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PERFORMANCE ANALYSIS OF PV PANEL FOR DIFFERENT WORKING CONDITIONS IN KIRKUK REGION

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By Mohammed Madhat Rashid RASHID

February 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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Mohammed Madhat Rashid RASHID

ABSTRACT

PERFORMANCE ANALYSIS OF PV PANEL FOR DIFFERENT WORKING CONDITIONS IN KIRKUK REGION

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Master of Science in Electrical and Electronics Engineering

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In this study, we evaluated the effect that different factors of the environment have on the photovoltaic PV system performance. It is well knowledge that the weather conditions in a given area can have a significant impact on the amount of electricity produced by a photovoltaic (PV) system. The amount of solar energy that strikes the panels, the temperature and humidity of the surrounding air, and the velocity of the wind are the most readily apparent factors. The degree to which the panels get dirty or contaminated is impacted by the local weather conditions and the amount of precipitation that falls, which in turn has an effect on the amount of electricity produced. In this thesis, the sensitivity of monocrystalline solar modules to changes in environmental parameters like dust and high temperature buildup and cloud cover in the Kirkuk environment is studied from the start of March to the end of August 2022. Three identical solar photovoltaic (PV) modules were used in a controlled experiment to determine the impact of various environmental conditions on a PV module. Every morning throughout April and May, the modules are cleaned so that the impact of dust accumulations on the panel’s surface may be tracked. The results show that the daily energy yield of the uncleaned module is drastically reduced due to the accumulation of dust. However, this effect last for a very long time. The effect on the sky's clouds is instantly noticeable. This limitation highlights the challenges associated with routinely cleaning the surface of the module and renders solar photovoltaics (PV) panel an unreliable power source for far-flung devices.

The second contribution of this thesis is to compute the consumption of a regular house in Iraq for six months (March-August) to find the optimum design of a soalr system to be enough for this house without using the goverment electricity.

2023, 82 pages

Keywords: Solar panel, Photovoltiac, Environmental conditions, Dust effect, PV performance, Solar system, Pv multiconditions

ÖZET

KERKÜK BÖLGESİNDE FARKLI ÇALIŞMA KOŞULLARINA GÖRE PV PANEL PERFORMANS ANALİZİ

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Bu çalışmada, çevrenin farklı faktörlerinin fotovoltaik PV sistem performansı üzerindeki etkisi değerlendirilmiştir. Belirli bir alandaki hava koşullarının bir fotovoltaik (PV) sistem tarafından üretilen elektrik miktarı üzerinde önemli bir etkiye sahip olabileceği iyi bilinmektedir. Panellere çarpan güneş enerjisi miktarı, çevreleyen havanın sıcaklığı ve nemi ve rüzgârın hızı en çok etki eden faktörlerdir. Panellerin kirlenme derecesi, yerel hava koşullarından ve düşen yağış miktarından etkilenir ve bu da üretilen elektrik miktarını etkilemektedir. Bu tezde, monokristal güneş modüllerinin Kerkük çevresindeki toz ve yüksek sıcaklık oluşumu ve bulut örtüsü gibi çevresel parametrelerdeki değişikliklere duyarlılığı, Mart ayının başından Ağustos 2022'nin sonuna kadar incelenmiştir. Üç özdeş güneş fotovoltaik (PV) modülü çeşitli çevresel koşulların bir PV modülü üzerindeki etkisini belirlemek için kontrollü bir deneyde kullanılmıştır. Nisan ve Mayıs ayları boyunca her sabah modüller temizlenerek toz birikintilerinin pano yüzeyindeki etkisi ortaya konulmuştur. Sonuçlar, temizlenmemiş modülün günlük enerji veriminin, toz birikmesi nedeniyle büyük ölçüde azaldığını göstermektedir. Bu etki çok uzun süre devam ettiği görülmüştür. Gökyüzündeki bulutlanmanın da üretim üzerindeki etki anında fark edilmektedir. Bu sınırlamalar, modülün yüzeyinin rutin olarak temizlenmesiyle ilgili gereklilikleri ve güneş fotovoltaik (PV) panelinin erişimi zor olan uzak kullanımlar için verimi etkileyen bir faktör olarak karşımıza çıkar.

Bu tezin ikinci kısmında, Kerkük bölgesinde yer alan standart bir konut için altı aylık (Mart-Ağustos) tüketimini göz ününe alındığında, şebeke elektriğini kullanmadan bu konuta yetecek optimum güneş sistemi tasarımıve maliyet analizini yapılmıştır.

