in sunbathing are needed.
- Approximately 10 m^2 of the area is required for each kW of power.
- In regions receiving a lot of sunlight, there is a decrease in efficiency due to heat.

2. LITERATURE REVIEW

In the beginning, books, articles, journals, scientific standards, library and internet resources have been examined and reviewed. Previous studies including former researches on the performance of photovoltaic solar panel systems, solar energy potential, the parameters that affect the efficiency of solar panels have been analyzed.

Sabounchi (1998) determined the effect of the ambient temperature on the energy produced by the panel at different placement angles of the panel by experimental study. Sabounchi also determined that the incident radiation value continues to increase up to a certain point according to the placement angle of the panel and it decreases after a certain point.

Notton et al. (2005) stated that part of the radiation that does not transform emerges as heat loss. They determined that the real data obtained from the environment were applied to the thermal model created for the panel and the performance of the panel under real conditions.

Bulut et al. (2006) carried out the experimental investigation of the values of solar radiation on the inclined surface, the solar radiation on the inclined surface was experimentally measured and compared with existing methods. Solar radiation intensity on 15°, 30°, 45°, 60° and 90° inclined surfaces was transferred to a computer environment with a pyranometer and data logger. Measurements were made only for Şanlıurfa province in their study. They compared that the measured and calculated inclined surface radiation values.

Şenpınar (2006) analyzed to obtain high efficiency from sunlight by using fixed and tracer solar panel systems. Fixed systems are placed at a certain inclination relative to the horizontal. This slope varies according to the geographical location of the region and the seasons. He calculated the optimum slope angle in the region depending on the seasons during the year.

Varınca and Gönüllü (2006) investigated that both existing and potential power generation systems based on solar among renewable energy sources have an important place in terms of the different production technologies. They also investigated that Turkey's solar energy potential and this potential degree and method of use.

Dobrzanski (2010) compared the electrical properties of monocrystalline and polycrystalline silicon solar cells. He carried out this process in line with current-voltage characteristics and mathematical calculations.

Dinçer (2011) examined the solar energy potential in Turkey. He made comparative cost analyzes of electricity generation from solar energy between EU countries and our country and accordingly stated that incentives and support should be given to increase the use of solar panels by encouraging the private sector to participate in the development of renewable energy resources.

Ju and Fu (2011) investigated the effect of dust on photovoltaic panel performance in their study. They reported that in order to clearly express the effect of photovoltaic panel power generation on efficiency under the same light intensity and the same ambient conditions, the ratio of the polluted surface photovoltaic panel electricity generation efficiency to the clean surface photovoltaic panel electricity generation efficiency is named as "Photovoltaic Pollution Factor Coefficient". In their study, two separate experimental setups were set up, namely the panel assembly that was left to be contaminated under natural conditions and the panel setup that was left to artificial contamination. In the system, which was left to be dusted under natural conditions between 20 July and 4 August, the dirt on the photovoltaic panel surface was swept at certain intervals and the weight of the dirt was measured and temperature data were taken from the photovoltaic panel during the experiment. According to these data, they observed that the efficiency decreases as the amount of dust on the panel surface increases.

Karaca et al. (2011) revealed Konya's solar energy potential and included the details of an exemplary application made in Konya on solar electricity generation.

Parida et al. (2011) studied photovoltaic systems and electricity generation technology in their research. They stated that solar energy is the most abundant, inexhaustible and cleanest of all renewable energy sources used to date and also one of the best ways to benefit from solar energy is photovoltaic technology. The researchers touched upon the subjects of photovoltaic technology, power generation capacity, application areas and environmental aspects.

Turhan and Çetiner (2012) presented parameters that affect the performance of using PV systems in buildings. They studied factors such as location, orientation and surface inclination angle, shading, panel type, maintenance and cleaning, the temperature behind the modules separately. They gave information by relating the building analysis results to the factors affecting performance. They observed that PV panels achieve maximum performance in applications that prefer regions with high annual solar energy values, are placed with the right inclination angle, use panels made with high-performance cell technologies, take precautions against shading risks, provide ventilation on the back of the module, and pay attention to surface cleaning during use.

Özçalık, Yılmaz and Kılıç (2013) derived the mathematical model of a single diode photovoltaic panel and graphed the changes in the current, voltage and power characteristics of solar cells.

Thevenard and Pelland (2013) stated that the uncertainties affecting the long-term efficiency of photovoltaic panels under atmospheric conditions and real field conditions. They reveal these uncertainties affecting the operating performance of the system as the atmospheric and environmental conditions. At the beginning of the atmospheric conditions that adversely affect the operation of the solar panel are the environmental temperature, wind, dust and falling snow mass. They stated that there are connection losses in the connections of electrical equipment along with environmental factors.

Başoğlu et al. (2015) presented the energy performance analysis of three different photovoltaic (PV) modules under İzmit and Kocaeli weather conditions. He made some comparative analyzes to show the solar energy potential of İzmit and Kocaeli. For this purpose, using crystalline (cSi), polycrystalline (mc-Si) and cadmium-telluride (Cd-Te) modules, he installed three on-grid photovoltaic power systems on the roof of Kocaeli University Engineering Faculty. He monitored these photovoltaic power systems from October 2013 to December 2014. He calculated the average values of the performance ratios as 83.8%, 82.05% and 89.76% for the Mc-Si, c-Si and Cd-Te, respectively. He concluded that Cd-Te can be considered as more reliable sequences under İzmit climatic conditions for all months since it has the highest capacity factors during Cd-Te.

Esen and Kapıcıoğlu (2015) examined how the proximity of solar panels to the ground affects solar cell efficiency in their study. For this, they determined 4 different heights at 0, 10, 20, 30 cm from the ground and reported that they obtained the best efficiency in the solar cell they placed at a height of 20 cm.

Oğuz et al. (2015) realized that the energy generation by mounting 100 W monocrystalline, polycrystalline and thin-film solar panels on the roof of Afyon Kocatepe University Technology Faculty. With the C # software, they instantly monitored the electrical energy (volt / watt) produced by the solar panels. They recorded the measured values in the database in 10 seconds time interval. By examining the data recorded in the database, they determined which solar panel's efficiency is suitable for this region. They stated that while monocrystalline and polycrystalline solar panels are required in approximately the same amount to meet the electrical energy need of a house in the installed system, thin-film solar panels are required twice as much, the efficiency values of monocrystalline and polycrystalline solar cells are very close to each other and that polycrystalline panel is suitable in terms of price.

Taşçıoğlu (2015) measured the power outputs of polycrystalline and monocrystalline panels with two different technologies under the conditions of Bursa province and stated that the power output increases with the increase of the radiation intensity and there is a linear relationship between radiation and power. He obtained that 87.14 W power from a monocrystalline solar panel under 1001.13 W / m2 total solar irradiance and 80.17 W power from a polycrystalline solar panel under 1001.13 W / m2 total solar radiation.

Demiröz et al. (2016) produced electrical energy using solar cells. He collected solar hourly data of Bilecik and Kütahya provinces.

Kaddoura et al. (2016) stated that the angle of inclination in PV modules is the most important factor affecting the amount of radiation falling on the panel surface. In their study by using the MATLAB simulation program, the researchers state that changing the angle of inclination 6 times a year helps to benefit from 99.5% of the sun rays coming to the PV surface.

Kutlu (2016) calculated that an off-grid solar energy system installation to meet the needs of a house in Isparta climate conditions, and his results show that it would be profitable when evaluated for summer and winter months.

Zaraket et al. (2017) determined the effects of cell temperature on performance, power and efficiency in PV modules. Researchers stated that cell temperature is the most important factor affecting these three properties. They reported that an inverse relationship between cell temperature and performance. As the cell temperature increases, the efficiency of the PV panels decreases.

Arslan (2018) investigated the efficiency of 150 W monocrystalline and polycrystalline panels under Tekirdağ conditions. He compared the efficiency of the incoming radiation, current, voltage, power parameters generated by the panel. He aimed to determine the most suitable panel type for Tekirdağ and West Marmara region and thus to provide scientific data to investors and to prevent loss of productivity and unnecessary investments with the help of applied and comparative experiment setup. He measured that the efficiency of the monocrystalline panel under Tekirdağ climate conditions as 15%, and the efficiency of the polycrystalline panel under Tekirdağ climate conditions as 14.9%.

By Er et al. (2018) examined that the effect of temperature and radiation on photovoltaic panel performance, temperature values, voltage and current values were taken for solar panels. Experimental studies show that the conditions in which the efficiency of a PV panel is affected. Their results show that the high temperatures that occur in the solar panels to reduce the open-circuit voltage and cause the current values of the panel to decrease. They observed that the damaged part of the cell cannot generate electricity, therefore the cell has increased its own temperature, and they reported that the performance is reduced.

Alaaeddin et al. (2019) stated that both the PV cell structure and conversion efficiency may contribute to the progression of the PV system. They used a wide range of advanced materials within the PV cell. The improvement of PV structures and their optical properties results in optimizing solar radiation and reflectance. They reported that modelling and implementing appropriate parameters such as diode, optical, current, voltage, filling factor contributed to the efficiency and performance of the PV system.

Senthil Kumar et al. (2019) reported that solar energy is an important energy source for the future. They determined that solar PV panel performance changes with temperature increase. They stated that the photovoltaic solar cell's efficiency may be decreased owing to the increase of temperature. They determined that the life of the solar panel will be decreased.

Ogbulezie et al. (2020) stated that solar cells are sensitive to temperature. They examined the impact of temperature and irradiance source on the efficiency of polycrystalline photovoltaic (PV) solar panels in an environment. Their result showed that there is a decrease in voltage with increasing temperature.

Shafique et al. (2020) determined that the benefits and challenges related to PV-green roofs. They reported that the PV-green roof is an effective strategy for producing clean energy on the building. They stated that providing the optimum design of PV-green roofs for climatic region; improving laws and regulations; evaluating life-cycle including social, environmental, and economic benefits; and cooperation tools for the adoption of PV-green roof systems.

Sonsuz et al. (2020) investigated that the effect of pollution on monocrystalline and polycrystalline PV panels on short circuit current and open circuit voltage was investigated by external experiments. They conducted under climate conditions in Hatay province. Environmental factors have been found to affect the short circuit current of the panels. It has been observed that cleaned panels have higher short circuit current values than uncleaned panels.

2.1. Historical Development of Solar Cells

French physicist Alexandre Edmond Becquerel noticed the effect of light on the voltage between electrons in the electrolyte in 1839 and observed the first photovoltaic phenomenon. With the discovery of silicon crystals in 1876, William G. Adams and Richard E. Day observed that photovoltaic effects also exist in solid bodies. However, the full disclosure of the photovoltaic effect was first made by Albert Einstein in 1905, and these works brought him the Nobel Prize in Physics in 1921. In 1954, with the development of technology, the efficiency of the photovoltaic module made of silicon was measured as 6% by Darly Chaphin, Calvin Fuller and Gerald Pearson, and this development was accepted as a turning point for photovoltaic cells. The first photovoltaic system was used in space technology, which was developing rapidly at that time, and the first technical application took place in the "Vanguard 1" satellite. With the oil crisis that emerged in 1973, large-budget and comprehensive research began on photovoltaic batteries. Over time, with the increase of environmental awareness, interest in photovoltaic batteries has increased gradually (Erkul, 2010).

The historical development of PVs is summarized below depending on the years (Mutluay, 2016).

- In 1839, it was discovered by the French scientist Edmond Becquerel that two electrodes placed in a conductive solution generate electricity when exposed to light.
- In 1876, William Grylls Adams and Richard Evans Day discovered that selenium generates electricity when exposed to light.
- In 1883, the first solar cell made of selenium is described by Charles Fritts.
- In 1916, Robert Millikan experimentally proved the photoelectric effect.
- In 1918, polish Jan Czochralski developed monocrystalline silicon.
- In 1932, the PV effect of cadmium sulfide was discovered by Audobert and Stora.
- In 1951, the first germanium-based solar cell was discovered.
- In 1954, a silicon solar cell was patented in Bell Laboratory.
- In 1955, Western Electric obtained the commercial license to sell silicon PV technologies.
- In 1957, Hoffman Electronic achieved 8% efficiency in PV cells.
- In 1960, Hoffman Electronic achieved 14% efficiency in PV cells.
- In 1964, NASA launched the nimbus spacecraft into space. Its satellite is powered by 470 W PV.
- In 1966, NASA launched a 1 kW array PV-powered sky observatory.
- In 1981, the first solar-powered airplane was built by Paul Mac Cready. It flew from France to England with more than 16000 solar cells and 3000 W of energy.
- In 1985, South Wale University silicon solar cell has achieved 20% efficiency.
- In 1992, by the University of South Florida, the efficiency was increased to 15.9% by using cadmium telluride in thin-film solar cell.

3. MATERIAL AND METHOD

The materials used are described thoroughly and the measurement process is presented. The details of PV solar panels and devices used in the experiment and method are presented. The measurement values for a monocrystalline and polycrystalline photovoltaic solar panel at a different angle of inclination are presented. An experimental study of monocrystalline and polycrystalline solar panels is conducted by using measuring devices in August and September.

3.1. Materials Used In Experimental Study

The monocrystalline panel is illustrated in Figure 3.1. The number of cells is 36. On the other hand, the maximum power output of it is 80 W. The monocrystalline photovoltaic solar panel technical specifications are listed in Table 3.1.

Figure 3.1. Monocrystalline photovoltaic solar panel

Table 3.1. Monocrystalline photovoltaic solar panel technical specifications

Technical Specifications	Values
Maximum Power (P_{max})	80 W
Maximum Power Voltage (V_{mp})	17.20 V
Maximum Power Current (I_{mp})	4.66 A
Open Circuit Voltage (V_{oc})	22.10 V
Short Circuit Current (I_{SC})	5.30 A
Maximum System Voltage	700 V DC
Number of Cells	36
Dimension	1190X550X30 mm

The polycrystalline photovoltaic solar panel is illustrated in Figure 3.2. The number of cells is 36. On the other hand, the maximum power output of it is 80 W. The polycrystalline photovoltaic solar panel technical specifications are listed in Table 3.2.

Figure 3.2. Polycrystalline photovoltaic solar panel

Table 3.2. Polycrystalline photovoltaic solar panel technical specifications

Technical Specifications	Values
Maximum Power (P_{max})	80 W
Maximum Power Voltage (V_{mp})	17.7 V
Maximum Power Current (I_{mp})	4.51 A
Open Circuit Voltage (V_{oc})	21.5 V
Short Circuit Current (I_{SC})	5.05 A
Maximum System Voltage	1000 V DC
Power Tolerance	± 3%
Dimension	810X670X30 mm
Weight	8 kg

The pyranometer solar radiation measurement device is illustrated in Figure 3.3. It is used to measure solar radiation values. The Apogee MP-200 pyranometer solar radiation measurement device technical specifications are listed in Table 3.3.

Figure 3.3. Pyranometer solar radiation measurement device

Table 3.3. Apogee MP-200 pyranometer solar radiation measurement device technical specifications

Technical Specifications	Values
Calibration Uncertainty	± 5 %
Measurement Repeatability	< 1 %
Non-stability (Long-term Drift)	< 2 % per year
Non-linearity	< 1 % (up to 1750 W/m^2)
Response Time	< 1 ms
Field of View	180°
Spectral Range	360 to 1120 nm
Directional (Cosine) Response	± 5 % at 75° zenith angle
Temperature Response	0.04 ± 0.04 % per C
Operating Environment	0 to 50 C
Meter Dimensions	12.6 cm length, 7.0 cm width, 2.4 cm height
Sensor Dimensions	2.4 cm diameter and 2.8 cm height
Mass	180 g

The TT-TECHNIC Class MY-62 digital multimeter measurement device is illustrated in Figure 3.4. It is used to measure values of the current, voltage and panel surface temperature with K-type thermocouple. The TT-TECHNIC Class MY-62 digital multimeter measurement device technical specifications are listed in Table 3.4.

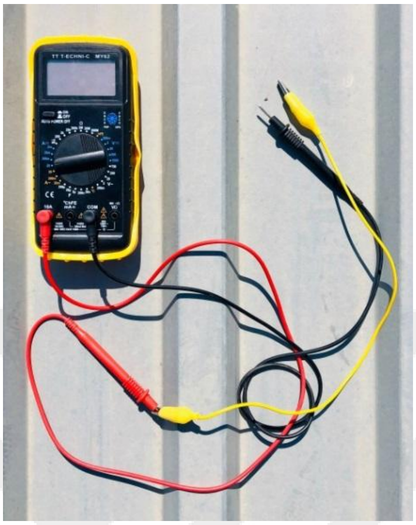


Figure 3.4. Class my-62 digital multimeter measurement device

Table 3.4. Class my-62 digital multimeter measurement device technical specifications

Technical Specifications	Values
Reading	1999Count
DC Voltage	1000V
DC Voltage Stage	200mV, 2V, 20V, 200V, 1000V... [± 0.8% + 1]
AC Voltage	700V
AC Voltage Stage	200mV, 2V, 20V, 200V, 700V... [±1.2% + 3]
DC Current	10A
DC Current Stage	2mA, 20mA, 200mA, 10A... [±2% + 5]
AC Current	10A
AC Current Stage	2mA, 20mA, 200mA, 10A... [±3% + 7]
Temperature	-20 ~ 1000 degree
Dimension	91 X 189 X 31.5mm
Battery	9V

The K type thermocouple for photovoltaic solar panel surface temperature measurement is illustrated in Figure 3.5. It is used to measure values of panel surface temperature by using a digital multimeter.

Figure 3.5. K type thermocouple for photovoltaic solar panel surface temperature measurement

The smd led light flexible strips is illustrated in Figure 3.6. It is used to measure current and voltage values by generating a charge on a photovoltaic system. The smd led light flexible strips technical specifications are listed in Table 3.5.

Figure 3.6. Led light

Table 3.5. Led light flexible strips technical specifications

Technical Specifications	Values
Voltage	16 V
Current	5 A
Length	5 m
Color	Blue
Number of Lights	60
Type of Bulb	Led

3.2. Experimental Data Measurement

In this experimental study, a system stand with adjustable inclination in a single axis, 80 W monocrystalline and polycrystalline solar panels, two digital multimeters measuring current, voltage and temperature, a pyranometer, a 5 meter long LED light that enables the panel to generate current again by using the generated direct current is used as a test setup. The current and voltage values produced by the photovoltaic panel are measured by digital multimeters and recorded hourly. At the same time, the solar radiation value and the panel surface temperature are determined and the measured parameters are recorded simultaneously. In the experimental study carried out by using the test setup established in Aydın Adnan Menderes University Faculty of Engineering in Aydın province, a total of 8 days of measurements were made in August and September period. The relationship between the instantaneous power produced hourly on the measurement days and the radiance value of that moment and the panel surface temperature was determined. With this experimental system, solar radiation (G), panel surface temperature (T), voltage (V) and current (A) values are measured and the panels are compared with each other hourly for 8 different days. It has been determined that the power and efficiency values obtained under real operating conditions and the power and efficiency values given by the manufacturer of the photovoltaic panel are different. The monocrystalline and polycrystalline photovoltaic solar panels are illustrated in Figure 3.7.

Figure 3.7. Monocrystalline and polycrystalline photovoltaic solar panels

There are factors such as efficiency and filling factors affecting the performance of photovoltaic panels. The photovoltaic panel efficiency effect is the relationship between the power obtained from the solar cell and the power obtained from the sun rays. The efficiency parameter of the solar cell is the ratio of the output power obtained from the solar cell to the P_{max} input power (P_{in}). The input power is obtained by dividing the solar intensity (W/m^2) on the cell by the cell area. Photovoltaic panel efficiency is given in Equation 1.

Photovoltaic panel efficiency(Chandler, 2015);

$$\eta = \frac{P_{max}}{P_{in}} = \frac{(V_{max}\ I_{max})}{G \times A} = \frac{(FF\ V_{oc} I_{sc})}{G \times A} \qquad (1)$$

where;

η = Photovoltaic Panel Efficiency

V_{max} = Maximum Voltage

P_{max} = Maximum Power

I_{max} = Maximum Current

P_{in} = Input Power

G = Solar Radiation

A = Cell Area

FF = Filling Factor

V_{oc} = Open Circuit Voltage

I_{sc} = Short Circuit Current

One of the important factors affecting panel efficiency is the filling factor. The Filling Factor (*FF*) defines the maximum output power based on the open-circuit voltage and short circuit current. The filling factor is a parameter expressing the quality of the cell. The filling factor is given in Equation 2 (Rahmanov, 2019).

$$FF = \frac{(P_{max})}{(V_{oc}\, I_{sc})} = \frac{(V_{max}\, I_{max})}{(V_{oc}\, I_{sc})} \quad (2)$$

where;

FF = Filling Factor $\quad$ P_{max} = Maximum Power

V_{max} = Maximum Voltage $\quad$ I_{max} = Maximum Current

V_{oc} = Open Circuit Voltage $\quad$ I_{sc} = Short Circuit Current

Monocrystalline and Polycrystalline solar panels are mounted at angles of 10 °C, 20 °C, 30 °C, 40 °C, 50 °C, 60 °C on the system stand with adjustable inclination and the radiation, current, voltage and power values generated by the panels shown in Tables (3.6 – 3.7). In addition, the optimum inclination angle for both solar panels where they generate the most power is determined as 20 °C. Table 3.6 presents the measurement values for the monocrystalline photovoltaic solar panel at a different angle of inclination.