2023, 82 sayfa

Anahtar Kelimeler: Güneş paneli, Fotovoltiyak, Çevre koşulları, Toz etkisi, PV performansı, Güneş sistemi, Pv çoklu koşulları

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Mohammed Madhat Rashid RASHID
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CONTENTS

LIST OF SYMBOLS

AC	Alternating current
AM	Air mass
AMO	Alien spectrum
CdS	Cadmium sulfide
d ʎ	Wavelength differentation
DC	Daily cleaning
E	Energy
E(ʎ)	Energy with respect to the wavelength
G	Solar radiation
g/m2	Gram/meter sequare
Gon	Extraterrestrial radiation
Gsc	Solar constant
H	Solar elevation
hc	Constant of plank
ID	Diode current
Io	Diode saturted current
Isc	Short circuit current
Isc	Short curcuit current
I-V	Current -voltage relationship
JSC	Short circuit current density
K	Boltizman factor
Km	Kilometer
kWh/m2	Yearcumulative irradiation annually
N	Refractive index
Na	Acceptor impurity concentration
p-n	Positive - negative junction
q	Colomb number
R	Aorrelation factor
R2	Humidity determination factor
Rh	Humidity level
SR	Short circuit current in the PV
SR(ʎ)	The short circuit current in the PV with respect to the wavelength
T	Atomic charge
Voc	Open circuit voltage
W/m2	Watt / meter sequare
ʎ	Wavelength
XE	Lectron affinity
Ɵz	Zenith angle
V	Voltage at the output terminal

LIST OF ABBREVIATIONS

AM	After middy
AZ	Arezona
CPV	Concentrator photovoltaic
CCZTSe	Copper cadmium zinc tin selenium
CZTS	Copper, zinc, tin and sulfur
EHP	Electron-hole pair
Eg	Energy gap
FF	Fill factor
FTO	Fluorine doped Tin oxide
MODIS	Moderate resolution imaging spectroradiator
NREL	National renewable energy laboratory
NiCd	Nickel-cadmium
PV	Photovoltiac
PM	Post middy
MTS	Solar system cooporation
TV	Television

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1 INTRODUCTION

The two essential resources that give the necessities for any human activity for an acceptable and sustained life quality are energy and fresh water. Growth is fueled by energy, which is a prerequisite for both social and economic advancement. Due to the exhaustibility and environmental damage of conventional energy sources, interest in the development of renewable energy sources has grown (Sen 2009).

At some point, it becomes vital to take into account the environmental effect of using fossil fuels; in fact, the burning process of these fuels results in the release of toxic compounds including sulphurous anhydride, nitrogen monoxide, and carbon hydrazine (15-billion ton of CO2 are falled out into the atmosphere yearly). While carbon anhydride is the principal greenhouse gas responsible for global warming, sulphides anhydride and oxides of nitrogen both play a role in the creation of acid rain (greenhouse effect). Therefore, the danger of grave repercussions for both the environment (desertification, arctic ice melt, sea level rise, etc.) and indirectly the human health is concealed behind the use of fossil fuels (Lorenzini *et al.* 2010).

These occurrences make it clear that the world's energy balance has to be adjusted in favor of clean renewable power sources, along with the skyrocketing rise in energy costs since the start of the twenty-first century. We may need simultaneously increase all technologies' energy efficiency (Vesselinka *et al.* 2009).

The benefits of renewable energy include its sustainability (nondepletability), ubiquity (they can be found all over the globe, unlike fossil energy and materials), and almost zero pollution. In contrast to fossil fuel and nuclear-fired steam plants, wind turbines and solar panels may produce energy without the need of water. Renewable energy's drawbacks include variableness and poor density, which often leads to a higher initial cost. Other drawbacks or perceived issues for various types of renewable energy include visual pollution, odor from biomass, bird and bat death from wind turbines, and saltwater from geothermal power. There will be perceived and actual issues for the locals wherever a sizable renewable energy project is to be built. There is the issue of "not really in my neighborhood" for nuclear power, conventional fossil fuel power plants, and even renewable energy (Vesselinka 2009).

The majority of the world's sustainable energy originates either directly or indirectly from the sun. It is possible to make a direct use of daylight or solar power for a variety of purposes, including the heating and lighting of homes and other buildings, the production of electrical power, the water boiling for heating purposes, the cooling of solar, and a number of commercial and mechanical applications (Abaasand and Chaichan 2009). In a similar fashion, the warmth of the sun is what drives the winds, and the energy from those winds may be captured by wind turbines. At that time, the water evaporates because of the wind and the heat from the sun. The vitality that is released from this water vapor in the form of precipitation, such as rain or snow, and the subsequent formation of rivers or streams may be captured and employed as hydroelectric power (Chaichan and Kazem 2016).

Photovoltaic (PV) systems, which are powered by sunlight and are recognized for their ability to generate electric power, have been more popular in recent years (Kazem et al. 2013). These systems may be installed on residential and commercial buildings that can benefit from the storage of solar energy. Solar photovoltaic (PV) systems are quickly becoming the primary vision in the growth of enhanced sustainability, cleaner energy, and reduced service prices, particularly in parts of the nation where solar energy is the most grounded (Kazem et al. 2015). This is particularly true in regions where solar energy is the most based. In any event, further research and development effort in the area of producing suction is still required for this technique. In addition, qualified professionals are obligated to educate their customers on the many benefits that come with the installation of PV systems (Kazem *et al.* 2013).