Table 3.6. Measurement values for monocrystalline photovoltaic solar panel at different angle of inclination

Angle of Inclination	**Solar Radiation (W/m^2)**	**Current (A)**	**Voltage (V)**	**Power (W)**
10°	820	2.56	18.60	47.62
20°	950	2.62	18.80	49.26
30°	860	2.58	18.70	48.25
40°	790	2.52	18.50	46.62
50°	780	2.48	18.40	45.63
60°	760	2.45	18.30	44.84

Table 3.7 presents the measurement values for a polycrystalline photovoltaic solar panel at a different angle of inclination.

Table 3.7. Measurement values for polycrystalline photovoltaic solar panel at different angle of inclination

Angle of Inclination	**Solar Radiation (W/m^2)**	**Current (A)**	**Voltage (V)**	**Power (W)**
10°	810	2.34	17.80	41.65
20°	940	2.40	18.00	43.20
30°	850	2.36	17.90	42.24
40°	780	2.30	17.70	40.71
50°	770	2.26	17.60	39.78
60°	750	2.23	17.50	39.03

4. RESULTS AND DISCUSSION

The measurement of the current, voltage and power values produced by photovoltaic cells under different radiation intensities and operating conditions is very important to assess the system performance. Because the current, voltage and power output of photovoltaic devices depend on the radiation intensity, panel surface temperature and other climatic parameters. In addition to these parameters, factors such as regular maintenance of the panel, cleaning, proper orientation and set the appropriate angle of inclination, the shading should also be taken into consideration.

The environmental factors that effect the performance of photovoltaic panels are solar radiation intensity, temperature, humidity(moisture), shading, air pollution, dust accumulation, wind speed and panel inclination angle. Considering the solar radiation effect, increasing the intensity of solar radiation increases the current and power value as it will increase the possibility of breaking more electrons than the n-type semiconductor material on the photovoltaic cell. Considering the temperature effect, solar radiation falling on the photovoltaic cells significantly changes the temperature of the photovoltaic cell. This changing temperature of the cells also causes the efficiency values to change by affecting the structure of the semiconductors in the cell. There is an inverse relationship between efficiency and surface temperature of PV. When the surface temperature of PV increases, the efficiency of PV decreases. Therefore, high operating temperatures negatively affect the efficiency of PV systems. Considering the moisture effect, excess water vapor in the atmosphere causes the radiation to be shielded. Thus, it is seen that the efficiency of the panels decreases in humid areas. In other words, small puddles formed on the panels cause low efficiency in the panels by shading. As shading effect, shading of photovoltaic panels also significantly reduces panel efficiency. Considering the shading factor, which is a parameter that especially affects the amount of radiation, the shadows made by the elevations close to the areas where the panels will be placed cause the photovoltaic efficiency to decrease. For this reason, it is a point to be careful that there are no obstacles to create shadows on the facade where photovoltaic panels receive sunlight. As air pollution effect, the pollution of the air causes the radiation to be shielded in the sky, preventing the photovoltaic panels from receiving sufficient radiation and reducing the electrical power generation of the solar panel. As dust accumulation effect, dust in the air accumulates by falling on photovoltaic panels due to different factors. Dust accumulation increases over time and prevents the radiation coming to the panel from reaching the cells. The decrease in radiation causes the current generated to decrease and consequently the panel power generation to decrease. As wind speed effect, the photovoltaic panel positively affects the power output of the system, as the wind speed will reduce the PV panel temperature (Koca, 2019). As panel inclination angle effect, positioning of the panel is very important for maximum electricity generation. This angle of inclination, which varies according to the geographical location and the seasons, should be at the optimum value.

As a result, it is possible to examine and interpret the efficiency of two types of solar panels, 80 W monocrystalline and polycrystalline, in Aydın province conditions. The prices of panels based on different technologies are different, as well as their efficiency under STC (Standard Test Conditions). The values obtained as a result of the measurements made in the real environment are also different. In the framework of efficiency and cost analysis, optimum efficiency panel type has been determined for Aydın province and Aegean Region. In the framework of the research, the efficiencies were compared in terms of the amount of radiation coming to the panel, current, voltage, panel surface temperature, and the maximum power parameters produced by the panel and concluded. As a result of the measurements made in the system implemented, the voltage and power values produced by the monocrystalline and polycrystalline solar panels are close to each other. The maximum efficiency of the monocrystalline solar panel was determined to be 13.94%, and the maximum efficiency of the polycrystalline solar panel was 12.13% in the Aydın climate conditions. The average efficiency of the monocrystalline panel was obtained as 8.13%. The average efficiency of the polycrystalline panel was obtained as 8.52%. The temperature varied between 27 °C and 48 °C in the Aydın province because of the summer season during the experiment. Considering the conditions of our country and the amount of solar radiation in Aydın, it can be said that the use of monocrystalline panels will be suitable in terms of high efficiency.

In this section, the instantaneous power values produced by 80 W monocrystalline and polycrystalline solar panels in August and September are discussed. In the trials between 10:00 and 16:00 hours, in the monocrystalline solar panel, the highest power value is observed at 13:00 and measured as 49.74 W. In the polycrystalline solar panel, the highest power value is also observed at 13:00 and measured as 44.47 W. The electrical energy produced by an electrical system is directly proportional to the current and voltage values.

The results of current, voltage, panel efficiency, filling factor, performance ratio and solar radiation and the measurement results of monocrystalline and polycrystalline solar panels regarding time, panel surface temperature and solar radiation power values are given in the following separate headings. Tables (4.1 - 4.8) present the measurement values for photovoltaic solar panels between dates of 10.08.2020 and 13.08.2020.

The maximum current, voltage and power output values of monocrystalline solar panel are 2.66 A, 18.80 V, 49.74 W as listed in Tables (4.1 - 4.8). Solar radiation value of monocrystalline solar panel increased towards noon with respect to time. The maximum solar radiation value of monocrystalline is 1050 W/m^2 at hour of 13:00. The maximum efficiency value of it is 13.94% at hour of 10:00. The maximum filling factor and performance rate of monocrystalline are 0.42, 62.18% at hour of 13:00.

The maximum current, voltage and power output values of polycrystalline solar panel are 2.43 A, 18.30 V, 44.47 W as listed in Tables (4.1 – 4.8). Solar radiation value of polycrystalline solar panel increased towards noon with respect to time. The maximum solar radiation value of it is 1050 W/m^2 at hour of 13:00. The maximum efficiency value of it is 12.13% at hour of 10:00. The maximum filling factor and performance rate of it are 0.41, 55.59% at hour of 13:00.

Table 4.1. Measurement values for monocrystalline photovoltaic solar panel on the date of 10.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m²)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.12	18.50	39.22	430	30	13.94	0.33	49.03
11:00	2.46	18.60	45.76	640	31	10.92	0.39	57.20
12:00	2.56	18.40	47.10	730	40	9.86	0.40	58.88
13:00	2.66	18.70	49.74	860	36	8.84	0.42	62.18
14:00	2.62	18.50	48.47	920	42	8.05	0.41	60.59
15:00	2.60	18.40	47.84	950	43	7.69	0.41	59.80
16:00	2.54	18.10	45.97	836	39	8.40	0.39	57.46
Average	**2.51**	**18.46**	**46.3**	**766.57**	**37.29**	**9.67**	**0.40**	**57.88**

Table 4.2. Measurement values for polycrystalline photovoltaic solar panel on the date of 10.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m²)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	1.59	17.80	28.30	430	32	12.13	0.26	35.38
11:00	1.98	17.90	35.44	640	33	10.20	0.33	44.30
12:00	2.31	18.00	41.58	730	42	10.50	0.38	51.98
13:00	2.43	18.30	44.47	860	38	9.53	0.41	55.59
14:00	2.38	18.10	43.09	920	45	8.63	0.40	53.86
15:00	2.36	18.00	42.48	950	44	8.24	0.39	53.10
16:00	2.26	17.60	39.78	836	40	8.77	0.37	49.73
Average	**2.19**	**17.96**	**39.31**	**766.57**	**39.14**	**9.71**	**0.36**	**49.13**

Table 4.3. Measurement values for monocrystalline photovoltaic solar panel on the date of 11.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.49	18.40	45.82	560	32	12.50	0.39	57.28
11:00	2.55	18.60	47.43	740	40	9.79	0.40	59.29
12:00	2.59	18.80	48.69	890	39	8.36	0.42	60.86
13:00	2.50	18.40	46.00	990	46	7.10	0.39	57.50
14:00	2.44	18.20	44.41	1020	48	6.65	0.38	55.51
15:00	2.40	18.00	43.20	940	47	7.02	0.37	54.00
16:00	2.34	17.70	41.42	826	43	7.66	0.35	51.78
Average	**2.47**	**18.3**	**45.28**	**852.29**	**42.14**	**8.44**	**0.39**	**56.60**

Table 4.4. Measurement values for polycrystalline photovoltaic solar panel on the date of 11.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.05	16.90	34.65	560	35	11.40	0.32	43.31
11:00	2.35	17.80	41.83	740	40	10.42	0.39	52.29
12:00	2.40	18.00	43.20	890	38	8.94	0.40	54.00
13:00	2.35	17.80	41.83	990	48	7.79	0.39	52.29
14:00	2.33	17.70	41.24	1020	46	7.45	0.38	51.55
15:00	2.32	17.70	41.06	940	45	8.05	0.38	51.33
16:00	2.22	17.30	38.41	826	41	8.57	0.35	48.01
Average	**2.29**	**17.6**	**40.32**	**852.29**	**41.86**	**8.94**	**0.37**	**50.40**

Table 4.5. Measurement values for monocrystalline photovoltaic solar panel on the date of 12.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.35	17.90	42.07	590	27	10.89	0.36	52.59
11:00	2.41	18.10	43.62	790	35	8.44	0.37	54.53
12:00	2.45	18.20	44.59	920	43	7.41	0.38	55.74
13:00	2.46	18.40	45.26	1034	44	6.69	0.39	56.58
14:00	2.40	18.20	43.68	1040	45	6.42	0.37	54.60
15:00	2.36	18.00	42.48	950	41	6.83	0.36	53.10
16:00	2.30	17.70	40.71	836	37	7.44	0.35	50.89
Average	**2.39**	**18.07**	**43.20**	**880**	**38.86**	**7.73**	**0.37**	**54.00**

Table 4.6. Measurement values for polycrystalline photovoltaic solar panel on the date of 12.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	1.95	16.20	31.59	590	28	9.87	0.29	39.49
11:00	2.28	17.60	40.13	790	35	9.36	0.37	50.16
12:00	2.33	17.80	41.47	920	41	8.31	0.38	51.84
13:00	2.32	17.80	41.23	1034	42	7.36	0.38	51.54
14:00	2.27	17.70	40.18	1040	45	7.12	0.37	50.23
15:00	2.24	17.70	39.65	950	42	7.69	0.37	49.56
16:00	2.14	17.30	37.02	836	38	8.16	0.34	46.28
Average	**2.22**	**17.44**	**38.75**	**880**	**38.71**	**8.27**	**0.36**	**48.44**

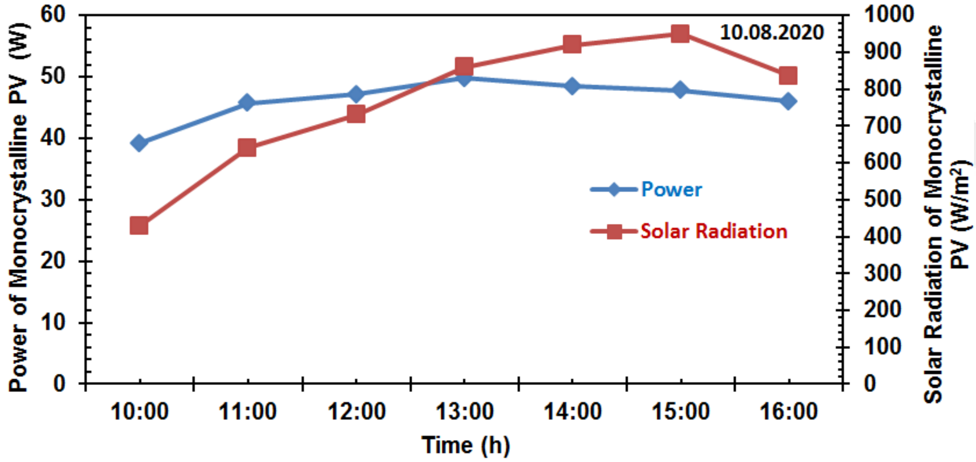
Table 4.7. Measurement values for monocrystalline photovoltaic solar panel on the date of 13.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.35	17.70	41.60	620	35	10.25	0.36	52.00
11:00	2.54	18.50	46.99	820	36	8.76	0.40	58.74
12:00	2.50	18.40	46.00	950	43	7.40	0.39	57.50
13:00	2.47	18.30	45.20	1050	47	6.58	0.39	56.50
14:00	2.44	18.20	44.41	1030	46	6.59	0.38	55.51
15:00	2.43	18.30	44.47	950	42	7.15	0.38	55.59
16:00	2.37	18.00	42.66	850	44	7.67	0.36	53.33
Average	**2.44**	**18.20**	**44.48**	**895.71**	**41.86**	**7.77**	**0.38**	**55.59**

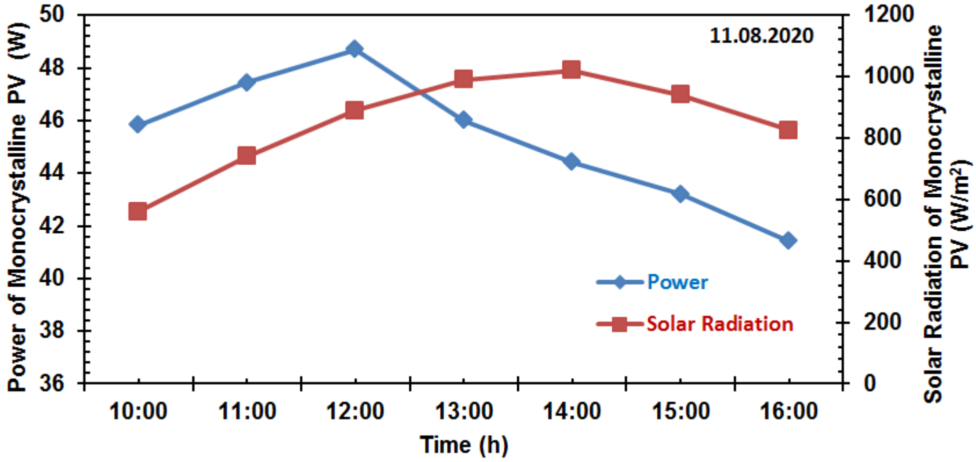
Table 4.8. Measurement values for polycrystalline photovoltaic solar panel on the date of 13.08.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.05	16.60	34.03	620	37	10.11	0.31	42.54
11:00	2.34	17.70	41.42	820	38	9.31	0.38	51.78
12:00	2.31	17.70	40.89	950	42	7.93	0.38	51.11
13:00	2.30	17.60	41.23	1050	46	7.10	0.37	51.54
14:00	2.29	17.60	40.48	1030	46	7.21	0.37	50.60
15:00	2.24	17.40	38.98	950	41	7.56	0.36	48.73
16:00	2.12	17.00	36.04	850	44	7.81	0.33	45.05
Average	**2.24**	**17.37**	**39.01**	**895.71**	**42**	**8.15**	**0.36**	**48.76**

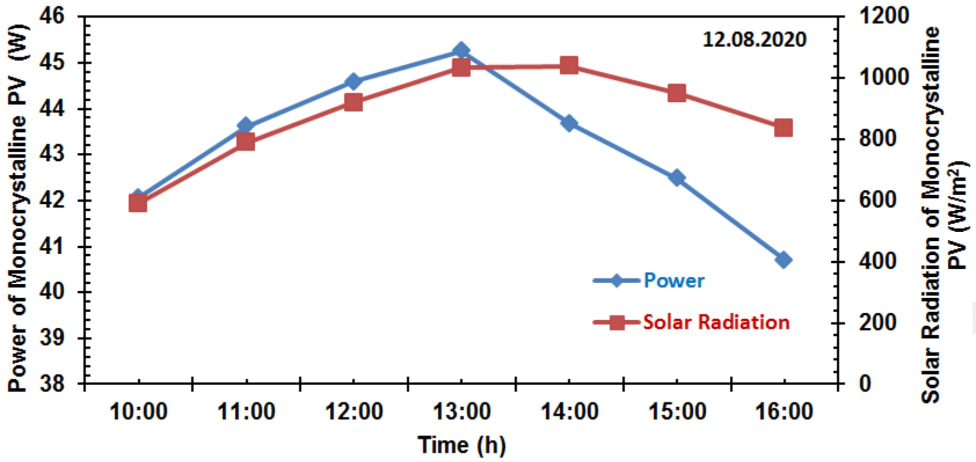
Figure 4.1 presents the relation between the power and solar radiation values of monocrystalline solar panel with respect to time. When measured power output and solar radiation values of monocrystalline PV are compared, there is a linear relationship between power output and solar radiation of monocrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.1. When the solar radiation of monocrystalline PV increases, the power output of monocrystalline PV increases. When the maximum power output value of monocrystalline PV is 49.74 W, the solar radiation of it is 860 W/m^2 on date of 10.08.2020 at hour of 13:00. When the minimum power output value of monocrystalline PV is 39.22 W, the solar radiation of it is 430 W/m^2 on date of 10.08.2020 at hour of 10:00.



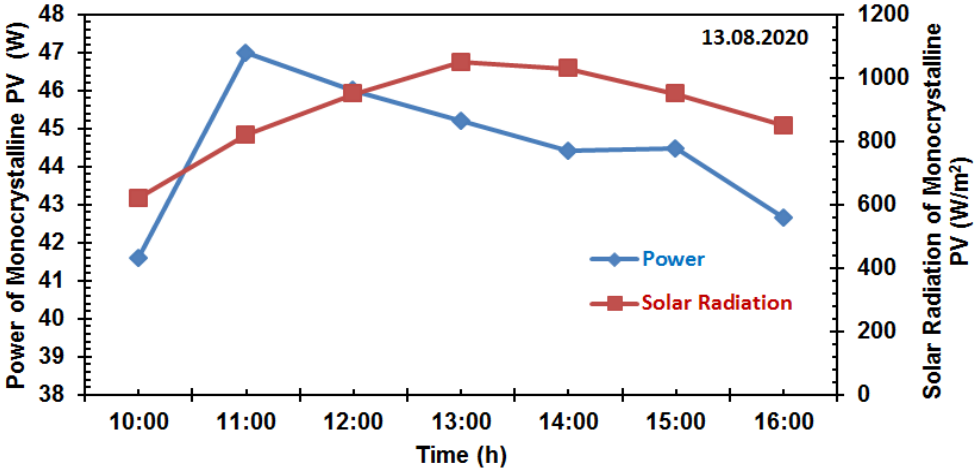
-a-



-b-



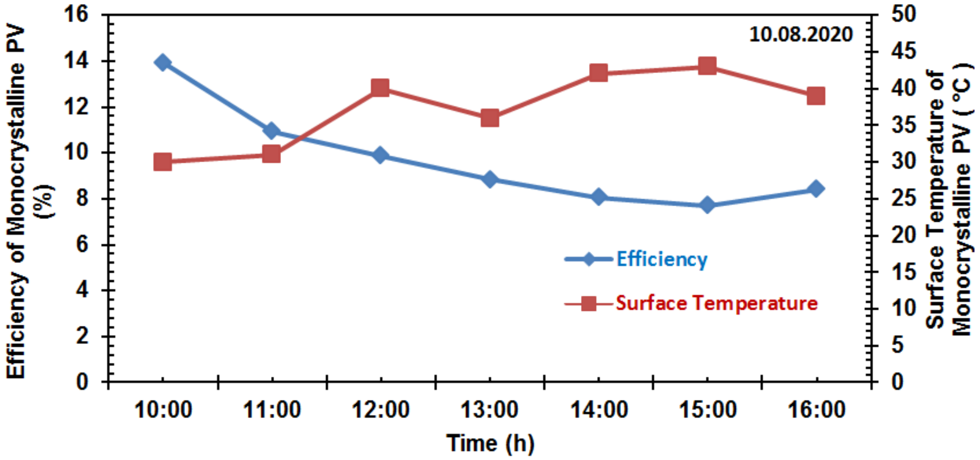
-c-



-d-

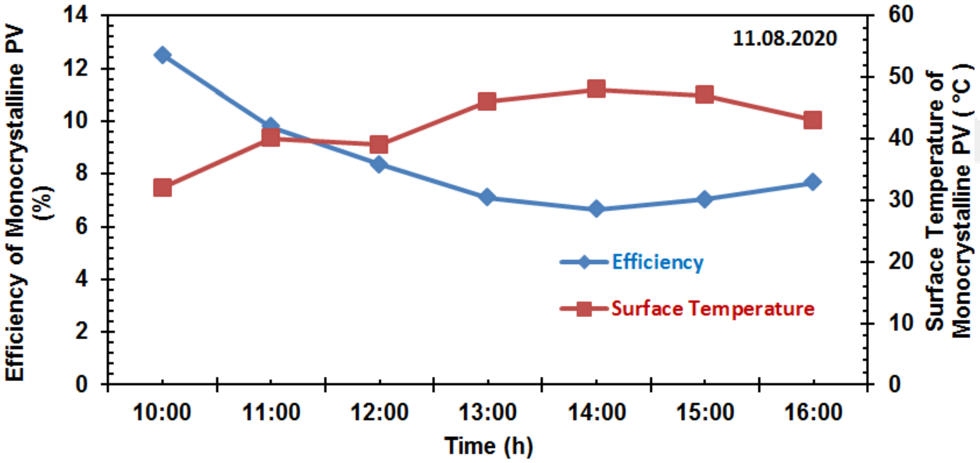
Figure 4.1. Relation between the power and solar radiation values for monocrystalline solar panel with respect to time

Figure 4.2 presents relation between the efficiency and surface temperature values of monocrystalline solar panel with respect to time. When measured efficiency and surface temperature values of monocrystalline PV are compared, there is an inverse relationship between efficiency and surface temperature of monocrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.2. When the surface temperature of monocrystalline PV increases, the efficiency of monocrystalline PV decreases. When the maximum efficiency value of monocrystalline PV is 13.94%, the surface temperature of it is 30 °C on date of 10.08.2020 at hour of 10:00. When the minimum efficiency value of monocrystalline PV is 6.42%, the surface temperature of it is 45 °C on date of 12.08.2020 at hour of 14:00.



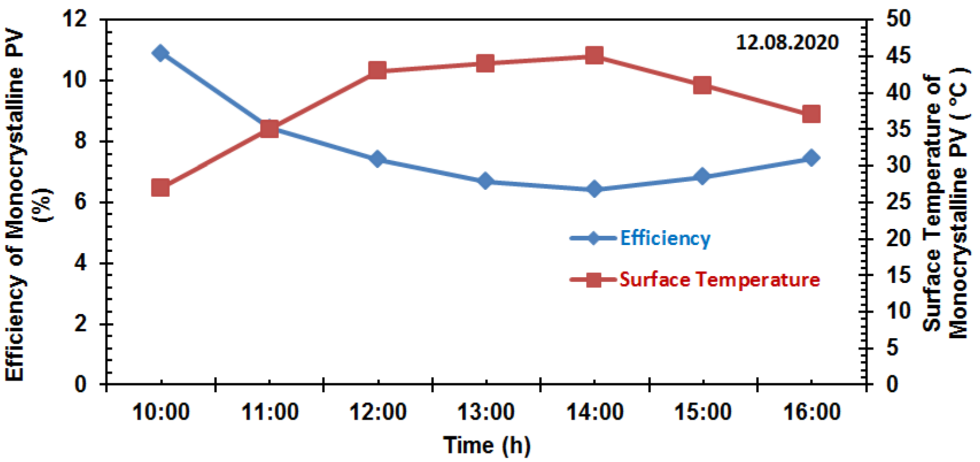
10.08.2020
Efficiency of Monocrystalline PV (%)
Surface Temperature of Monocrystalline PV (°C)
Efficiency
Surface Temperature
Time (h)
10:00
11:00
12:00
13:00
14:00
15:00
16:00

-a-



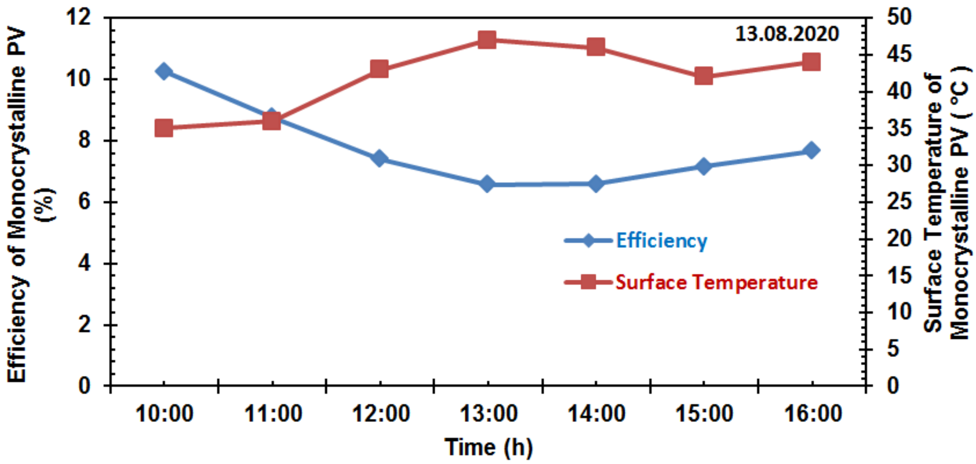
11.08.2020
Efficiency of Monocrystalline PV (%)
Surface Temperature of Monocrystalline PV (°C)
Efficiency
Surface Temperature
Time (h)
10:00
11:00
12:00
13:00
14:00
15:00
16:00

-b-



12.08.2020
Efficiency of Monocrystalline PV (%)
Surface Temperature of Monocrystalline PV (°C)
Efficiency
Surface Temperature
Time (h)
10:00
11:00
12:00
13:00
14:00
15:00
16:00

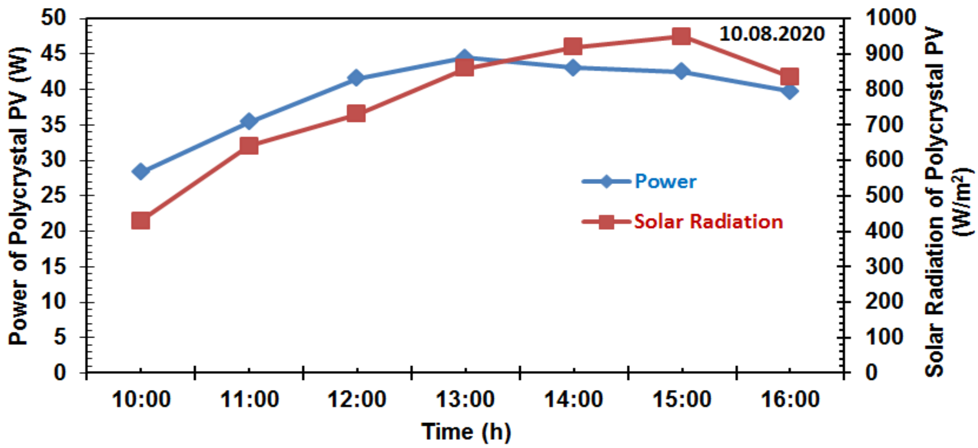
-c-



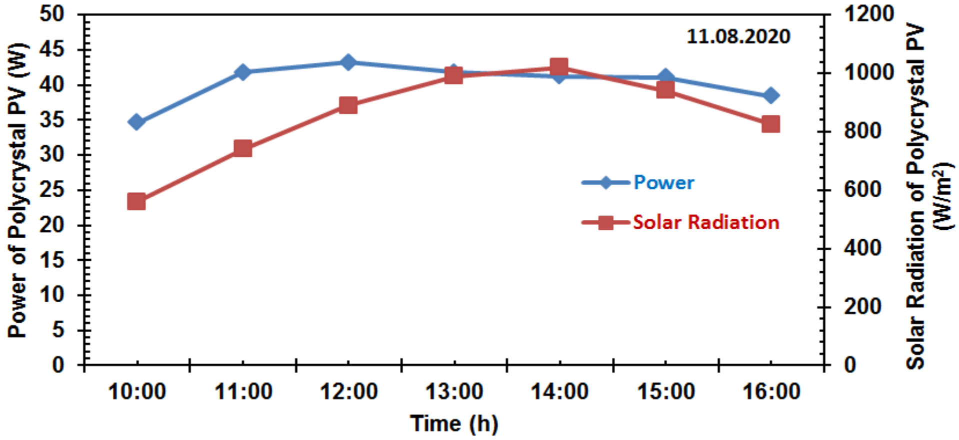
-d-

Figure 4.2. Relation between the efficiency and surface temperature values for monocrystalline solar panel with respect time

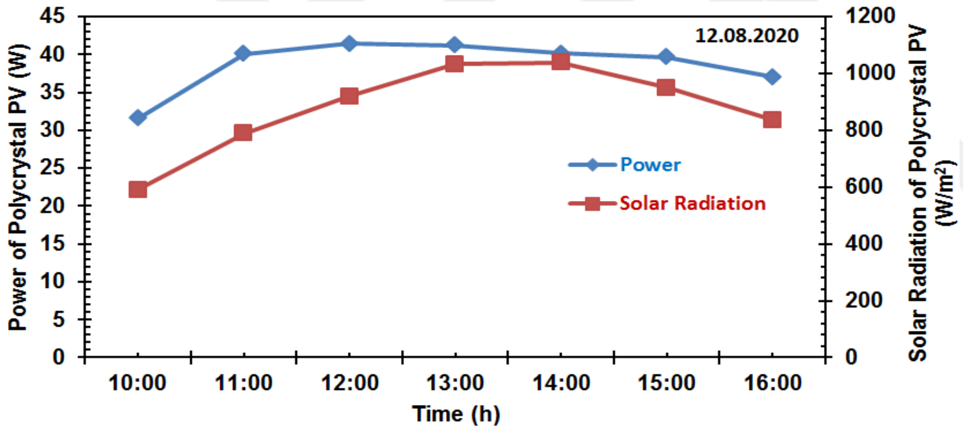
Figure 4.3 presents relation between the power and solar radiation values of polycrystalline solar panel with respect to time. When measured power output and solar radiation values of polycrystalline PV are compared, there is a linear relationship between power output and solar radiation of polycrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.3. When the solar radiation of polycrystalline PV increases, the power output of polycrystalline PV increases. When the maximum power output value of polycrystalline PV is 44.47 W, the solar radiation is 860 W/m^2 on date of 10.08.2020 at hour of 13:00. When the minimum power output value of polycrystalline PV is 28.30 W, the solar radiation of it is 430 W/m^2 on date of 10.08.2020 at hour of 10:00.



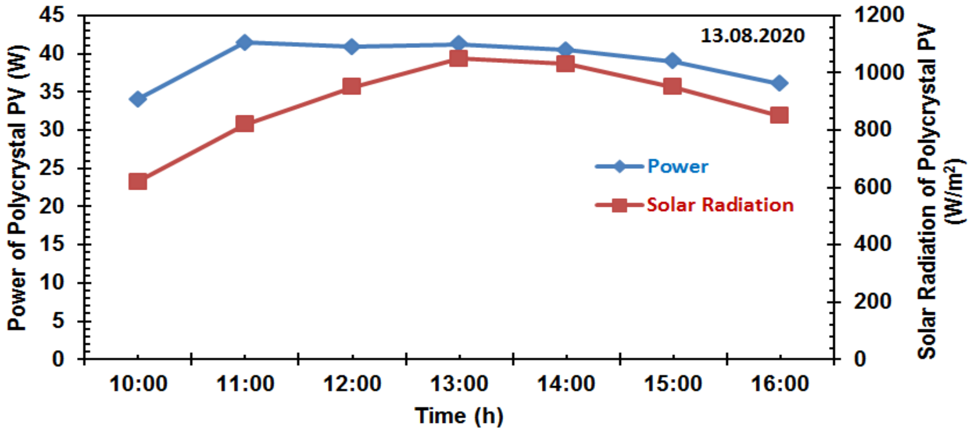
-a-



-b-



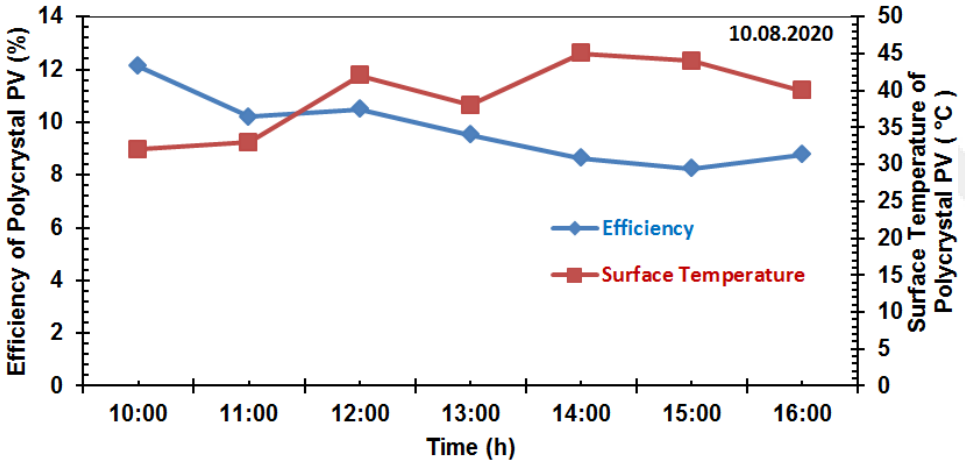
-c-



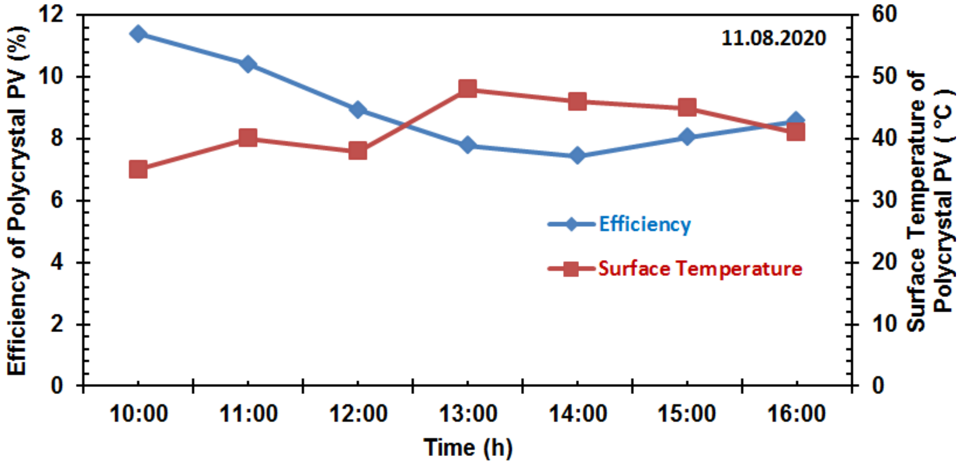
-d-

Figure 4.3. Relation between the power and solar radiation values for polycrystalline solar panel with respect to time

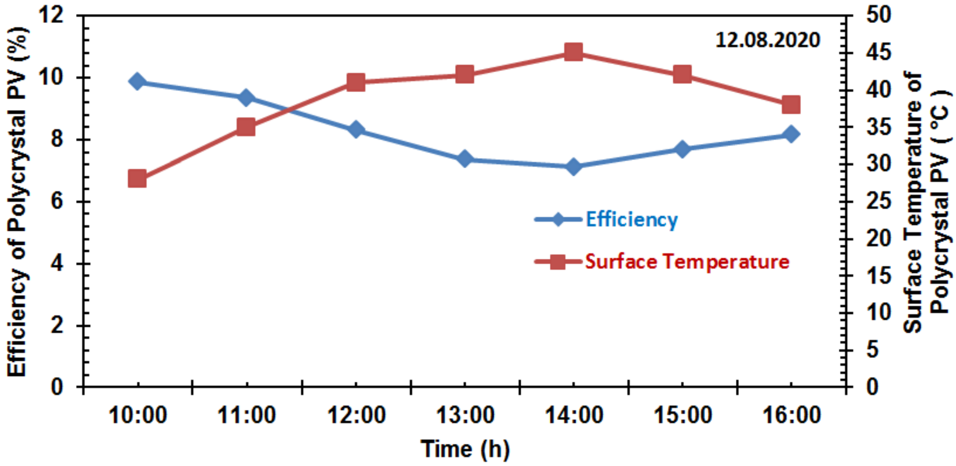
Figure 4.4 presents relation between the efficiency and surface temperature values of polycrystalline solar panel with respect to time. When measured efficiency and surface temperature values of polycrystalline PV are compared, there is an inverse relationship between efficiency and surface temperature of polycrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.4. When the surface temperature of polycrystalline PV increases, the efficiency of polycrystalline PV decreases. When the maximum efficiency value of polycrystalline PV is 12.13%, the surface temperature of it is 32 °C on date of 10.08.2020 at hour of 10:00. When the minimum efficiency value of polycrystalline PV is 7.10%, the surface temperature of it is 46 °C on date of 13.08.2020 at hour of 13:00.



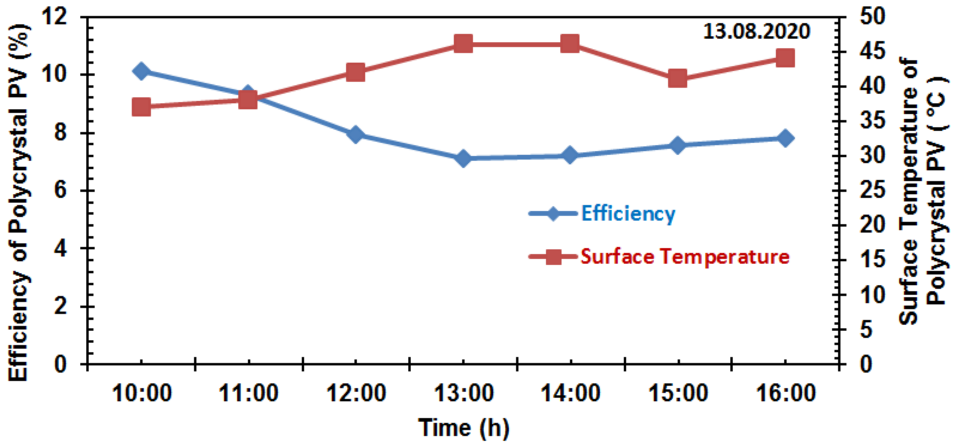
-a-



-b-



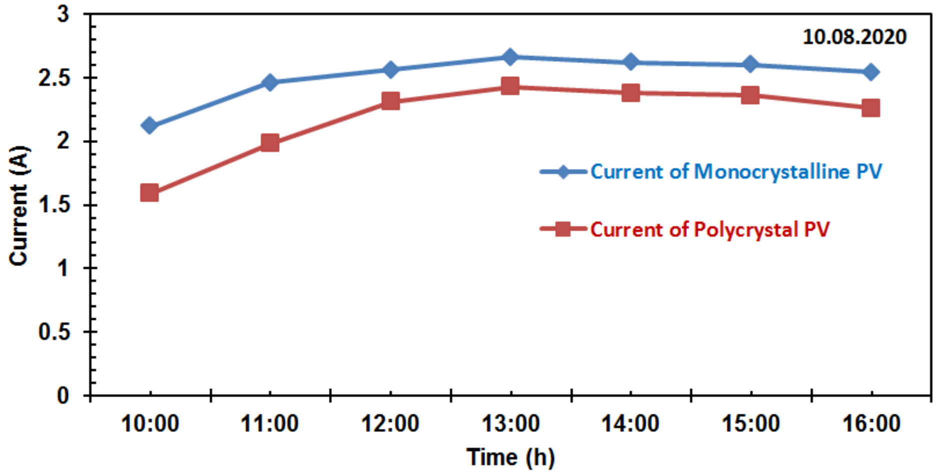
-c-



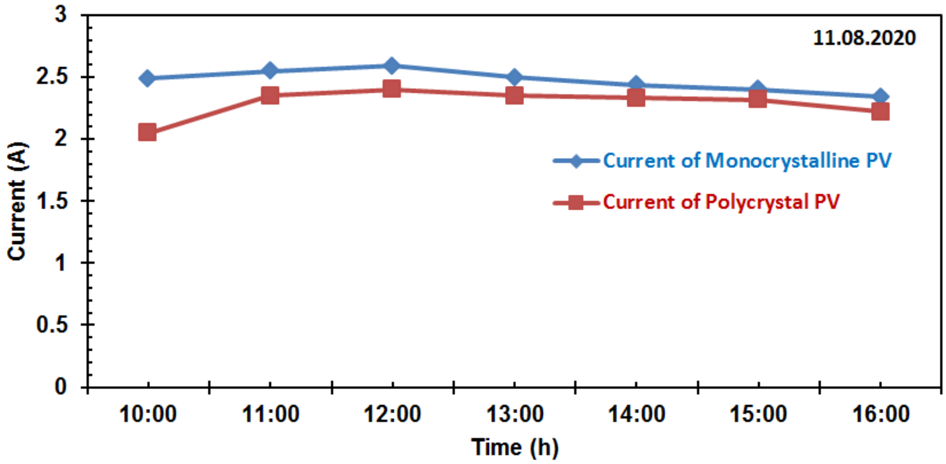
-d-

Figure 4.4. Relation between the efficiency and surface temperature values for polycrystalline solar panel with respect to time

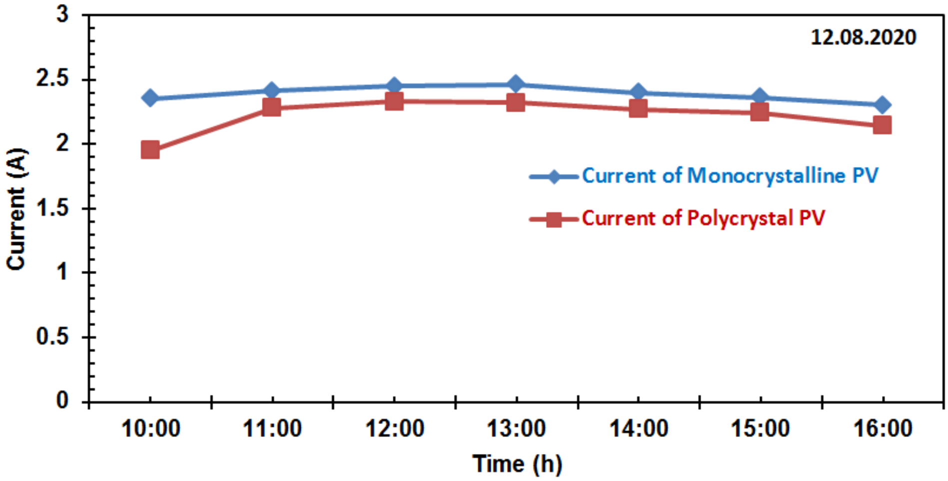
Figure 4.5 presents the variation of current values belong to monocrystalline and polycrystalline solar panels with respect to time. Current values of monocrystalline PV are greater than current values of polycrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.5. The current values of both PV increased towards noon. The maximum current values of monocrystalline and polycrystalline PV are 2.66 A on date of 10.08.2020 at hour of 13:00 and 2.43 A on date of 10.08.2020 at hour of 13:00.