Numerous researchers have investigated the effect of meteorological conditions. The quantity of energy that may be harvested from solar cells is affected by a variety of factors, including temperature, the intensity of solar radiation, relative humidity, and wind. According to the findings of the research which are cited in references (Hanif *et al.* 2012), scientists looked at how ambient temperature affected cell productivity, and they found that warmer temperatures led to less output. Kempe (2006) evaluated the influence of humidity levels on the productive production of the PV cell and found that the impact of relative humidity was maybe lower than that of the effect of temperature on the productive output of the cell, but it emphasizes a decrease in the cell's efficiency. The researchers determined that the effect of relative humidity on the productive output of the cell was less significant than the effect of temperature.

According to Thongpao *et al.* (2010), it was discovered that an increase in the solar radiation raises the degree of cell activity temperature. However, if the cells are not cooled, their productivity decreases because the vast majority of the solar radiation is used to raise the temperature of the cells. (Kimber *et al.* 2006, Goossens and Van Kerschaever 1999) stated that the wind is helping to reduce dust off the surface of the cell, which in turn cleans the surface and increases the productivity of the cell.

The same cell that the wind helps to boost productivity in also feels more at ease as a result of its effects. However, high-speed winds have the potential to inflict damage to the cell, which might then lead to the base being damaged or broken.

All of the studies came to the conclusion that a reduction in productivity of the cell results from the buildup of dust and pollutants, and as a result, the cell has to be cleaned on a regular basis in order to get rid of the dust and contaminants that have collected (ANS 2002, ASTM 2018). In the case of the dust deposition on PV systems, there are two aspects that interact with one another; these are the dust specs and the local climatic conditions. The human activities and the building of the solar cell system attributes such as its kind, surface polishing, installation height, and orientation are included in the site-local weather. In addition to this, the kind of vegetation that exists at the location has an important effect in this respect.

The collection and aggregation of dust are profoundly affected by the dust's many features, including its electrostatic, chemical, biological, and physical aspects. It is common knowledge that dust deposition makes it more likely for further dust to settle. This is because the particles that have already settled attract and encourage other particles to settle, which in turn makes the surface of the PV panel more receptive to collecting dust (Duffie and Beckman 1974).

The aformaentioned information makes that abundantly evident. Also the factors have roles in the productivity of the solar panels, and the influence of variables has been investigated individually or in conjunction with one another. In addition to the fact that the climatic conditions in each region are distinct from one another, there is no one rule that can be used to determine the effect.

The need for energy sources that are both clean and sustainable has seen a significant uptick in demand over the past few years. It has reached a stage when governments worldwide acknowledge the necessity for a very clean and reliable reference of electricity to gradually concaret traditional energy sources and eventually replaces them in the long run. This requirement has been brought about as a result of the current state of affairs. Solar photovoltaics is one of the environmentally friendly alternatives that are available (PV). The conversion of solar radiation into electrical power is carried out via photovoltaic modules, which are solid-state electronics. The utilization of a source of energy that is both environmentally friendly and inexhaustible is the primary benefit of PV modules (solar irradiance). That is still seen to be a significant cost, despite the fact that the cost of producing PV modules is decreasing (Abaasand and Chaichan 2009), which is causing this perception to shift. The current size of the market influences the high original outlay because it is very tiny. A governmental incentive are required to establish the economy of scale that are necessary for a large cost reduction in order to drive down the prices of PV systems. This is accomplished through the use of tariffs or subsidies, which become a vital critical aspect since the system will return its initial investment over a time period and continue to generate a surplus after that. PV systems become an extremely appealing source of energy due to the fact that they have very long lifetimes (Abaasand and Chaichan 2009, Chaichan and Kazem 2016). This is because manufacturers guarantee that the performance reduction of PV modules will be less than 10 percent within the first decades and less over 20 percent for the next centuray for crystallin Silicon technology. A battery of stress tests is performed on the PV module to determine its performance, durability, and the extent to which it may be used safely (Chaichan and Kazem 2016). The results of these tests are then used to calculate the lifetime of the module. These tests, unfortunately, do not take into account all of the variables that the PV panels are subjected to in their actual operating environments. Some of these factors include prolonged cell mismatch as a result of manufacturing defects as well as organic soil such like bird droppings, snowy wheater, pollutant, and drops of dust.

The "Sun Belt," which is a zone of primarily arid regions all around the equator with exceptional amounts of sunlight, is becoming an attractive location for the construction of solar systems due to the declining prices of these systems as well as the high levels of irradiance. High temperatures and infrequent rainfall are not the only characteristics of arid regions; sand dust may also be found in many of these areas, particularly in the regions that make up the Middle East. In terms of the applications of solar energy, this is a factor that should be avoided at all costs which depicts a dust storm obscuring an image captured by a satellite above the Red-Sea between Egypt and Saudi Arabia. The storm is located in the region between Egypt and Saudi Arabia. This thesis will demonstrate that when particles such as dust or sand fall onto Photovoltiac panels, they disrupt the quality of lighting by absorption and dispersing light. Sand and dust are examples of foreign substances.

Kazem et al. (2013), repoated some points such as the total yearly irradiance, the annual total rain, the average annual temperature and humidity, and the total annually losses owing to dust drops at a slanted surfaces. (Kazem *et al.* 2015)

The efficiency of a PV system is assessed using the total energy production that is measured over the course of a specific amount of time. The amount of energy that a module generates per power unit, also known as the array yield, is another measure that is commonly used for comparison between different technologies, proper installation, orientation, balancing of systems, and so on. The amount of energy that a PV module has produced over a certain amount of time can be defined by its energy yields, as indicators of the profitability. Calculations for electricity tariff as well as other payback estimates are based on the simple assumption of assessing how much electricity a solar panel is anticipated to produce in a certain climate. Therefore, dust continues to play a key part in the computation of the PV yield, since it has a considerable impact on external circumstances by concealing the illuminance falling on the module's exterior (Kazem *et al.* 2013, Hanif *et al.* 2012) and by modifying the solar radiation which affects PV modules because they are spectrally dependent devices (Charabi *et al.* 2003). The quantity of sunlight that hits the module's surface is diminished when dust is present (Hanif *et al*. 2012). Dust also has an effect on the PV. Any one of these effects, or all of them together, will have an impact on the yield of the PV system. In this thesis, the effect of those parameters on dust is explored using specialized outdoor measurements carried out in an environment characterized by a high level of airborne particulate matter (Charabi *et al.* 2003).

The increase in energy utilization that preceded the industrialization gave rise to worries about the climate and the sources of energy, which ultimately led to an increase in global overall temperature of the earth and a reduction in the utilization of fossil fuels. These outcomes ultimately resulted in an increase in the temperature of the earth. It is a widely held belief that fossil fuels account for more than 80 percent of the total energy consumption on the planet and serve as the preeminent source of energy all over the world (Abaasand and Chaichan 2009). It is possible that the rapid use of a wide variety of non-renewable resources, which results in the release of a substantial number of emissions, is contributing to the acceleration of global warming. Because of the problems that are linked with fossil fuels and the huge environmental issues, academics and engineers have been motivated to look for alternative resources that are environmentally friendly (Kazem *et al.* 2013). Because of this, researchers have been investigating whether or not it is possible to make use of solar power, which is a type of renewable energy, in order to lessen the impact of these issues. Edmond Becquerel made the discovery that would later pave the way for the creation of the photovoltaic (PV) system in the year 1839. Solar photovoltaic (PV) systems are regarded as a kind of sustainable energy (Kazem *et al.* 2012) since they do not result in the emission of any pollutants. Solar panels are currently being utilized in the majority of countries throughout the world as a primary source for the creation of electrical energy. This is possible as a consequence of the considerations that were stated earlier in this article.

The installation of solar panels does not have any unfavorable consequences on the environment that they are placed in, such as an increase in the amount of carbon dioxide emissions or a worsening of global warming. In addition, solar panels get their power from the sun, which is a source of energy that never runs out and may be used in indefinite amounts. (Kazem *et al.* 2015). Although there is a direct correlation between the amount of energy produced and the intensity of the radiation, there is also a correlation between the angle of irradiance deflection and the amount of intensity of the sun's radiation. This is because the angle of irradiance deflection has an effect on how the sun's radiation is deflected. Therefore, the ratio of the amount of power that is output by the PV is dependent not only on the intensity of the irradiance but also the angle at which it is received. The most effective and efficient angle is a normal angle, which implies that the PV is exposed to sunlight in a manner that is typical. This angle is the most productive and effective angle.

In spite of the clue that the PV panels have a low performance, the climatic conditions may further reduce their efficiency and output which will cause the system to be in an unstable state.

Scholars such as (Hanif *et al.* 2012), have been carried out in different regions of the world in order to investigate the impact that dust has on the operation of solar systems. Having said that, these inquiries were carried out in a specific region. In point of fact, research (Kazem and Chaichan 2015) discovered that there was a higher decline in the performance of PV.

In addition, (Makrides *et al.* 2012) suggested that the output power was dropping at a rate of 17.4% each month. In addition, studies on the impact that cloud shadows have on the efficiency of distributed solar electricity have been carried out in the state of Massachusetts (Kazem *et al.* 2012). The results of observations and analyses of the irradiation from the sun and the operation of photovoltaics showed that there were insufficient step fluctuations in the load levels to cause issues with voltage flickering. The impact that the cloud cover has on the amount of photovoltaic energy produced in South Africa was another topic of investigation (Hughes *et al.* 2011). However, across the area of the study, no work of this kind has been done for at least a month to evaluate the effects of dust and even cloud cover on the efficiency of the photovoltiac modules. This is the case despite the clue that this topic has been under investigation.

The purpose of this work is to investigate the effects of dust deposition (between the months of March and August) and cloud cover on a monocrystalline solar module in Kirkuk city in Iraq from March to the end of August 2022. Iraq serves as the site of this particular research endeavor. Therefore, it is of the utmost relevance to undertake an analysis of the effects of these elements in order to assure correct planning of the consumption of solar photovoltaic energy.