10.08.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
3
2.5
2
1.5
1
0.5
0
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time (h)

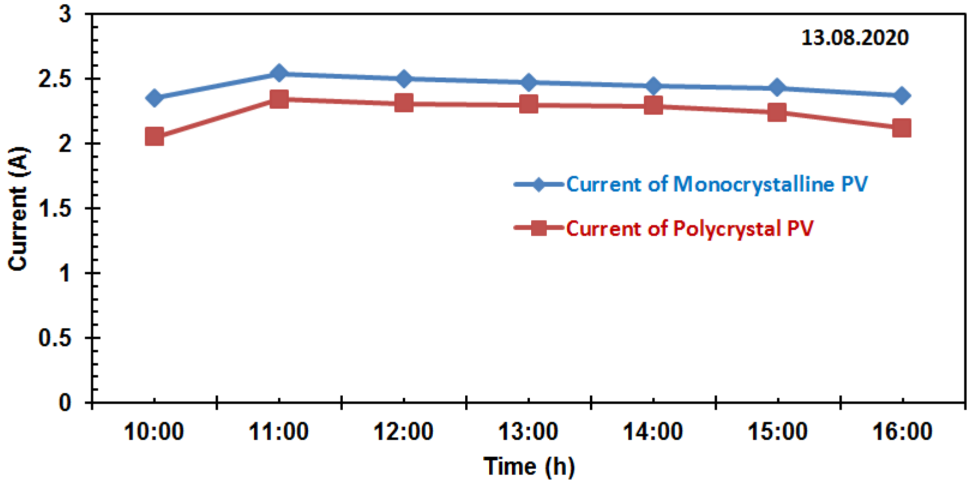
-a-


11.08.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
3
2.5
2
1.5
1
0.5
0
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time (h)

-b-


12.08.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
3
2.5
2
1.5
1
0.5
0
10:00
11:00
12:00
13:00
14:00
15:00
16:00
Time (h)

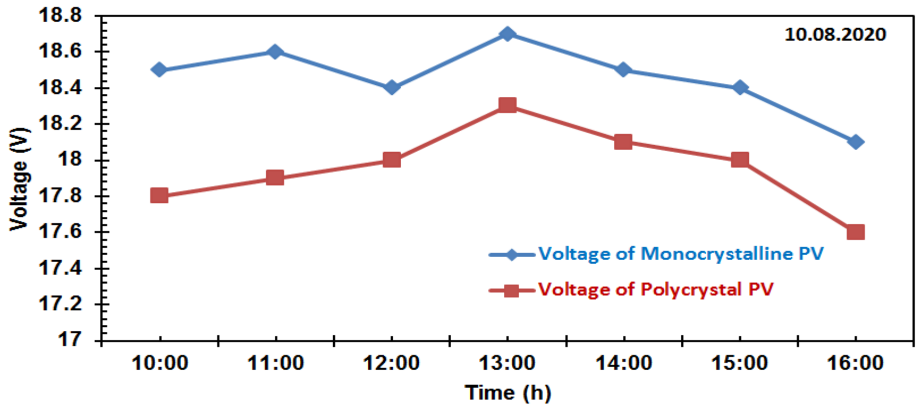
-c-



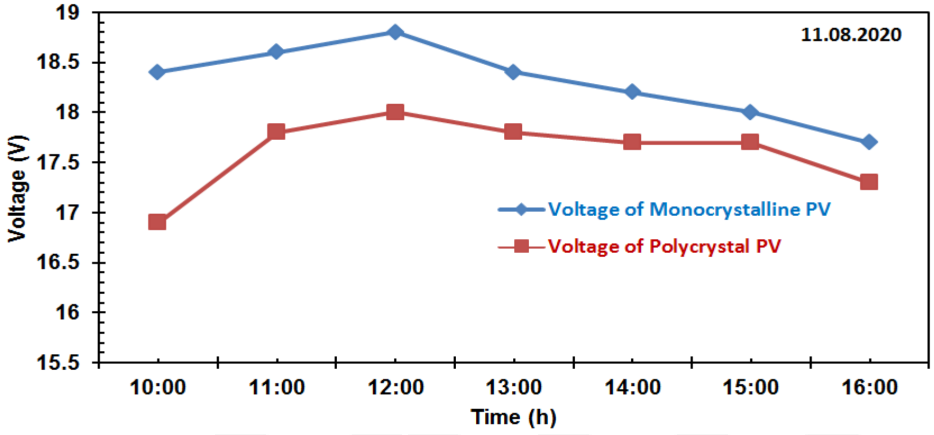
-d-

Figure 4.5. Variation of current values for monocrystalline and polycrystalline solar panel with respect to time

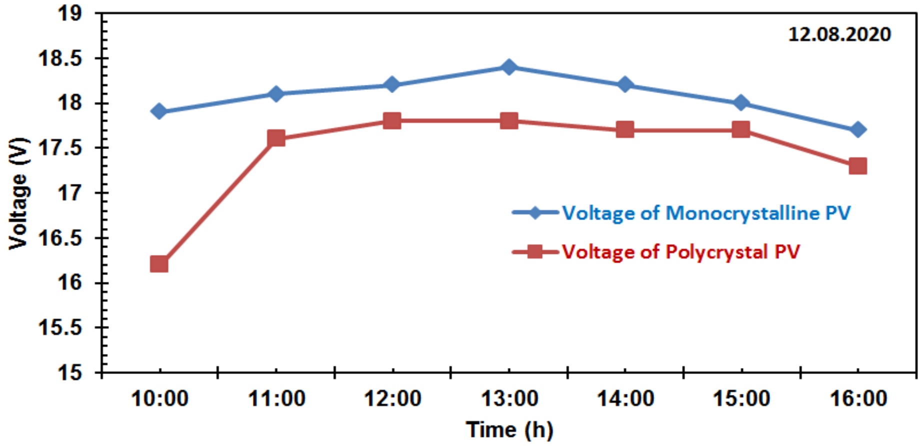
Figure 4.6 presents the variation of voltage values belong to monocrystalline and polycrystalline solar panels with respect to time. Voltage values of monocrystalline PV are greater than voltage values of polycrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.6. The voltage values of both PV increased towards hour of 12:00. The maximum voltage values of monocrystalline and polycrystalline PV are 18.8 V on date of 11.08.2020 at hour of 12:00 and 18.30 V on date of 10.08.2020 at hour of 13:00. On the other hand, the voltage value of solar panels can be affected by factors such as cloudiness affecting the performance of photovoltaic panels.



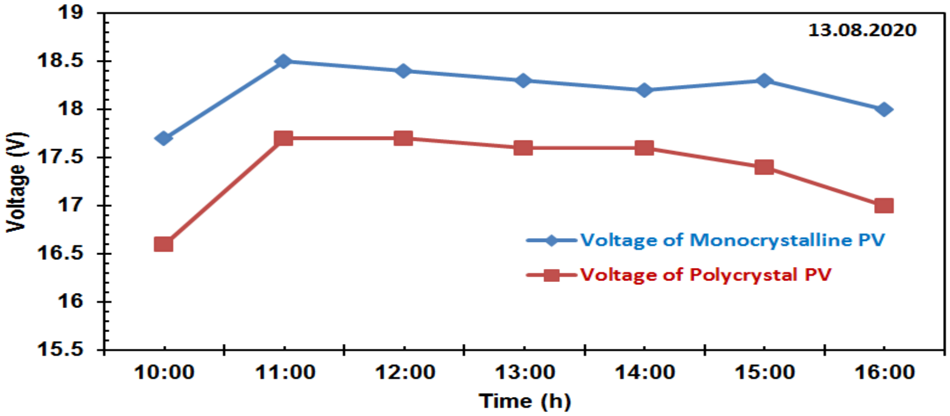
-a-



-b-



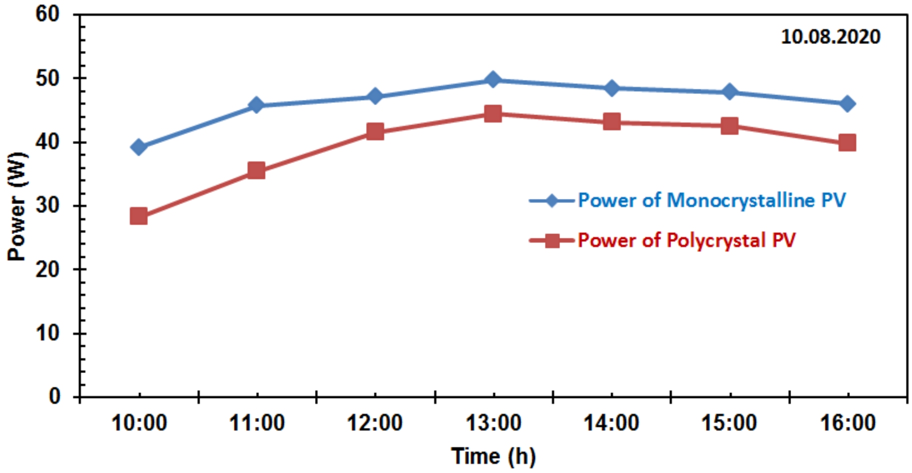
-c-



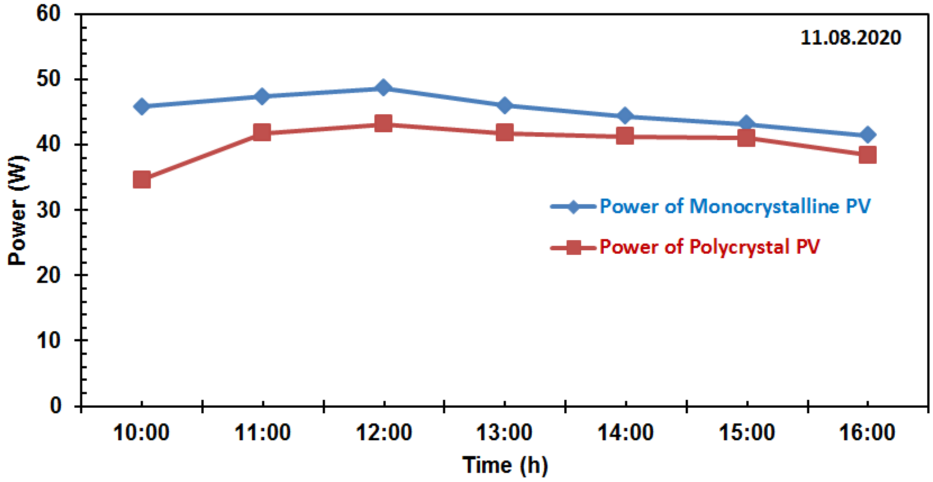
-d-

Figure 4.6. Variation of voltage values for monocrystalline and polycrystalline solar panel with respect to time

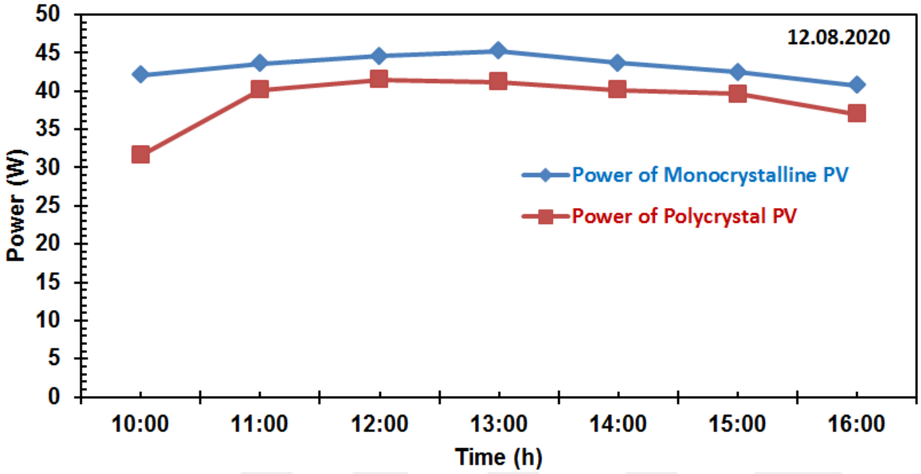
Figure 4.7 presents the variation of power values belong to monocrystalline and polycrystalline solar panels with respect to time. Power output values of monocrystalline PV are greater than power output values of polycrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.7. The power output values of both PV increased towards noon. The maximum power output values of monocrystalline and polycrystalline PV are 49.74 W on date of 10.08.2020 at hour of 13:00 and 44.47 W on date of 10.08.2020 at hour of 13:00.



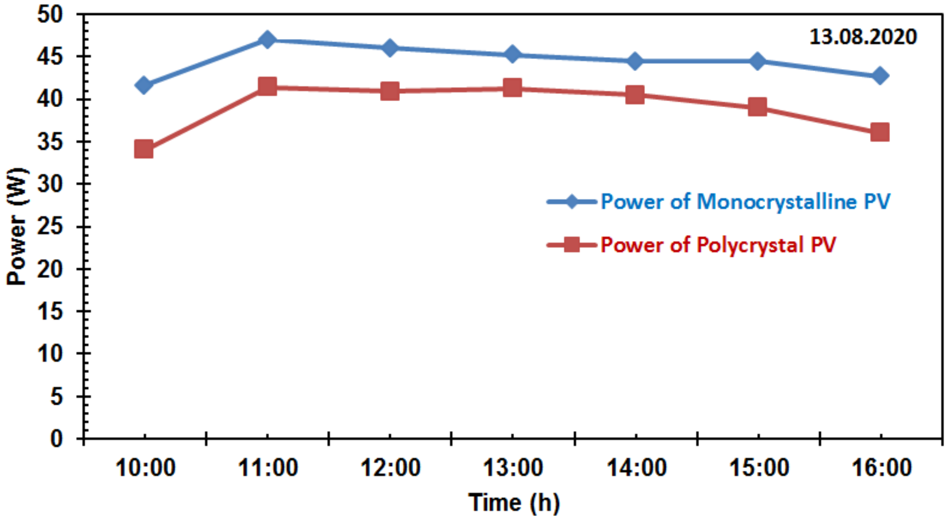
-a-



-b-



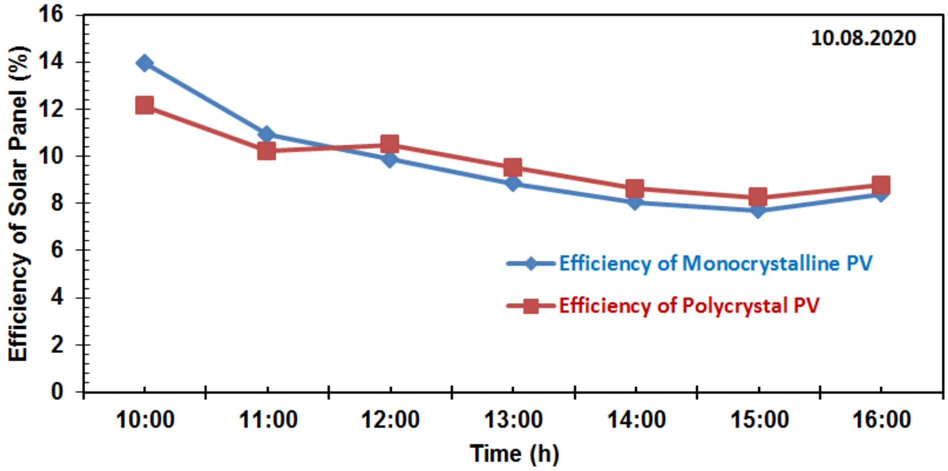
-c-



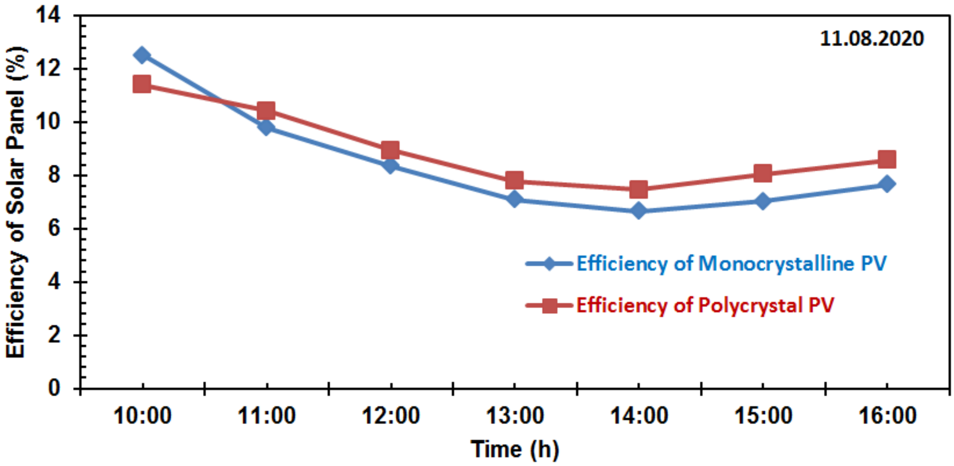
-d-

Figure 4.7. Variation of power values for monocrystalline and polycrystalline solar panel with respect to time

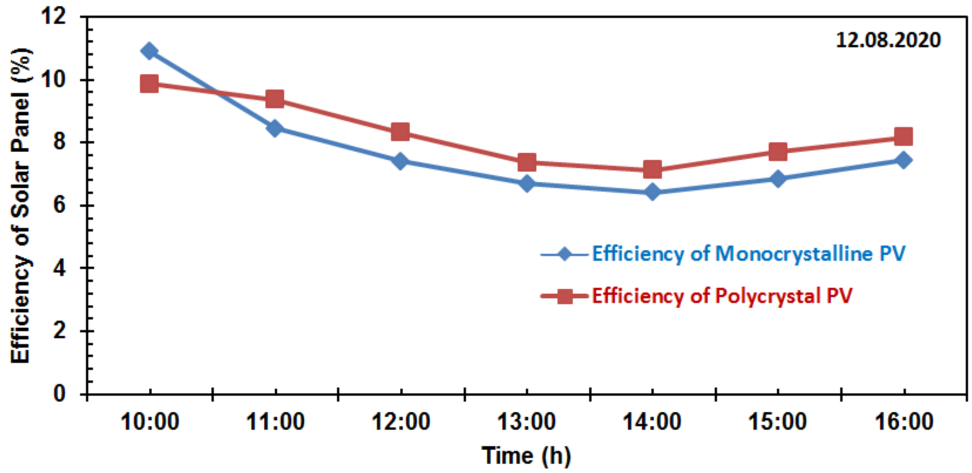
Figure 4.8 presents the variation of efficiency values belong to monocrystalline and polycrystalline solar panels with respect to time. Efficiency values of polycrystalline PV are greater than efficiency values of monocrystalline PV with respect to time between dates of 10.08.2020 and 13.08.2020 as shown in Figure 4.8. But the efficiency values of monocrystalline PV are greater than efficiency values of polycrystalline PV at hour of 10:00. Also, their efficiency values are close to each other. The reason why the efficiency values of polycrystalline PV is greater than the efficiency values of monocrystalline PV is that the area value of monocrystalline PV is greater than the area of polycrystalline PV. Actually, the power output values of monocrystalline PV are greater than power output values of polycrystalline PV. The maximum efficiency values of monocrystalline and polycrystalline PV are 13.94% on date of 10.08.2020 at hour of 10:00 and 12.13% on date of 10.08.2020 at hour of 10:00.