1.1 Photovoltaics' Capability of Direct Energy Conversion

The term "photovoltaic" is a compound word: the Greek word "photo," which refers to light, and the Latin word "voltaic," which refers to electricity. Light is converted into electricity through the use of a technology known as photovoltaics, which is also the name of the hardware that makes it possible to use solar energy. The direct transformation of light's photons into electricity's voltage is what photovoltaics making use of semiconductor materials, are all about (Elena 2011).

The photovoltaic (PV) panels which carry out this conversion offer a variety of advantages (Richard 2008):

1- Solar photovoltaic panels produce no emissions of greenhouse gases, making them carbon neutral.
2- It does not generate any waste byproducts.
3- Without any significant maintenance, most pieces of equipment have a lifespan of 25 to 30 years.
4- It makes use of a resource that does cost anything (the sun) and it allows for energy independence from sources of fuel that come from other countries.

5- Solar energy systems that have been erected by their owners supply the owner with dispersed electricity and insulate the owners from difficulties with the grid, like as shortages, blackouts, and increases in the cost of electricity.
6- It can produce electricity even on overcast days and in environments with colder temperatures.
7- It may produce power during the day, when electricity costs the most, so avoiding the biggest expenditures associated with the production of electricity and reducing the peak demand for utilities.
8- The declining costs of solar power, which are falling at an average rate of five percent per year, have already making solar energy competing against retail electricity pricing in several countries around the world (like, Japan).
9- It can make use of the same silicon chips which are utilized either by semiconductor devices, which indicates that the two businesses have a common knowledge base and investment in research and development (R&D).
10- We are already in the stage of mass production, as well as the economy is investing significant sums of money into research and development efforts.

1.2 A Brief Overview of the Development of Photovoltaics

The discovery by Becquerel in 1839 of a photovoltiac generated by the light acting on to electrodes in an electrolyte marks the beginning of the construction of photovoltaic panels as we know them today. Adams and Day made the discovery of the photoelectric effect in selenium around 40 years later. By roughly the year 1914, selenium as well as copper indium cells had achieved solar performances of about 1%. When Chapin, Fuller, and Pearson achieved a photovoltaic performance of 6% for a silicon junctions' cell in 1954, the modern age of semiconductor photovoltaics was officially kicked off (Richard 1998).

Between the years 1957 and 1959, Hoffmann Electronics was able to attain an efficiency of 8, 9, and 10% and create the grid contact, which considerably lowered the device's series resistance. In the year 1960, Hoffmann Technology made the switch to photovoltaic (PV) cells with an efficiency of 14%. These cells were primarily utilized for space technology and other space-related applications. With a power of 242 W, the world's biggest array for terrestrial uses at the time was erected by Sharp in Japan in 1963 (Vesselinka *et al.* 2009).

In 1973, photovoltaics had a momentous year: Cherry Hill Conference in the United States (confirmed photovoltaic's potential and credibility for governmental funding for research); world's first solar powered dwelling (University of Delaware, USA) constructed using Cu2S (not c-Si) photovoltaic panels. Yet, there was a worldwide oil crisis. 1975 saw the publication of Hovel's first book solely devoted to PV technology and science (USA). Saudi Arabia saw the installation of a 350 kW Concentrating array in 1981. GaInP/GaAs 2-terminal concentrator multijunctions with efficiencies more than 30% were announced by NREL in the United States of America in 1994 (Antonio and Steven 2003).

More than 25 percent of all photovoltaic modules made globally in 2006 were installed in Germany (Vesselinka *et al.* 2009). In 2008, a new efficiency benchmark was reached using solar cells. Scientists working at the Renewable Energy Laboratory nrel (NREL), which is part of the United States Department of Energy, have broken the world record for the efficiency of solar cells by creating a photovoltaic device that transforms 40.8% of the light that falls on it into energy. In 2011, the rapidly expanding manufacturing sector in China drove down the cost of producing silicon photovoltaic panels to around $1.25 per watt. Installations doubled all over the planet.

In the year 2012, solar3D, Inc., the developer of a revolutionary 3-dimensional solar cell technology to maximize the conversion of sunlight into electricity, had also announced the successful formation and procedure of a working 3-dimensional silicon solar cell that generates at least 250% of the power of a basic silicon solar cell. The National Renewable Energy Laboratory (NREL), a designer and producer of concentrated photovoltaic (CPV) solar energy systems, stated today that it has achieved an efficiency rating of 35.9% under the usual test parameters of 1000 W/m2 and 25°C cell temperature.

1.3 Utilization of a Photovoltaic (PV) System to the Generation of Electricity

A solar photovoltaic (PV) system consists of a variety of components, each of which should be chosen with consideration given to the building's system component, location of the project, and application needs. The following is a list of the primary components that make up a solar PV system:

1- Photovoltaic module: A device that transforms solar into direct current electricity (Elena 2012).
2- Charge controller for solar panels: Charge controllers are installed in the circuit that connects the solar generator to the battery in order to avoid the battery from being either overcharged or deeply drained.

In most cases, the charge controller will be equipped with a blocked diode that prohibits the batteries from being discharged by the solar generator when it is nighttime. A reliable charge controller will have an incredibly low interior energy consumption and will also be equipped with a loading trimmed switch to prevent the battery from discharging. Overall battery voltage of the solar system may need to be adapted to match that of the load, which may need the use of power conditioning (Antonio and Steven 2003).

There are a few distinct varieties of charge controllers, including:

- Shunt controller: The purpose of this component is to control how quickly the battery is charged. This controller is essentially wired in parallel with both the battery and the array.
- Serial controllers: The controller is often used in smaller photovoltaic (PV) systems and is linked in series between the PV array and the battery.
- Tracking control: This controller monitors the PV array in order to determine where the greatest power point is located (Djamila and Ernest 2012).

3- Solar batteries are typically steering deep cycle batteries. There are three types of solar batteries. These are the kind of batteries that can tolerate the manner where charging and discharging occurs in a solar system. In addition, their lifespan is far longer than that of standard automobile batteries. Batteries designed for deep cycling may have up to 80% of thier rated capacity discharged. Deep-cycle batteries are preferred for use in photovoltaic systems so that even when there is a lack of sunshine, the battery can still meet the load requirement (Ahmed and Ramesh 2011).

It is standard practice to utilize nickel-cadmium (NiCd) batteries as rechargeable batteries for home appliances. These batteries may also be acceptable for use in stand-alone PV systems, particularly in colder locations. When compared to lead-acid batteries, they provide a variety of distinct benefits. They are:

- Capable of being sold at inflated prices**.**
- Capable of being completely discharged, removing the need for excessive oversizing.
- Are more rugged.
- Operate very well at low temperatures and can withstand freezing without suffering harm to their cellular structure.
- Exhibit low resistances inside their own bodies.
- May be subject to a significantly increased rate of charge.
- Maintain consistent voltage during discharge.
- Live a more long and healthy life.
- Have little maintenance needs.
- Produce a minimal amount of discharge while they are not in use.

On the other hand, they do come with a few drawbacks, which are as follows:

- Typically cost between two and three times as much as the other option.
- Have decreased charge storage efficiency (between 60 and 70 percent).

- Can Be Required to Be Fully Discharged in Order to Prevent the Development of Memory and the Following Inability to Deeply Charge
- Have A Significantly Lower Capacity Increase as A Result of Low Discharge Rates (Wenham *et al.* 2007).

4- Inverters are employed to transform the direct current (DC) output of photovoltaic (PV) panels or a storage battery to alternating current (AC) power (Goetzberger and Hoffmann 2005), which can then either be supplied into the grid or utilized to power a hold system. A photovoltaic (PV) system needs an inverter in order for an AC appliance (240 V/50 Hz or 110 V/60 Hz) to work properly (This should be done only for appropriate appliances; it is not sensible to power an electric heater from a PV system). The conversion from low voltage DC power to higher voltage AC power is accomplished by a standalone inverter via the use of an inner frequency's converter and switches circuitry. The shape of the alternating current waveform may either be a square wave, which is characteristic of inexpensive inverters, or the almost pure sinusoidal start waving (sophisticated solid state electronic inverter). The inverter should be sized appropriately for the specific installation so that it can handle the surge currents that are associated with starting the motor (if this is applicable), but it should not be so big that this really ordinarily operates at a low percentage of its rated power (for example, less than 15 percent), which would result in a low level of efficiency (less than 85 percent). There are commercially available solid-state electronic inverters that have great efficiency and reliability (95%), in addition to having a cost that is acceptable (John and Tony 2006).

5- Net-metering: The production of a grid-connected Photovoltaic may not completely meet the on-site energy demand. A house or company with a PV system may export surplus power to the electric grid at certain periods and acquire power from of the network at another period.

When photovoltaic (PV) systems produce more electricity, the electric meter will run in the other direction, accumulating credit with the utility. The term "net-metering" refers to the system where just one electric meter is used. Yet it measures electricity use in both directions. In the process known as "net metering," the electricity generated by the solar array is sent into the local power grid so that it may be credited immediately. The excess solar energy that is generated by a home's photovoltaic system and is not used by the occupants is sent back into the local power grid. When excess electrical power is returned to the electricity network, the meter in the homeowner's house begins to rotate in the other direction. This implies that the power produced by the solar system but not utilized in the house is "sold" to the local utility in order for the user to see a reduction in their monthly energy bill. This decrease in the cost of the power bill has a beneficial effect just on economy of investment. Because the cost of the electricity decreases, the amount of time it takes to recoup the initial investment decreases as well (Ahmed and Ramesh 2011).

6- Load refers to electrical items such as lights, radios, televisions, computers, and refrigerators that are linked to a solar photovoltaic (PV) system (Elena 2012).

1.4 Drawbacks Inherent in the Use of Photovoltaics

There are a set of drawback in the use of photovoltaics:

1- Diffused Fuel sources (sunlight is a relatively low-density energy).

2-The high expense of installation.

3-The auxiliary (balancing the systems) parts, including storage, have a dependability that is three times worse.