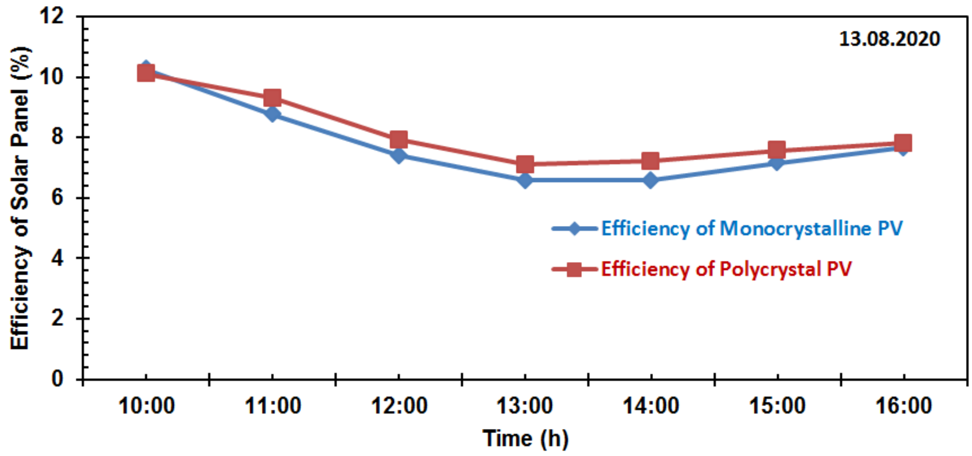
-a-



-b-



-c-



-d-

Figure 4.8. Variation of efficiency values for monocrystalline and polycrystalline solar panel with respect to time

Tables (4.9 - 4.16) present the measurement values for photovoltaic solar panels between the dates of 11.09.2020 and 14.09.2020. The maximum current, voltage and power output values of the monocrystalline solar panel are 2.59 A, 19.10 V, 49.47 W as listed in Tables (4.9 – 4.16). Solar radiation value of monocrystalline solar panel increased towards noon with respect to time. The maximum solar radiation value of it is 1095 W/m^2 at hour of 14:00. The maximum efficiency value of it is 11.51% at hour of 10:00. The maximum filling factor and performance rate of it are 0.42, 61.84% at hour of 12:00.

The maximum current, voltage and power output values of polycrystalline solar panel are 2.48 A, 18.60 V, 46.13 W as listed in Tables(4.9 – 4.16). Solar radiation value of polycrystalline solar panel increased towards noon with respect to time. The maximum solar radiation value of it is 1095 W/m^2 at hour of 14:00. The maximum efficiency value of it is 10.97% at hour of 10:00. The maximum filling factor and performance rate of it are 0.42, 57.66% at hour of 12:00.

Table 4.9. Measurement values for monocrystalline photovoltaic solar panel on the date of 11.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.44	18.4	44.90	596	30	11.51	0.38	56.12
11:00	2.55	18.8	47.94	840	35	8.72	0.41	59.93
12:00	2.59	19.1	49.47	972	33	7.78	0.42	61.84
13:00	2.54	19	48.26	1090	36	6.76	0.41	60.33
14:00	2.51	18.7	46.94	1095	38	6.55	0.40	58.67
15:00	2.36	18.1	42.72	1000	39	6.53	0.36	53.40
16:00	2.43	18.4	44.71	860	34	7.94	0.38	55.89
Average	**2.49**	**18.64**	**46.42**	**921.86**	**35.00**	**7.97**	**0.40**	**58.02**

Table 4.10. Measurement values for polycrystalline photovoltaic solar panel on the date of 11.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.1	16.9	35.49	596	29	10.97	0.33	44.36
11:00	2.4	18.3	43.92	840	33	9.63	0.40	54.90
12:00	2.48	18.6	46.13	972	31	8.74	0.42	57.66
13:00	2.4	18.1	43.44	1090	34	7.34	0.40	54.30
14:00	2.47	18.5	45.70	1095	36	7.69	0.42	57.12
15:00	2.26	17.6	39.78	1000	37	7.33	0.37	49.72
16:00	2.29	17.8	40.76	860	36	8.73	0.38	50.95
Average	**2.34**	**17.97**	**42.17**	**921.86**	**33.71**	**8.64**	**0.39**	**52.72**

Table 4.11. Measurement values for monocrystalline photovoltaic solar panel on the date of 12.09.2020

Hour	I (A)	V (V)	P (W)	G (W/m^2)	Panel Surface Temperature (°C)	Panel Efficiency (%)	Filling Factor (FF)	Performance Rate (%)
10:00	2.38	18.1	43.08	600	28	10.97	0.37	53.85
11:00	2.44	18.3	44.65	800	36	8.53	0.38	55.82
12:00	2.48	18.4	45.63	930	44	7.50	0.39	57.04
13:00	2.49	18.6	46.31	1044	45	6.78	0.40	57.89
14:00	2.43	18.4	44.71	1050	46	6.51	0.38	55.89
15:00	2.39	18.2	43.50	960	42	6.92	0.37	54.37
16:00	2.33	17.9	41.71	846	38	7.53	0.36	52.13
Average	**2.42**	**18.27**	**44.23**	**890.00**	**39.86**	**7.82**	**0.38**	**55.28**

Table 4.12. Measurement values for polycrystalline photovoltaic solar panel on the date of 12.09.2020

Hour	I (A)	V (V)	P (W)	G (W/m^2)	Panel Surface Temperature (°C)	Panel Efficiency (%)	Filling Factor (FF)	Performance Rate (%)
10:00	1.98	16.4	32.47	600	29	9.97	0.30	40.59
11:00	2.31	17.8	41.12	800	36	9.47	0.38	51.40
12:00	2.36	18	42.48	930	42	8.42	0.39	53.10
13:00	2.35	18	42.30	1044	43	7.47	0.39	52.88
14:00	2.3	17.9	41.17	1050	46	7.22	0.38	51.46
15:00	2.27	17.9	40.63	960	43	7.80	0.37	50.79
16:00	2.17	17.5	37.98	846	39	8.27	0.35	47.47
Average	**2.25**	**17.64**	**39.74**	**890**	**39.71**	**8.37**	**0.37**	**49.67**

Table 4.13. Measurement values for monocrystalline photovoltaic solar panel on the date of 13.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.38	17.8	42.36	610	36	10.61	0.36	52.96
11:00	2.57	18.6	47.80	825	37	8.85	0.41	59.75
12:00	2.53	18.5	46.81	950	44	7.53	0.40	58.51
13:00	2.5	18.4	46.00	1050	48	6.69	0.39	57.50
14:00	2.47	18.3	45.20	1040	47	6.64	0.39	56.50
15:00	2.46	18.4	45.26	950	43	7.28	0.39	56.58
16:00	2.4	18.1	43.44	870	45	7.63	0.37	54.30
Average	**2.47**	**18.30**	**45.27**	**899.29**	**42.86**	**7.89**	**0.39**	**56.59**

Table 4.14. Measurement values for polycrystalline photovoltaic solar panel on the date of 13.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.08	16.7	34.74	610	38	10.49	0.32	43.42
11:00	2.37	17.8	42.19	825	39	9.42	0.39	52.73
12:00	2.34	17.8	41.65	950	43	8.08	0.38	52.07
13:00	2.33	17.7	41.24	1050	47	7.24	0.38	51.55
14:00	2.32	17.7	41.06	1040	47	7.28	0.38	51.33
15:00	2.27	17.5	39.73	950	42	7.71	0.37	49.66
16:00	2.15	17.1	36.77	870	45	7.79	0.34	45.96
Average	**2.27**	**17.47**	**39.62**	**899.29**	**43**	**8.29**	**0.36**	**49.53**

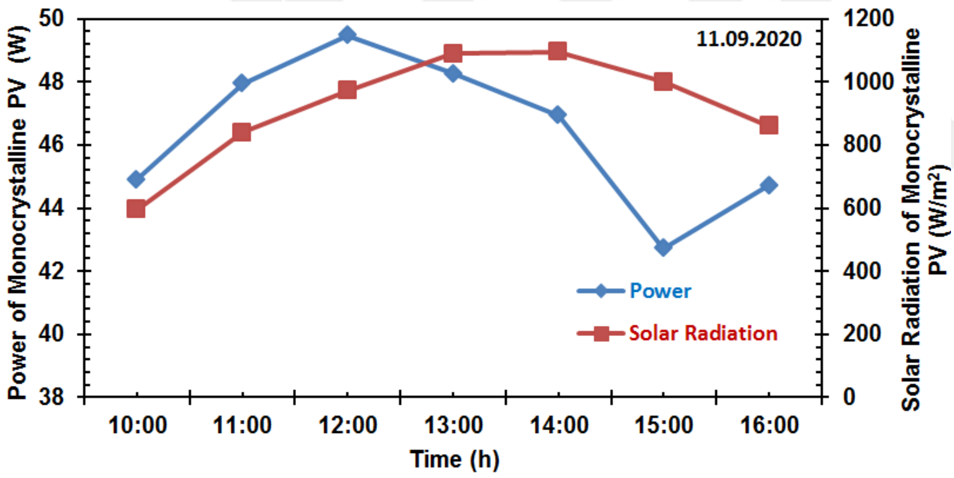
Table 4.15. Measurement values for monocrystalline photovoltaic solar panel on the date of 14.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.38	18	42.84	600	33	10.91	0.37	53.55
11:00	2.43	18.2	44.23	790	35	8.55	0.38	55.28
12:00	2.58	18.7	48.25	920	38	8.01	0.41	60.31
13:00	2.49	18.5	46.07	1040	42	6.77	0.39	57.58
14:00	2.43	18.3	44.47	1060	39	6.41	0.38	55.59
15:00	2.39	18.1	43.26	990	36	6.68	0.37	54.07
16:00	2.33	17.8	41.47	910	34	6.96	0.35	51.84
Average	**2.43**	**18.23**	**44.37**	**901.43**	**36.71**	**7.76**	**0.38**	**55.46**

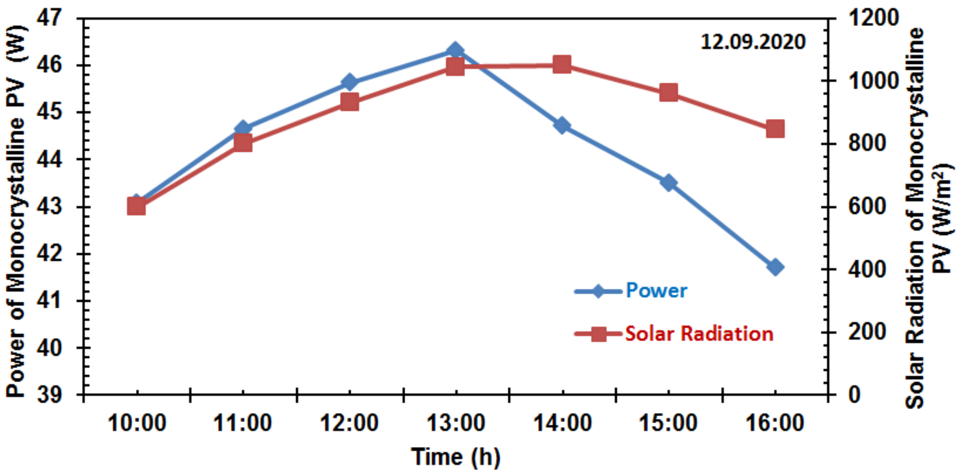
Table 4.16. Measurement values for polycrystalline photovoltaic solar panel on the date of 14.09.2020

Hour	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10:00	2.09	17	35.53	600	34	10.91	0.33	44.41
11:00	2.14	17.2	36.81	790	36	8.59	0.34	46.01
12:00	2.29	17.7	40.53	920	37	8.12	0.37	50.67
13:00	2.2	17.5	38.50	1040	43	6.82	0.35	48.13
14:00	2.14	17.3	37.02	1060	40	6.44	0.34	46.28
15:00	2.1	17.1	35.91	990	37	6.68	0.33	44.89
16:00	2.04	16.8	34.27	910	35	6.94	0.32	42.84
Average	**2.14**	**17.23**	**36.94**	**901.43**	**37.43**	**7.79**	**0.34**	**46.17**

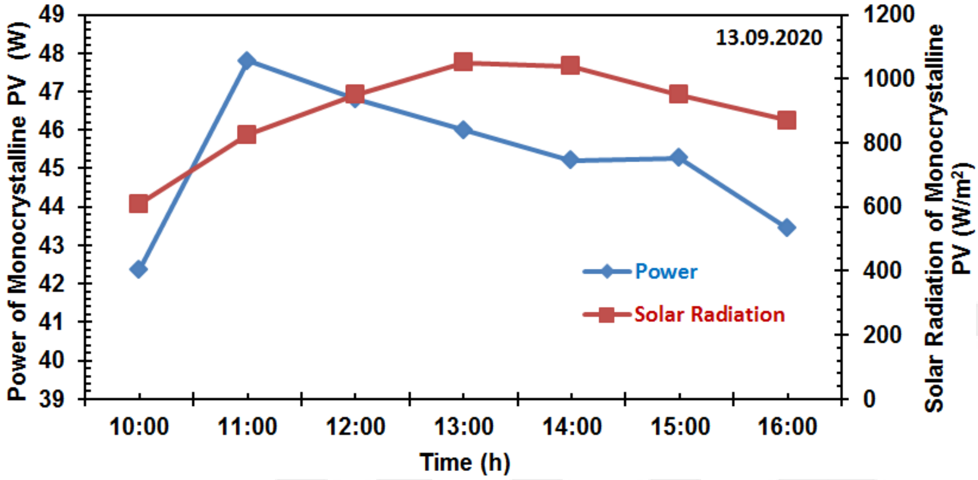
Figure 4.9 presents the relation between the power and solar radiation values of monocrystalline solar panel with respect to time. When measured power output and solar radiation values of monocrystalline PV are compared, there is a linear relationship between power output and solar radiation of monocrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.9. When the solar radiation of monocrystalline PV increases, the power output of monocrystalline PV increases. When the maximum power output value of monocrystalline PV is 49.47 W, the solar radiation of it is 972 W/m^2 on date of 11.09.2020 at hour of 12:00. When the minimum power output value of monocrystalline PV is 41.47 W, the solar radiation of it is 910 W/m^2 on date of 14.09.2020 at hour of 16:00.



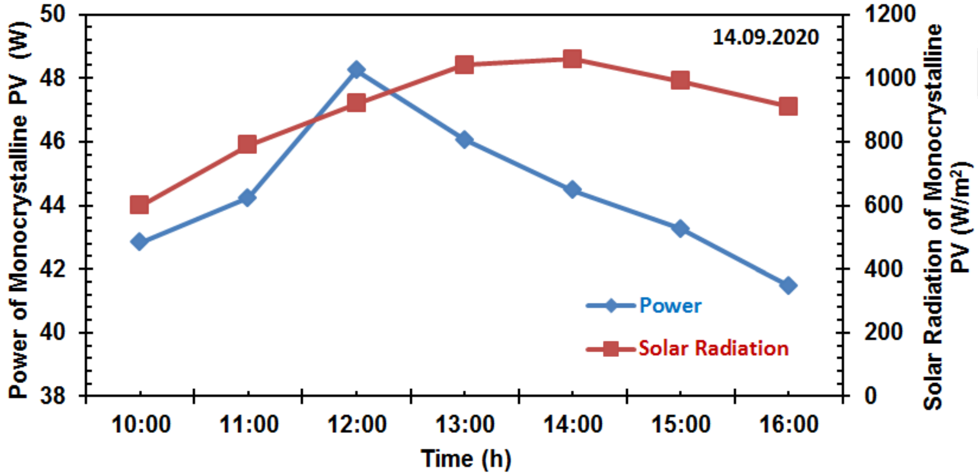
-a-



-b-



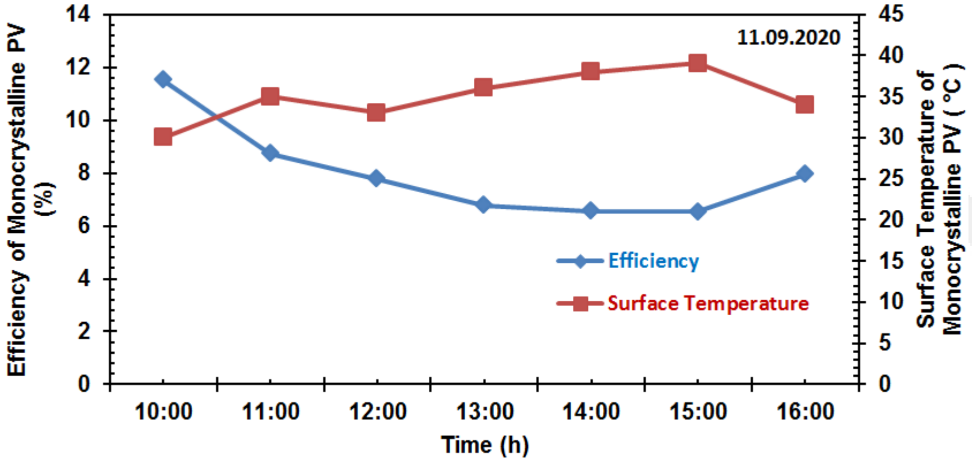
-c-



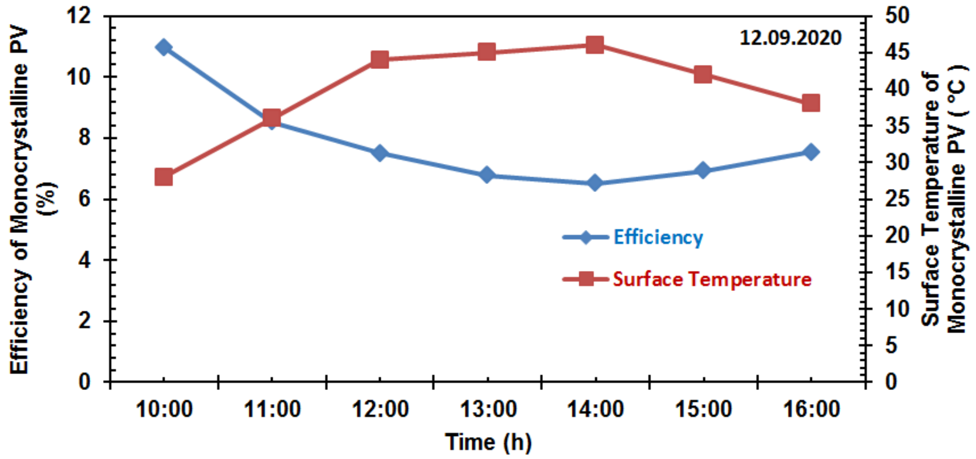
-d-

Figure 4.9. Relation between the power and solar radiation values for monocrystalline solar panel with respect to time

Figure 4.10 presents the relation between the efficiency and surface temperature values of monocrystalline solar panel with respect to time. When measured efficiency and surface temperature values of monocrystalline PV are compared, there is an inverse relationship between efficiency and surface temperature of monocrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.10. When the surface temperature of monocrystalline PV increases, the efficiency of monocrystalline PV decreases. When the maximum efficiency value of monocrystalline PV is 11.51%, the surface temperature of it is 30 °C on date of 11.09.2020 at hour of 10:00. When the minimum efficiency value of monocrystalline PV is 6.41%, the surface temperature of it is 39 °C on date of 14.09.2020 at hour of 14:00.