4- The lack of extensive commercially accessible systems development and installation up to the point of a lack of economically effective and viable storage options for energy.

1.5 Applications of PV in Urban Areas

The photographs that follow demonstrate various applications of photovoltaic systems in a variety of cities throughout the globe. Figure 1.1 and Figure 1.2 show some project with Photovoltaic system.

Figure 1.1 Small solar system and satellites communications network in Riyadh, Saudi Arabia

Figure 1.2 Richard Stockton School in New Jersey has solar umbrellas with a combined generating capacity of 2.1 megawatts that are powered by the arrays.

Figure 1.3 shown that follow demonstrate many applications of solar systems that may be found in the city of Kirkuk. Kirkuk University Presidency building contains 16 monocells, the value of each cell is 410 watts, and the inverter is 5 kilowatts. This system operates the server of the University colleges, in addition to the internet system and the computer network for all floors of the university presidency building, which consists of four floors and contains a large number of computers.

Figure 1.3 Solar panel in the University of Kirkuk

Figure 1.4 is to the Kirkuk University / College of Engineering / Department of Electrical Engineering, where the solar system contains 12 solar panel. The value of each panel is 450 watts and they generate around 18 amp and an invertor device with a capacity of 5 kilowatts that operates the entire computer lab. Note that the laboratory contains 40 laptops and 1 projector.

Figure 1.4 Solar panels in the university of Kirkuk, college of engineering

Figure 1.5 shows another solar system for the Electronics and Control Engineering Department at the technical College of Kikruk with has 32 panels and two inverters and 16 batteries where this system can generate about 35 amps. The system can feed two computer labs and most of the rooms' lightings.

Figure 1.5 A solar panel in the electronics and control engineering department at the Northern Technical University.

1.6 The Objectives of the Study

The following is a condensed list of the objectives of this work:

1. To provide accurate data regarding the generation of electricity from solar radiation in the city of Kirkuk using photovoltaic panels, as well as to determine the conditions for an improved harvesting of solar electricity.
2. To determine the conditions for an improved harvesting of solar electricity.
3. To collect data over the course of a period of six months, from the beginning of March until the end of August, and then analyzing those data with the intention of determining whether or not it is possible to predict the levels of solar radiation and the generated electrical energy, as well as the effect of a variety of environmental factors.
4. To determine the optimal size of a solar power system for a typical house in the city of Kirkuk by computing the amount of energy that a typical house in that city uses.

2 LITERATURE REVIEW

This review of the literature aims to accomplish a great number of primary goals. The first step is to investigate the many various techniques for storing energy that are now on the market or in theoretical development. Second, it is important to be aware of the various aspects that influence the efficiency of the energy storage process. Third, it identifies the component that influences the efficiency of the process of acquiring energy.

This survey is divided into three parts. The first part of this survey taled about the performance of the solar panel and the way that it is tested. The second part of the survey is demostrated the physical and the electrical details of the photovoltiac and the p-n juction. The last part of the survey is taking about the dust deposition and its afacts to the performance of the solar panels.

2.1 Performance of the Solar Panels

According to (Kazem and Chaichan 2015), it is shown that the influence that relative wet which called (humidity) has on the outputs of a photovoltaic system. Both the other climate parameters and the relative humidity itself are influenced by the relative humidity's presence or absence. Therefore, data on air temperature, sun brightness, and wind speed were optained from Sohar city in the country of Oman, and contrasted with humid levels during the periods of time spanning July-September of 2015. According to the findings, the relative humidity during the testing period had a significant impact on the effeciency of the PV panels. When the humidity levels were high, the photovoltaic system's voltage, current, as well as the system’s output power all fell. There is an inverse relationship involving humidity and wind speed, ambient temperature, and solar radiation, as indicated by the correlation factor R values of -0.6189, -0.9764, and -0.9681, correspondingly. In addition to this, it was discovered that the humidity determination coefficient, R2, has a substantial relationship to voltage, current, and power of the system. The influence on efficiency, on the other hand, falls somewhere in the midst between a strong correlation and a weak association. The findings suggest that the efficiency of the PV panels is reduced when exposed to high levels of relative humidity.

The humidity levels (rh) of a front coating layer are distinct from that of a backside encapsulant, as N. C as (Park *et al.* 2013) pointed out in their study (rhback). Within the scope of this research, the relative humidity (rheff) of a photovoltaic (PV) module was analyzed to determine the influence that changes in moisture have on the pace of degradation. When a PV module is subjected to specific moist heat circumstances, rheff describes the level of humidity that is homogeneous across the module. In order to determine the relationship between rheff and rhback, five different kinds of accelerated tests were carried out. When the temperature was held constant, the connection between rheff and rhback was linear. For the purpose of estimating the of PV modules, both the Eyring and the Peck models were utilized, and the results obtained from each were compared to one another. At a temperature of 0.49 eV, the PV modules were thermally activated. In addition, the temperatures and rheff histories of PV modules was analyzed at two different locations over the course of one year: Miami (Florida, United States), and Phoenix (AZ, USA). The aggregate values of a modules' temp and rheff were determined by adding up the hourly deterioration amounts over the course of the time history. These values were based on the modules.