-a-



-b-

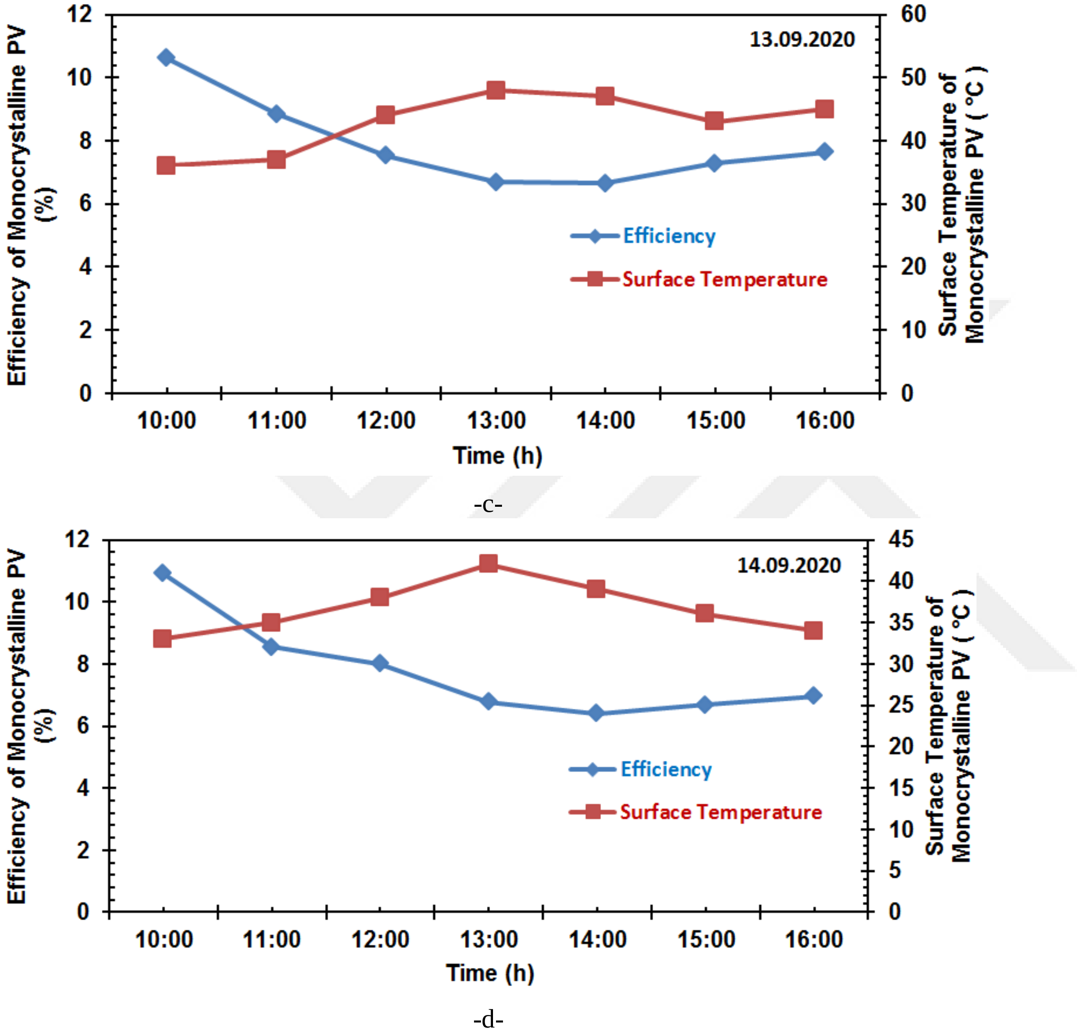
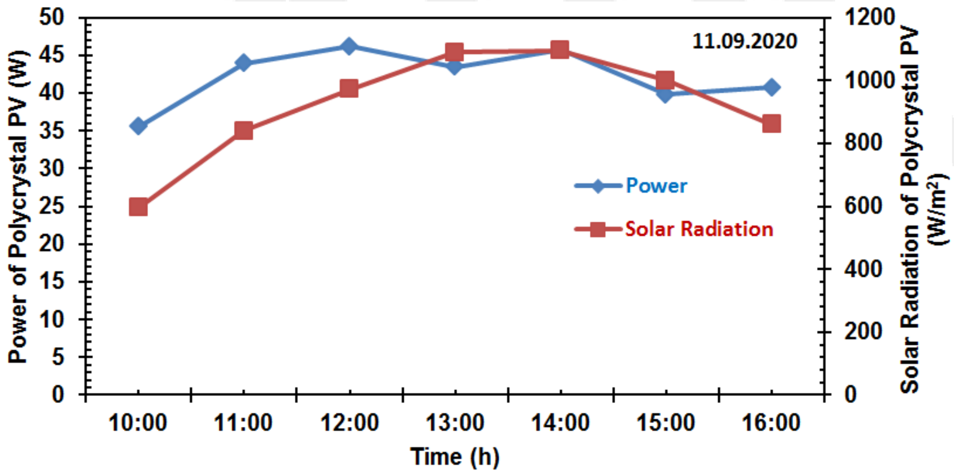
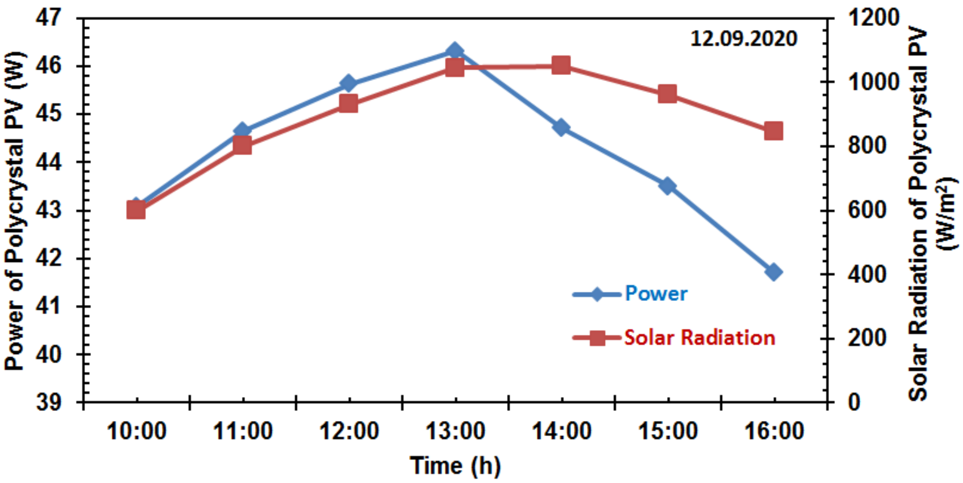


Figure 4.10. Relation between the efficiency and surface temperature values for monocrystalline solar panel with respect to time

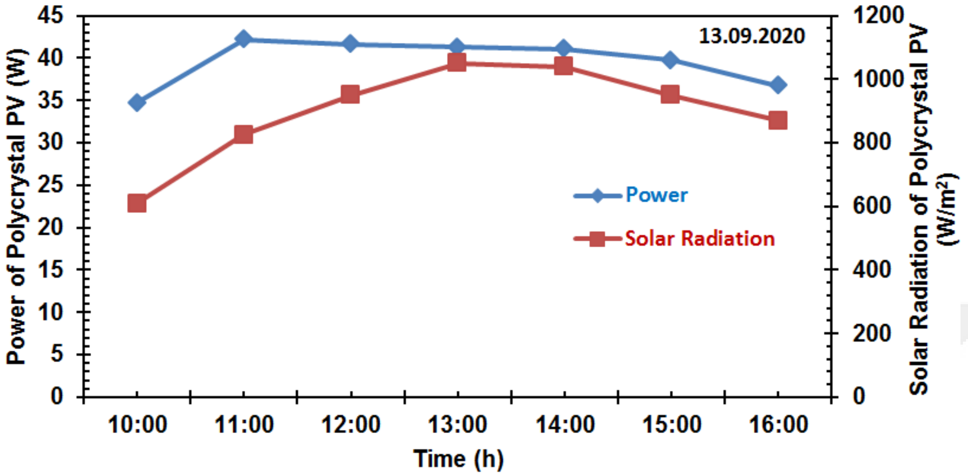
Figure 4.11 presents the relation between the power and solar radiation values of polycrystalline solar panel with respect to time. When measured power output and solar radiation values of polycrystalline PV are compared, there is a linear relationship between power output and solar radiation of polycrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.11. When the solar radiation of polycrystalline PV increases, the power output of polycrystalline PV increases. When the maximum power output value of polycrystalline PV is 46.13 W, the solar radiation of it is 972 W/m^2 on date of 11.09.2020 at hour of 12:00. When the minimum power output value of polycrystalline PV is 32.47 W, the solar radiation of it is 600 W/m^2 on date of 12.09.2020 at hour of 10:00.



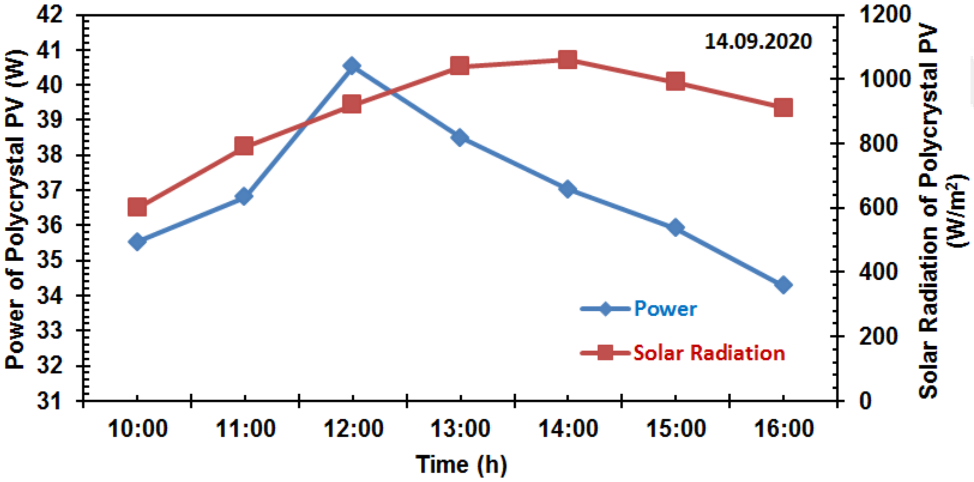
-a-



-b-



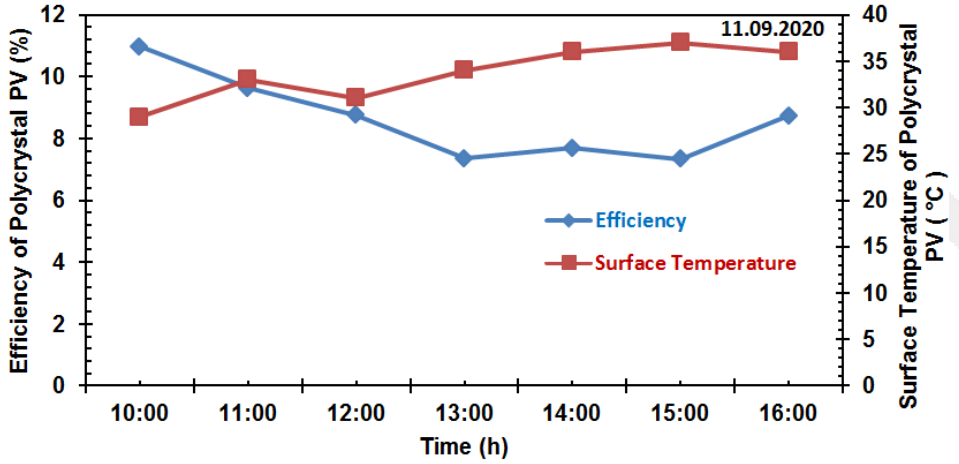
-c-



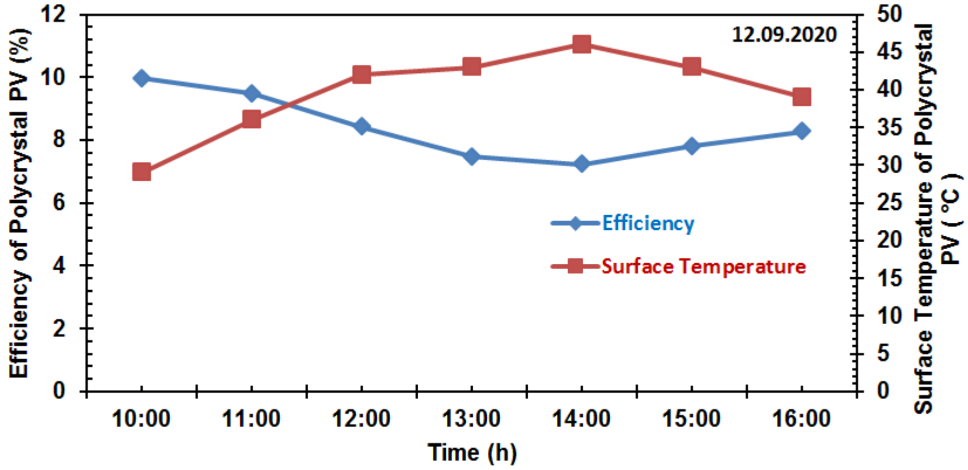
-d-

Figure 4.11. Relation between the power and solar radiation values for polycrystalline solar panel with respect to time

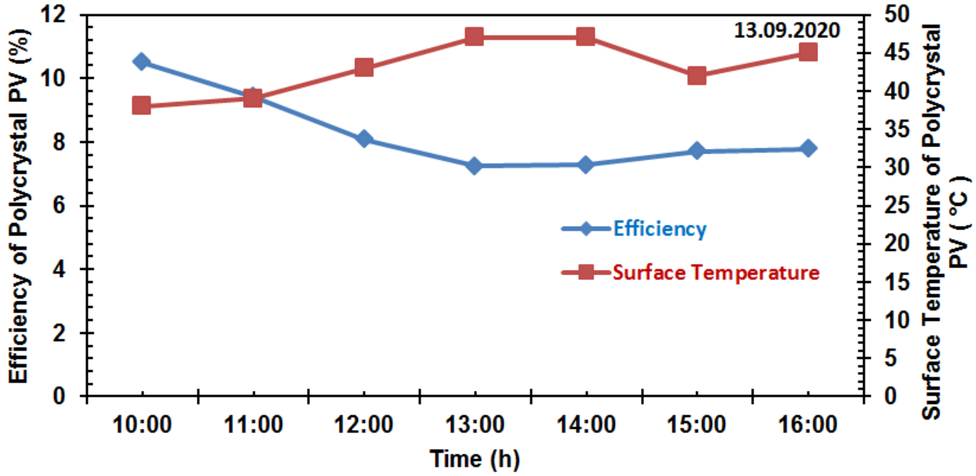
Figure 4.12 presents the relation between the efficiency and surface temperature values of polycrystalline solar panel with respect to time. When measured efficiency and surface temperature values of polycrystalline PV are compared, there is an inverse relationship between efficiency and surface temperature of polycrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.12. When the surface temperature of polycrystalline PV increases, the efficiency of polycrystalline PV decreases. When the maximum efficiency value of polycrystalline PV is 10.97%, the surface temperature of it is 29 °C on date of 11.09.2020 at hour of 10:00. When the minimum efficiency value of polycrystalline PV is 6.44%, surface temperature of it is 40 °C on date of 14.09.2020 at hour of 14:00.



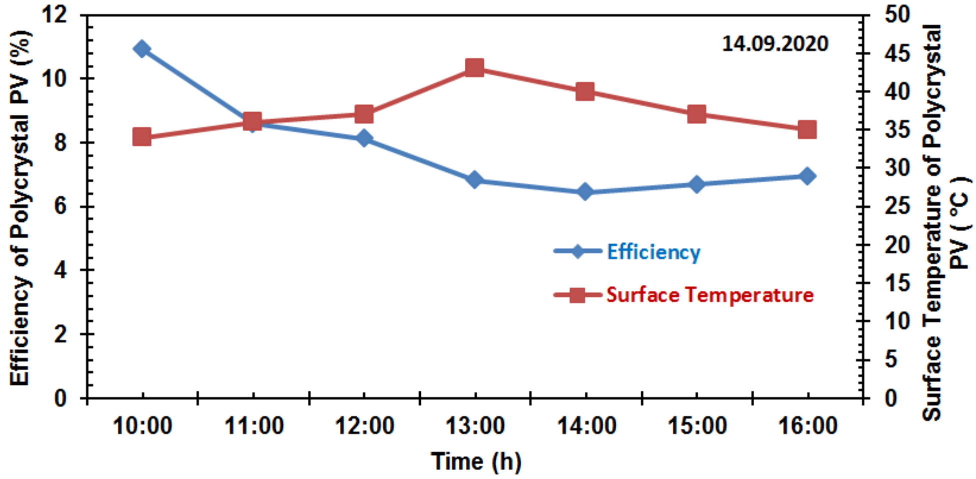
-a-



-b-



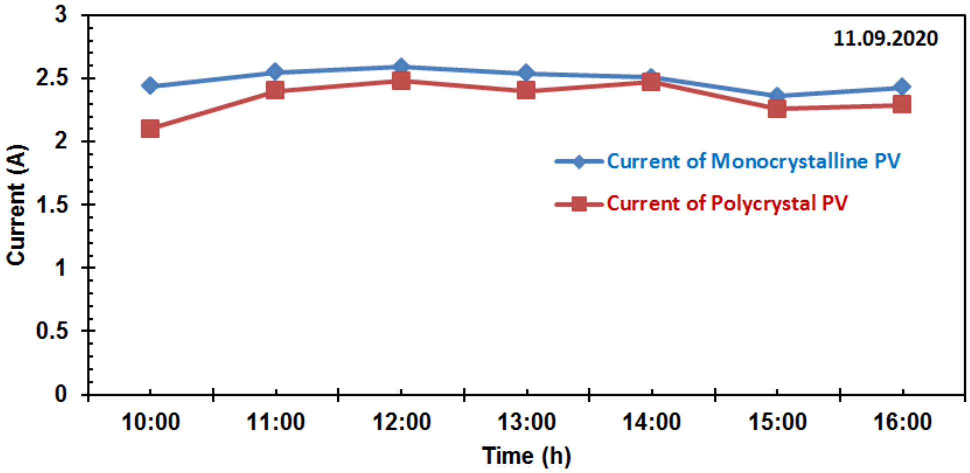
-c-



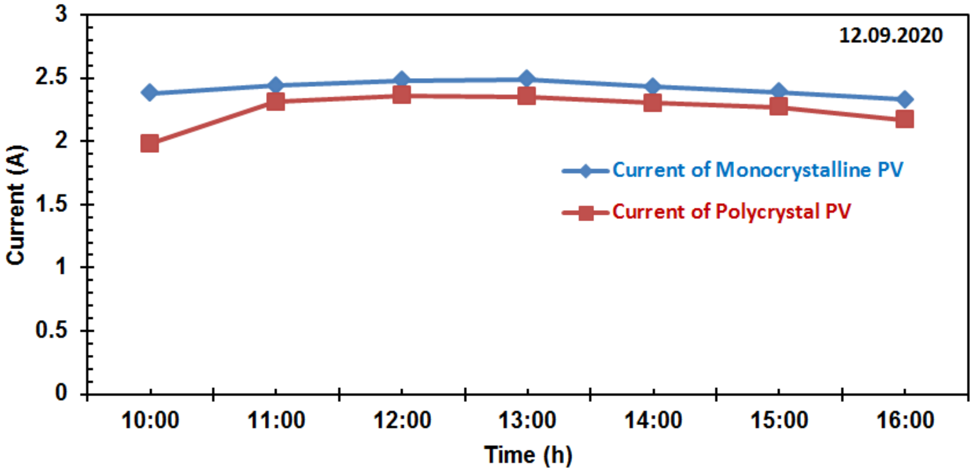
-d-

Figure 4.12. Relation between the efficiency and surface temperature values for polycrystalline solar panel with respect to time

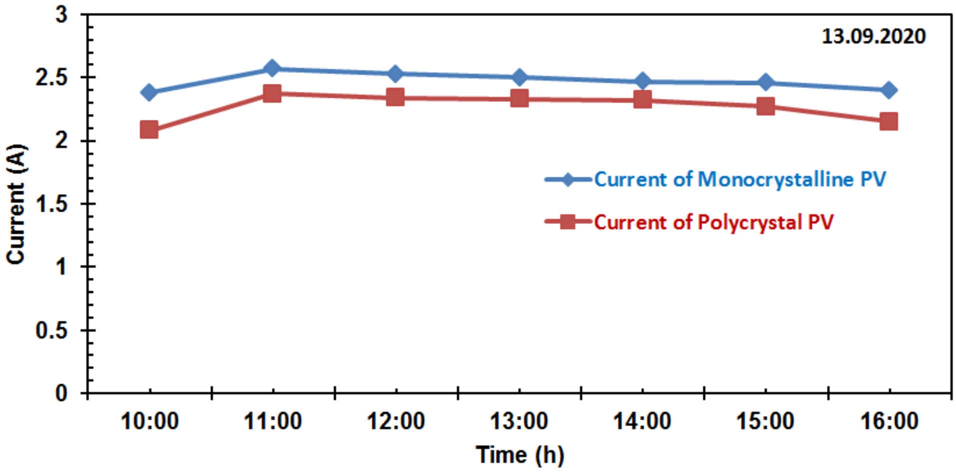
Figure 4.13 presents the variation of current values belong to monocrystalline and polycrystalline solar panels with respect to time. Current values of monocrystalline PV are greater than current values of polycrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.13. The current values of both PV increased towards noon. The maximum current values of monocrystalline and polycrystalline PV are 2.59 A on date of 11.09.2020 at hour of 12:00 and 2.48 A on date of 11.09.2020 at hour of 12:00.


11.09.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
Time (h)

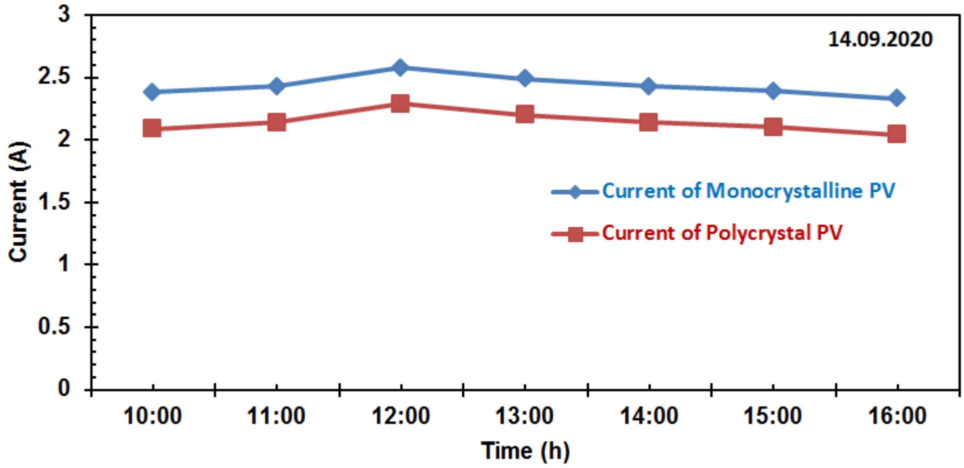
-a-


12.09.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
Time (h)

-b-


13.09.2020
Current of Monocrystalline PV
Current of Polycrystal PV
Current (A)
Time (h)

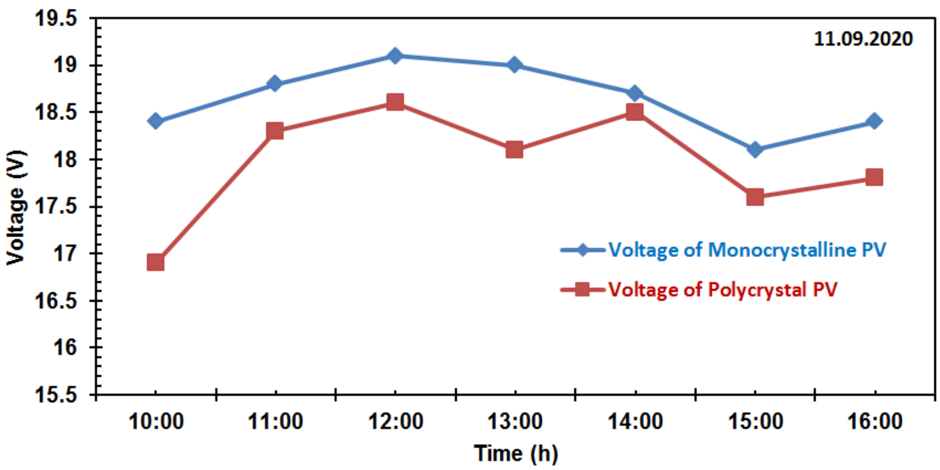
-c-



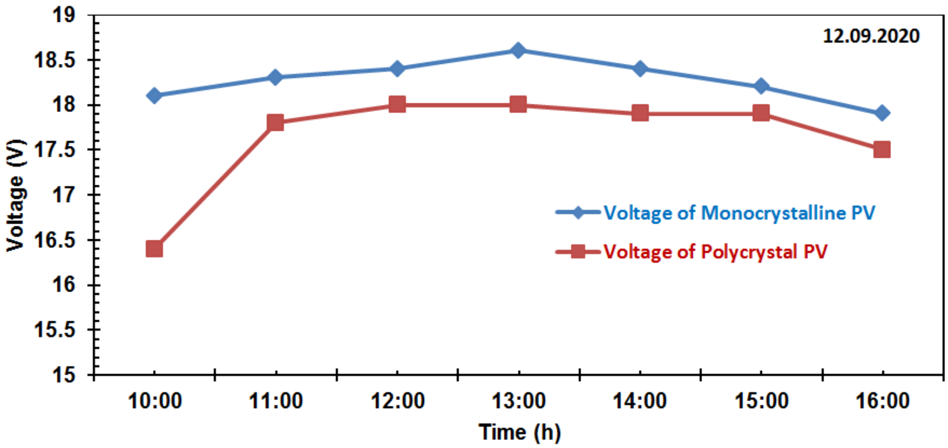
-d-

Figure 4.13. Variation of current values for monocrystalline and polycrystalline solar panel with respect to time

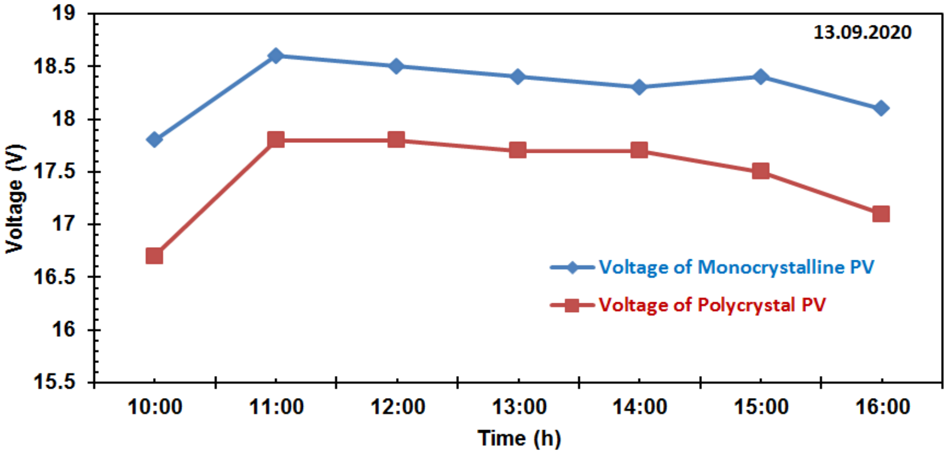
Figure 4.14 presents the variation of voltage values belong to monocrystalline and polycrystalline solar panels with respect to time. Voltage values of monocrystalline PV are greater than voltage values of polycrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.14. The voltage values of both PV increased towards hour of 12:00. The maximum voltage values of monocrystalline and polycrystalline PV are 19.1 V on date of 11.09.2020 at hour of 12:00 and 18.6 V on date of 11.09.2020 at hour of 12:00. On the other hand, the voltage value of solar panels can be affected by factors such as cloudiness affecting the performance of photovoltaic panels.



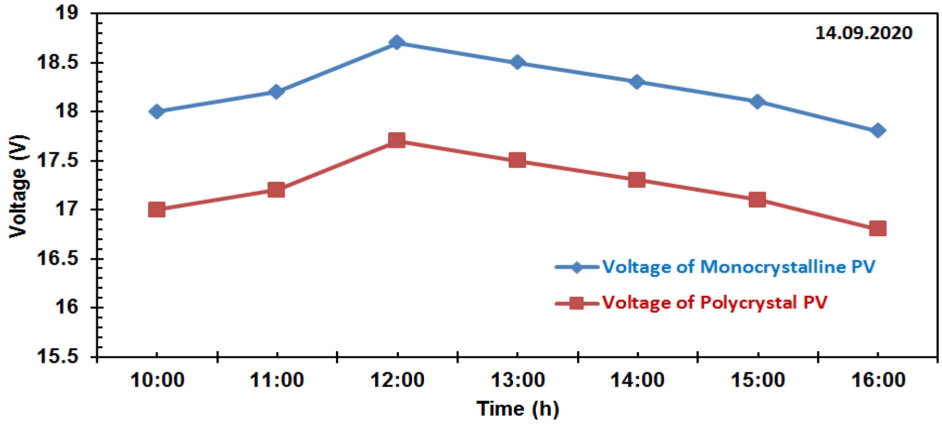
-a-



-b-



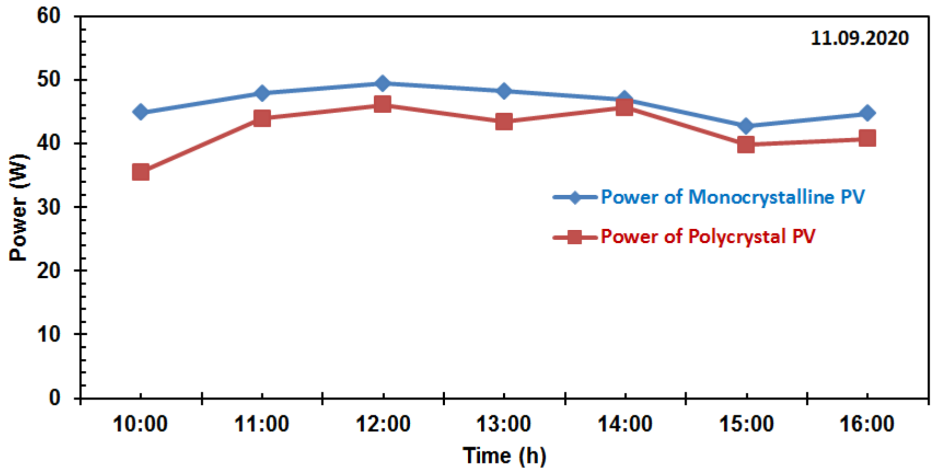
-c-



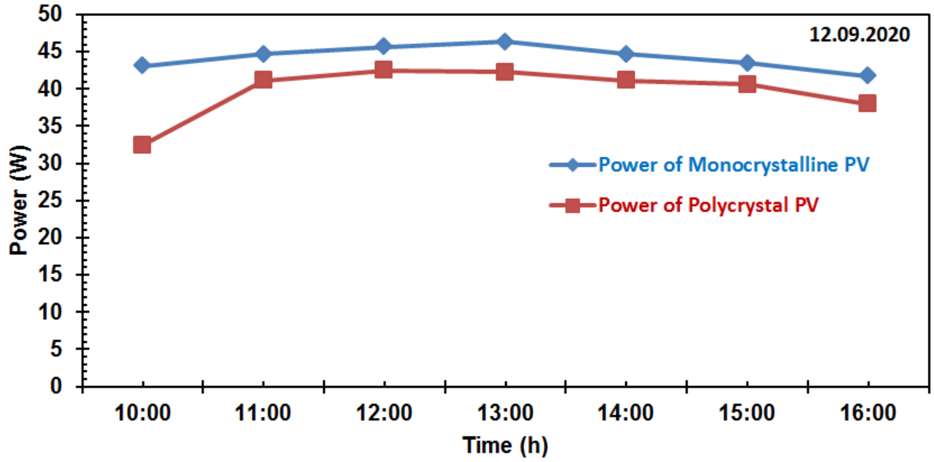
-d-

Figure 4.14. Variation of voltage values for monocrystalline and polycrystalline solar panel with respect to time

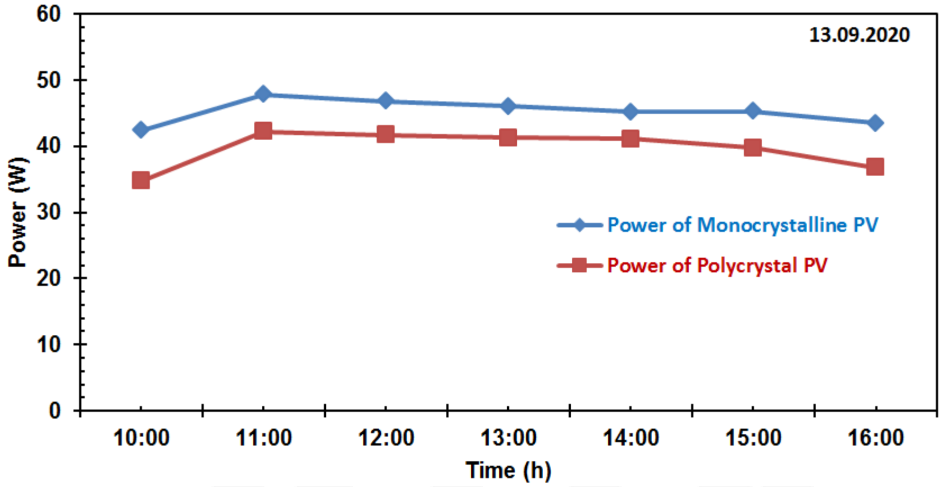
Figure 4.15 presents the variation of power values belong to monocrystalline and polycrystalline solar panels with respect to time. Power output values of monocrystalline PV are greater than power output values of polycrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.15. The power output values of both PV increased towards noon. The maximum power output values of monocrystalline and polycrystalline PV are 49.47 W on date of 11.09.2020 at hour of 12:00 and 46.13 W on date of 11.09.2020 at hour of 12:00.



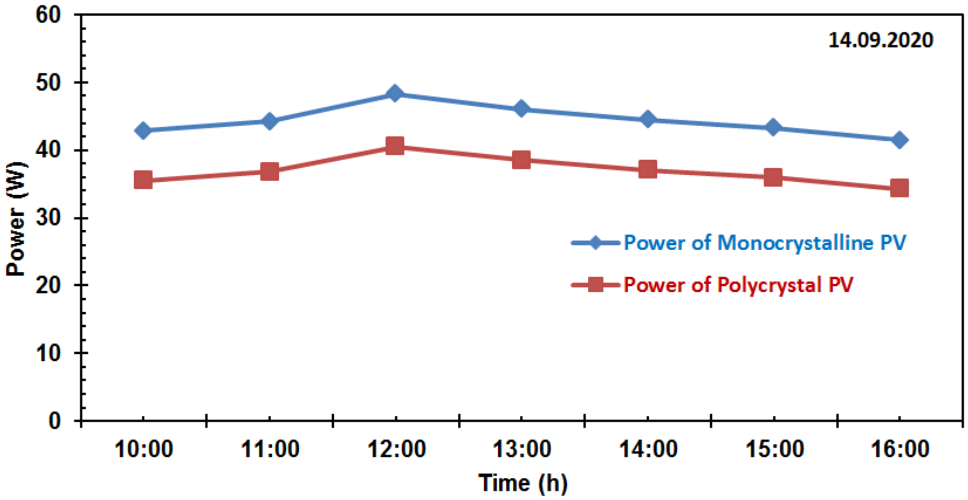
-a-



-b-



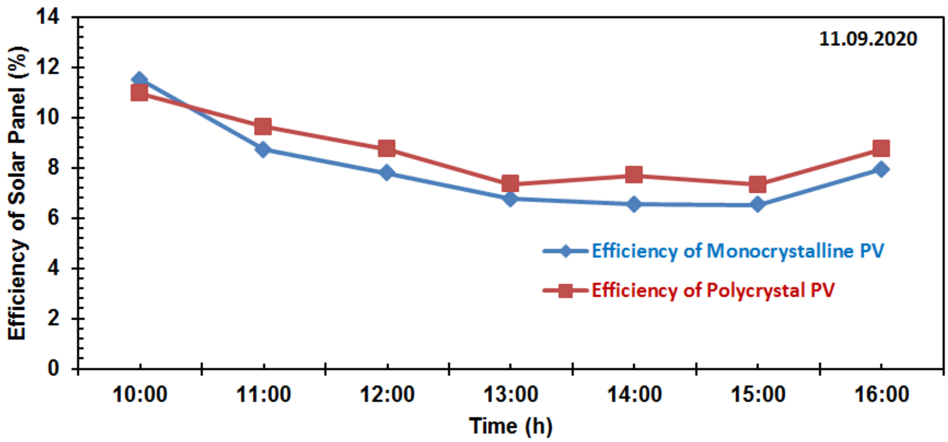
-c-



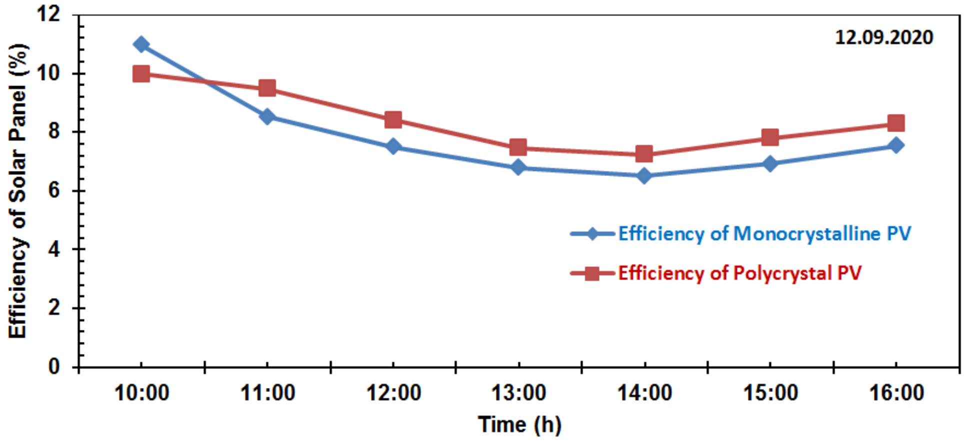
-d-

Figure 4.15. Variation of power values for monocrystalline and polycrystalline solar panel with respect to time

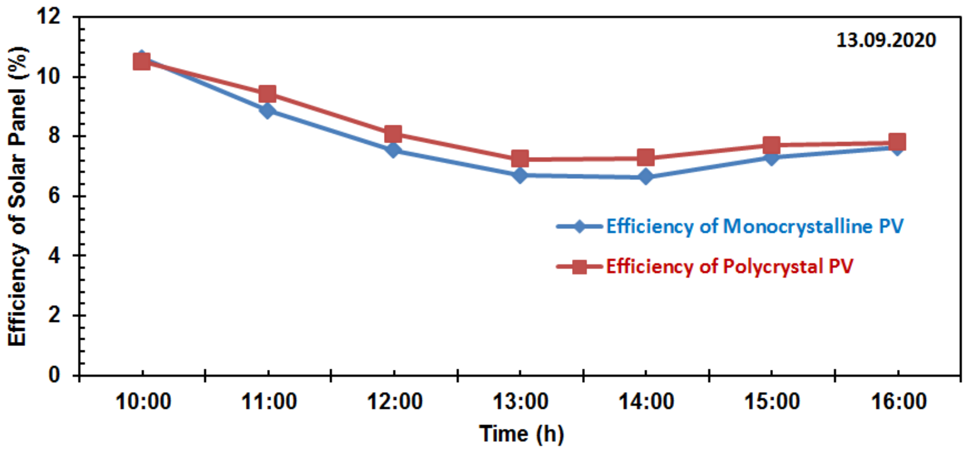
Figure 4.16 presents the variation of efficiency values belong to monocrystalline and polycrystalline solar panels with respect to time. Efficiency values of polycrystalline PV are greater than efficiency values of monocrystalline PV with respect to time between dates of 11.09.2020 and 14.09.2020 as shown in Figure 4.16. But the efficiency values of monocrystalline PV are greater than efficiency values of polycrystalline PV at hour of 10:00. Also, their efficiency values are close to each other. The reason why the efficiency values of polycrystalline PV are greater than efficiency values of monocrystalline PV is that the area value of monocrystalline PV is greater than area of polycrystalline PV. Actually the power output values of monocrystalline PV are greater than power output values of polycrystalline PV. The maximum efficiency values of monocrystalline and polycrystalline PV are 11.51% on date of 11.09.2020 at hour of 10:00 and 10.97% on date of 11.09.2020 at hour of 10:00.



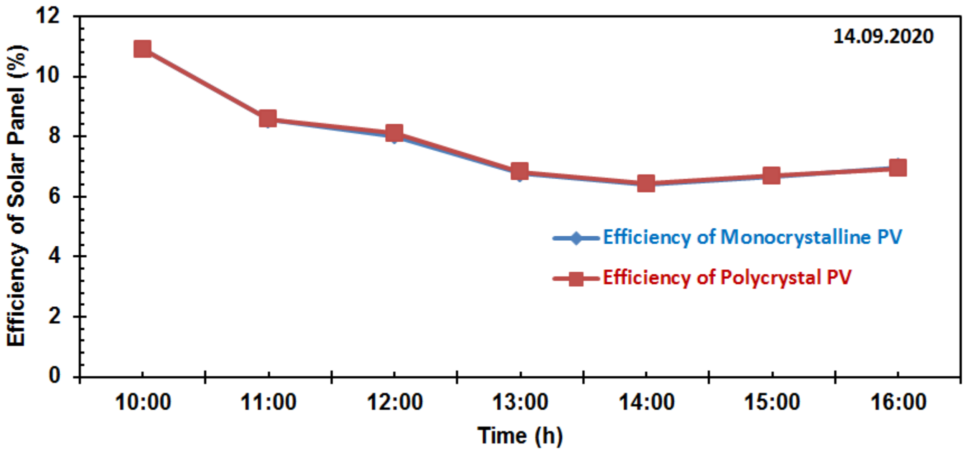
-a-



-b-



-c-



-d-

Figure 4.16. Variation of efficiency values for monocrystalline and polycrystalline solar panel with respect to time

Our country is in a position that is dependent on foreign energy and imports energy. In order to prevent this situation and contribute to the national economy, investors should be directed towards alternative energy sources and these resources should be encouraged. Thus, environmental pollution will be prevented, and a tendency will be made to clean energy resources by moving away from fossil fuels. Increasing profitability by decreasing investment costs and increasing energy production efficiency is a very important step to encourage investors.

5. CONCLUSIONS

The system is designed with 80 W photovoltaic solar panels in the area behind Aydın Adnan Menderes University Engineering Faculty Campus in Aydın province, which is chosen as the place where experimental measurements will be made. As a result of the measurements, the change of current, voltage and power changes of 80 W monocrystalline and polycrystalline solar panels, as well as the change of environmental factors of the working environment of the panel, were examined and thus the efficiency of the panels was calculated. In this thesis, the changes related to current, voltage, radiation intensity, panel surface temperature and generated power are obtained by using the measurement setup. In the experiments conducted with 80 W monocrystalline and polycrystalline solar panels, the real performance, potential and usability of the panels are observed in Aydın climatic conditions. All electrical parameters and environmental factors of the panel are interpreted in the light of the data and panel efficiency and panel performance rates are calculated. The variation of each associated parameter is examined day by day and it is determined that the experimental results obtained are compatible with the data in the literature. It is predicted that this study will be a reference to studies on energy analysis of solar panels in Aydın and will contribute to the literature.

In this thesis, the performance of monocrystalline and polycrystalline photovoltaic panels positioned at 20˚ constant angle to horizontal for 8 days in field conditions in Aydın summer period is experimentally investigated. As a result of the measurements made in August and September 2020, the average power produced by the monocrystalline solar panel is between 39.22 - 49.74 W and the average power produced by the polycrystalline solar panel is between 28.30 - 46.13 W. The most important determinant of the performance of photovoltaic panels is the solar radiation value. As a result of the measurements conducted, it is determined that the value of the power produced by the panel increased with the increase of the solar radiation value.

As a result of the research, it has been observed that 49.74 W power can be obtained from a monocrystalline solar panel under 860 W/m^2 solar irradiation and 46.13 W power can be obtained from a polycrystalline solar panel under 972 W/m^2 total solar radiation. In this context, it has been determined that the monocrystalline solar panel produces 7.8% more instantaneous power than the polycrystalline solar panel. According to the results of the study, 13.94% efficiency is obtained from the monocrystalline solar panel. The efficiency of the polycrystalline solar panel is found to be 12.13%. More precise results can be obtained with more precise measuring devices and if measurements are made for more months. There are differences between the conditions in which the panel is tested and the actual atmospheric conditions. Atmospheric conditions reduce the power generation potential of the panel. In addition to the decrease in power generation potential, wind, clouding and consequently excessive pollution of the panels are also factors that reduce efficiency. Making the cost and capacity calculations made in solar energy investments with catalog values brings serious errors. In solar energy investments, the catalog values of the panel should not be calculated with the production and cost. It should be known that losses occur in real operating conditions and the production power and efficiency of the panel decrease significantly in winter.

Monocrystalline and polycrystalline photovoltaic average measurement values between August 10.08.2020 - 13.08.2020 with the help of monocrystalline solar panel, polycrystalline solar panel, digital multimeter, pyranometer, K-type thermocouple, led light in the system established in Aydın province are given in Table 5.1 and Table 5.2. Table 5.1 presents the daily average measurement values for monocrystalline photovoltaic solar panel in August of month.

Table 5.1. Daily average measurement values for monocrystalline photovoltaic solar panel in august

Date	**I (A)**	**V (V)**	**P (W)**	**G (W/m^2)**	**Panel Surface Temperature (°C)**	**Panel Efficiency (%)**	**Filling Factor (FF)**	**Performance Rate (%)**
10.08.2020	2.51	18.46	46.3	766.57	37.29	9.67	0.40	57.88
11.08.2020	2.47	18.3	45.28	852.29	42.14	8.44	0.39	56.60
12.08.2020	2.39	18.07	43.20	880	38.86	7.73	0.37	54.00
13.08.2020	2.44	18.20	44.48	895.71	41.86	7.77	0.38	55.60
Average	2.45	18.26	44.82	848.64	40.04	8.40	0.38	56.02

The average current, voltage and power output values of monocrystalline solar panel are 2.45 A, 18.26 V, 44.82 W in August as listed in Table 5.1. The average efficiency value of it is 8.40% in August. The average filling factor and performance rate of it are 0.38, 56.02% in August. The average current, voltage, power output, filling factor and performance rate values of monocrystalline solar panel are greater than the values of polycrystalline solar panel in August as listed in the table. The reason why average efficiency value of polycrystalline PV are greater than average efficiency value of monocrystalline PV in August is that the area value of monocrystalline PV is greater than area of polycrystalline PV.

Table 5.2 presents the daily average measurement values for polycrystalline photovoltaic solar panel in August.

Table 5.2. Daily average measurement values for polycrystalline photovoltaic solar panel in august

Date	I (A)	V (V)	P (W)	G (W/m^2)	Panel Surface Temperature (°C)	Panel Efficiency (%)	Filling Factor (FF)	Performance Rate (%)
10.08.2020	2.19	17.96	39.31	766.57	39.14	9.71	0.36	49.14
11.08.2020	2.29	17.6	40.32	852.29	41.86	8.94	0.37	50.40
12.08.2020	2.22	17.44	38.75	880	38.71	8.27	0.36	48.44
13.08.2020	2.24	17.37	39.01	895.71	42	8.15	0.36	48.76
Average	2.24	17.59	39.35	848.64	40.43	8.77	0.36	49.18

The average current, voltage and power output values of polycrystalline solar panel are 2.24 A, 17.59 V, 39.35 W in August as listed in Table 5.2. The average efficiency value of it is 8.77% in August. The average filling factor and performance rate of it are 0.36, 49.18% in August. The average current, voltage, power output, filling factor and performance rate values of polycrystalline solar panel are less than the values of monocrystalline solar panel in August.

Monocrystalline and polycrystalline photovoltaic average measurement values between August 11.09.2020 - 14.09.2020 with the help of monocrystalline solar panel, polycrystalline solar panel, digital multimeter, pyranometer, K-type thermocouple, led light in the system established in Aydın province are given in the table 5.3 and table 5.4. Table 5.3 presents the daily average measurement values for monocrystalline photovoltaic solar panel in September.

Table 5.3. Daily average measurement values for monocrystalline photovoltaic solar panel in september

Date	I (A)	V (V)	P (W)	G (W/m^2)	Panel Surface Temperature (°C)	Panel Efficiency (%)	Filling Factor (FF)	Performance Rate (%)
11.09.2020	2.49	18.64	46.42	921.86	35.00	7.97	0.40	58.02
12.09.2020	2.42	18.27	44.23	890.00	39.86	7.82	0.38	55.28
13.09.2020	2.47	18.30	45.27	899.29	42.86	7.89	0.39	56.59
14.09.2020	2.43	18.23	44.37	901.43	36.71	7.76	0.38	55.46
Average	2.45	18.36	45.07	903.14	38.61	7.86	0.38	56.34

The average current, voltage and power output values of monocrystalline solar panel are 2.45 A, 18.36 V, 45.07 W in September as listed in Table 5.3. The average efficiency value of it is 7.86% in September. The average filling factor and performance rate of it are 0.38, 56.34% in September. The average current, voltage, power output, filling factor and performance rate values of monocrystalline solar panel are greater than the values of polycrystalline solar panel in September. The average efficiency values of them are same in September.

Table 5.4 presents the daily average measurement values for polycrystalline photovoltaic solar panel in September.

Table 5.4. Daily average measurement values for polycrystalline photovoltaic solar panel in september

Date	I (A)	V (V)	P (W)	G (W/m^2)	Panel Surface Temperature (°C)	Panel Efficiency (%)	Filling Factor (FF)	Performance Rate (%)
11.09.2020	2.34	17.97	42.17	921.86	33.71	8.64	0.39	52.72
12.09.2020	2.25	17.64	39.74	890.00	39.71	8.37	0.37	49.67
13.09.2020	2.27	17.47	39.62	899.29	43.00	8.29	0.36	49.53
14.09.2020	2.14	17.23	36.94	901.43	37.43	7.79	0.34	46.17
Average	2.25	17.58	39.62	903.14	38.46	8.27	0.36	49.52

The average current, voltage and power output values of polycrystalline solar panel are 2.25 A, 17.58 V, 39.62 W in September as listed in Table 5.4. The average efficiency value of it is 8.27% in September. The average filling factor and performance rate of it are 0.36, 49.52% in September. The average current, voltage, power output, filling factor and performance rate values of polycrystalline solar panel are less than the values of monocrystalline solar panel in September.

In this study, it is aimed to compare the performance analysis of photovoltaic module systems with different technologies installed in Aydın province in August and September of 2020. Measurement analysis involved the period in August and September. In addition to the system measurements, hourly current, voltage, radiation intensity on the surface and panel surface temperature were also measured. For Aydın province, both the power output and performance ratio of monocrystalline silicon modules are more profitable than polycrystalline silicon photovoltaic system. For this reason, monocrystalline silicon module should be preferred in systems to be installed in Aydın.

The efficiency of 80 W monocrystalline and polycrystalline type panels is investigated in Aydın province conditions. Measurements made in real environment, since the climatic conditions of the region depend on parameters such as outdoor temperature, solar radiation intensity, panel surface temperature. It is also different from their efficiency under Standard Test Conditions. Efficiency is determined as the most efficient panel type monocrystalline solar panel for Aydın province within the framework of cost analysis. Within the framework of the research, the results are obtained by comparing the amount of radiation coming to the panel, the current, voltage, and the efficiency and performance rates over the maximum power parameters produced by the panel.

- As a result of the comparisons, the highest power output is obtained from the monocrystalline panel as 49.74 W at hour of 13:00 in August.
- It has been observed that there is an approximately linear relationship between solar radiation and panel output power.
- It has been observed that there is an inverse relationship between efficiency and surface temperature.
- The maximum efficiency rate of the monocrystalline panel is obtained as 13.94% as a result of experimental study.
- The average efficiency of the monocrystalline panel is obtained as 8.13%

- The maximum efficiency of the polycrystalline panel is obtained as 12.13%
- The average efficiency of the polycrystalline panel is obtained as 8.52%
- The maximum performance rate of the monocrystalline panel is 62.18%
- The maximum polycrystalline panel performance rate is calculated as 57.66%
- Increasing intensity of solar radiation increases current and power.
- It is determined that a monocrystalline panel would be more suitable for Aydın summer conditions.

6. RECOMMENDATIONS FOR FUTURE WORK

This study has provided fundamental data on the monocrystalline solar panel should be preferred in systems to be installed in Aydın. This study also has highlighted the the most important factor that causes losses in the power generation of solar panels is atmospheric conditions. Radiation values, sunshine duration, precipitation regime, dusting condition, temperature values of the area to be invested are important parameters in the increase or decrease of power generation potential. Locations with low dusting and low humidity can be preferred in land selection. In addition, the efficiency, area, and power value of the panel should be taken into account while selecting the panel. Since panels with high production value will need less installation space, it will reduce the land cost. In addition, panels that can heat up quickly should not be preferred. Because high panel temperature will reduce the efficiency of the panel.

It is recommended that today, developing technology and increasing energy need direct us to new energy sources. The most popular of these sources are photovoltaic systems. Photovoltaic systems have a growing and developing market share every day. Turkey is investing a lot in recent years with the influence of this tendency. In parallel with this, academic studies on photovoltaic systems gained speed. Our country is among the countries that can benefit the most from solar energy due to its geographical location. For the solar panels to be used in our country to operate at the highest efficiency, the slope angles must be calculated correctly and positioned according to these calculations.

It has been shown that in order to increase the efficiency of electrical energy generation, the panels should be designed considering environmental, climatic conditions and placed according to these conditions. It has been stated that parameters such as dust accumulation, air pollution, temperature, wind speed, humidity, shading, solar radiation and panel inclination angle significantly affect panel efficiency, taking into account these factors, and necessary precautions should be taken to minimize their effects. In order to benefit from sunlight in the best way during the day and to maximize the amount of electrical energy produced, panels with solar tracking systems can be designed and implemented. It is predicted that this study will be a reference to possible studies on energy analysis of solar panels in Aydın and will contribute to the literature.

REFERENCES

Alaaeddin, M.H., Sapuan, S.M., Zuhri, M.Y.M., Zainudin E.S., Faris M. AL-Oqla. 2019. Photovoltaic applications: Status and manufacturing prospects. **Journal of Renewable and Sustainable Energy Reviews**, 102(2019): 318-332.

Arslan, İ. 2018. Comparison of the Efficiency of Polycrystalline and Monocrystalline Type Pv Solar Panels under Tekirdağ Conditions, Master Thesis Biosystem Engineering Department, Namık Kemal University Institute of Science, pp. 1-27. Tekirdağ.

Başoğlu, M., Kazdaloğlu, A., Erfidan, T., Bilgin, M., Çakır, B., 2015. Performance Analyzes Of Different Photovoltaic Module Technologies Under İzmit, Kocaeli Climatic Conditions. **Journal of Renewable and Sustainable Energy Reviews**, 52: 357-365.

Bayat, M. 2016. Energy and Exergy Analysis of a Silicon Based Polycrystalline Solar Panel in Karabük Climate Conditions, Master's Thesis in Mechanical Engineering, Karabük University Institute of Science, pp. 3-4. Karabük.

Bulut, H., Durmaz, A. F., Yeşilata, B., 2006. Experimental Investigation of Solar Radiation Values on Inclined Surface. **In Proceedings of First National Solar and Hydrogen Energy Congress**, 21-23 June 2006, Eskişehir.

Chander, S., Purohit, A., Sharma, A., Nehra, S.P., Dhaka, M.S., 2015. A Study on Photovoltaic Parameters of Monocrystalline Silicon Solar Cell with Cell Temperature. **Journal of Energy Reports**, 104-109.

Çıngı, A. 2019. Determination of Energy Efficiency of Photovoltaic Panels Used in Solar Energy Power Plants, Master's Thesis Electrical and Electronics Engineering Department, Kilis 7 Aralık University Institute of Science, pp. 18-19. Kilis.

Demiröz, E., Kurban, M., Dokur, E., 2016. Efficiency Analysis of Solar Energy Systems, Bilecik Kütahya Application, **Journal of Advanced Technology Sciences**, 5 (2), 87-100, Düzce.

Demirtaş, M. 2006. Computer Controlled Solar Tracking Mechanism Design and Application, **Journal of Polytechnic**, 9 (p): 247-253.

Dinçer, F. 2011. Overview Of The Photovoltaic Technology Status And Perspective İn Turkey. **Journal of Renewable And Sustainable Energy Reviews**, 15: 3768–3779.

Dişli, F., 2018, Detection of dust density on photovoltaic panels by image processing, Master Thesis, Fırat University Institute of Science and Technology, p 4. Elazığ.

Dobrzanski, LA., 2010. "Application Of Crystalline Silicon Solar Cells İn Photovoltaic Modules", Archives Of Materials Science And Engineering, Poland, **Journal of International Scientific**, 44: 96-103.

Er, Z., Rouabah, Z., Kızılkan, G., Orken, A.T. 2018. Standards And Testing Experiments For A Photovoltaic Module. **European Journal of Science and Technology**, 12-15.

Eren, C., 2019. Interface Design for Optimum Tilt Angle in the Placement of Solar Panels, Master's Thesis Electrical and Electronics Engineering Department, Gazi University Institute of Science and Technology, pp. 5-14. Ankara.

Erkul, A., 2010. Investigation of efficiency of Monocrystalline, Polycrystalline and Amorphous-Silicon solar panels and application of lighting system, Master Thesis, Gazi University Institute of Science and Technology, pp. 1-19. Ankara.

Esen, H., Kapıcıoğlu, A., 2015. Investigation of Efficiency of Solar Cells Placed at Different Heights. Bitlis Eren University, **BEU Journal of Science**, 4, 198- 204.

Girgin, M.H., 2011. Feasibility of a Photovoltaic Solar Power Plant, Energy Production Assessment and Economic Analysis for a 5 Mw Solar Power Plant in Karaman Region, Master Thesis, Istanbul Technical University Energy Institute, pp. 10-11.

Ju, F., Fu, 2011. Research On İmpact Of Dust On Solar Photovoltaic (PV) Performance. In Electrical And Control Engineering (ICECE), **In Proceedings of 2011 International Conference On** (Pp. 3601-3606). IEEE.

Kaddoura, TO., Ramli, MAM., Al-Turki, YA. 2016. On The Estimation Of The Optimum Tilt Angle Of PV Panel İn Saudi Arabia. **Journal of Renewable And Sustainable Energy Reviews,** 65:626–634.

Karaca Et Al., 2011. Solar Potential of Konya and Its Vicinity and Application of Solar Electricity Generation System in Selçuklu Municipality Muhtar Houses, **In Proceedings of First Konya City Symposium**, p.275-292, Konya.

Koca, T.F., 2019. Investigation of Environmental Effects Affecting Photovoltaic Properties of Silicon Solar Cells, Master Thesis, Fırat University Institute of Science and Technology, pp. 10-12. Elazığ.

Kutlu, N., 2016. Calculation of Number of Panels, Efficiency and Economic Analysis to Meet the Electricity Need of a House in Isparta Province. **Süleyman Demirel University Yalvaç Academy Journal**, 1 (1), 41-52.

Mutluay, B. 2016. System Simulation and Technoeconomic Feasibility of a Photovoltaic Power Plant Design, Master's Thesis Mechanical Engineering Department, Fırat University Institute of Science and Technology, pp. 5-6. Elazığ.

Notton, G., Cristofari, C., Mattei, M., Poggi, P. 2005. Modelling Of A Double-Glass Photovoltaic Module Using Finite Differences. **Journal of Applied Thermal Engineering**, 25(17-18). 2854-2877.

Ogbulezie, J.C., Njok, A.O., Panjwani, M.K., Panjwani, S. K. 2020. The impact of high temperature and irradiance source on the efficiency of polycrystalline photovoltaic panel in a controlled environment. **International Journal of Electrical and Computer Engineering**, 10(4): 3942-3947.

Oğuz, Y., Karakan, A., Uslu, B., 2015. Investigation of the Efficiency of Monocrystalline, Polycrystalline and Thin Film Solar Panels Installed in Afyonkarahisar. **In proceedings of the Second International Sustainable Buildings Symposium**, pp. 105 – 119. Ankara.

Özçalık, H.R., Yılmaz, Ş., Kılıç, E. 2013. "Mathematical Model of Solar Cell With The Help of An Equivalent Circuit With A Diode And Investigation Of Its Parameters", **KSU Journal Of Engineering Sciences**, 16 (1).

Parida, P., Iniyan, S., Goic, R. 2011. A Review Of Solar Photovoltaic Technologies. **Journal of Renewable And Sustainable Energy Reviews,** 15: 1625-1636.

Rahmanov, T. 2019. Investigation of Performance Enhancement Methods in Photovoltaic Panels, Mechanical Engineering Department Master Thesis, Ondokuz Mayıs University Institute of Science, p 35. Samsun.

Sabounchi, A. M. A. 1998. "Effect Of Ambient Temperature On The Demanded Energy Of Solar Cells At Different İnclinations", Renewable Energy, **Journal of Renewable Energy**, PII: S0960-1481 (98) 00061-5.

Senthil Kumar, M., Balasubramanian K.R., Maheswari L., 2019. Effect of temperature on solar photovoltaic panel efficiency. **International Journal of Engineering and Advanced Technology**, 8(6): ISSN: 2249-8958.

Shafique, M., Luo, X., Zuo, J. 2020. Photovoltaic-green roofs: A review of benefits, limitations, and trends. **Journal of Solar Energy**, 202(2020): 485-497.

Sonsuz, O. , Adıgüzel, E., Ortaç Kabaoğlu, R., Ersoy Yılmaz, A. 2020. The effect of pollution on photovoltaic panels under climate conditions in Hatay. **Journal of Science and Technology of Erzincan University**, 13(3): 1413-1423.

Şenpınar, A., 2006. Calculation of Optimum Fixed Solar Panel Angle Based on Sun Angles. Eastern Anatolia Region Studies, 4(2): 36-41. Elazığ.

Taşçıoğlu, A. 2015. A Research on the Power Performance of Monocrystalline and Polycrystalline Solar Panels in Bursa Conditions, Master Thesis Biosystem Engineering Department, Uludağ University Institute of Science, Bursa. **International Journal of Photoenergy**. 2016: 7 pages.

Thevenard, D., Pelland, S. 2011. "Estimating The Uncertainty İn Long-Term Photovoltaic Yield Predictions", **Journal of Solar Energy**, 91 (2013) 432–445.

Turhan, S., Çetiner, İ. 2012. Performance Evaluation in Photovoltaic Systems. **In Proceedings of the 6th National Roof & Facade Symposium**, 12 - 13 April 2012, Uludağ University Faculty of Engineering and Architecture - Görükle Campus – Bursa.

Varınca, K., Gönüllü, M.T. 2006. In Turkey, Solar Energy Potential and Use Degree of this Potential, Method And A Survey on Prevalence of this Potential, **In Proceedings of First National Solar and Hydrogen Energy Congress**, Eskişehir.

Yıldız, N. 2019. Investigation of Radiation-Energy Conversion in Electricity Generation with Photovoltaic Cells, Master's Thesis, Department of Energy Systems Engineering, Giresun University Institute of Science, pp. 4-6, Giresun.

Zaraket, J., Aillerie, M., Salame, C. 2017. Capacitance Evolution of PV Solar Modules Under Thermal Stress. Energy Procedia. **Journal of Energy Procedia**. 119: 702-708.

RESUME

Personal Information

Name Surname : Ramazan Burak DOMURCUK

Place and Date of Birth : Isparta - 1993

Education

Undergraduate : Eskişehir Osmangazi University

Post Graduate : Aydın Adnan Menderes University

Foreign Languages : English (Advanced)

Experience

The Institution and Year: Rbd Burak Engineering 2015 - Present

Contact

E-mail : burakdomurcuk@gmail.com

Date : 11/01/2021