Mekhilef et al. (2012) stated that the economic and environmental benefits of turning sunshine into energy using solar panels have led developed and developing countries to allocate more funding to PV systems to enhance their efficiency. This has resulted in an increase in the amount of sunlight energy that can be converted into energy. In addition to the parameters pertaining to the materials as well as the design, there are a number of ever-present elements, like as dust, moisture, and air velocity that can have an effect on the performance of the PV cell. There have been a few researches done on the influence that various relevant variables have on the performance and efficiency of photovoltaics; however, none of these studies have taken account all three of these characteristics at the same time. In this research, the impact of humidity level, dust, and air speed will each become translated on independently, and then the impact of each factor on the others will be clarified at the end of the study. It has been demonstrated that each of the following three factors has an effect on the other two, and the conclusion that should be drawn from this is that in sequence to have a tremendous understanding of the construction of solar cells, the consequences of each of those parameters should indeed must be taken into account simultaneously.

Another research work (Chaichan and Kazem 2016) expressed that the use of photovoltaic (PV) technologies is increasing all around the world and continues to see cost and output improvements. However, due to the fact that these Photovoltaic cells are open to the elements of the outdoors, it is significantly influenced by the characteristics of the weather. In a previous research, hot and muggy conditions in Sohar, Oman served as the setting for an investigation of how solar radiation interacts with photovoltaic modules. In order to evaluate the effects of the wind in this region, we utilized two PV modules that were connected in series. According to the findings, the effect of the wind on the temperature of the modules was minor throughout the duration of the test. The majority of the study's findings, in the sense of voltage fall with increasing temperature, high current value, and a large reduction of energy due to the increase in air temperature, were comparable to the findings of a number of other researchers. On the other hand, in this investigation, we utilized the idea of solar ambient temperature and investigated its impact on the heat of the panel. According to the findings, the solar air temperature was effective as a source of heating beginning at eight in the morning and lasting until approximately five in the afternoon during the winter and seven in the evening during the summer. It was also effective as a source of cooling after the times mentioned. A decrease in the sun radiation intensity was produced by the high relative humidity that was characteristic of the examined location in Sohar. This drop was reflected in a decreased solar air temperature.

There have been investigations on irradiation accessibility, effective operating methods, design and construction of these systems have traditionally been the primary focus of research and development efforts in photoelectric (PV) systems. On the other hand, the effect that dust has on the efficiency of PV systems has not received a lot of attention. The work that is discussed in this article makes a major contribution toward eliminating this shortfall. In order to demonstrate the correctness of that hypothesis, we have devised an experimental method that consists of one hundred glass samples with varying tilt (b) and azimuthal (c). After each and every rainstorm that occurred in the surrounding region, the glass's permeability was measured and analyzed at predetermined intervals over the course of approximately seven months. Even though this is just a brief view, the preliminary findings demonstrate that the decrease in glass standard transmitted light is strongly dependent on the dust sworn testimony density in combination with the plate tilt angle, as well as upon the orientation of the surface in relation to the predominant wind direction. This is the case even though this is only a short-term view. When this factor is taken into account, it is possible to see that the commensurate permittivity decreases by approximately 52.54–12.38%, respectively, if the dust deposition size drops from 15.84 g/m2 (for glass sample set at 0° tilt angle) to 4.48 g/m2 (for prepared samples installed at 90° and orientated with 135° deviation from north). The glass sample is positioned at 0° tilt. We also examined output power fluctuation as cell pollution increased. The slope of the best straight line that crosses through all the data points of a solar cell positioned at a 45-degree angle facing south reveals a 17.4% monthly power output decline.

Experiments were carried out to see how dust buildup on the surface of photovoltaic cells impacted their performance, the team of Mohammad S. El-Shobokshy discussed that in their paper. In their research, in order to evaluate the spatial distribution of the particles the dust that was utilized in this investigation was first manufactured in the lab using specific components, after which it was analyzed using a light microscopy. The average diameter as well as the confidence interval of the distribution were calculated as the two primary variables of interest in this analysis. For the purpose of carrying conduct-controlled experiments, a photovoltaic simulator made of halogen lamps was utilized. After the characteristics of the dust particles had been identified, they were distributed evenly across the photovoltaic panel that was being tested. During each run of the test, the amount of dust that was deposited on the panel's surface was measured in grams per square meter. It was determined and examined how the amount of dust deposition has an impact just on short-circuit current, the power output, and fill factor. The findings led the researchers to the conclusion that a dust accumulation significantly degrades the effectiveness of photovoltaic cells. However, in order to conduct out the inquiry on the influence of particle and particle contamination, it is necessary to define the physical characteristics of dust and then link those qualities with the consequences that have been seen.

2.2 Physical and Electronic Details of the Photovoltiac

A narrow spectral gap liquid-processed Cu2ZnSn (Se1-xSx)4 (CZTSSe) kesterite photovoltaic effect where the x set as 0.03 is made from earth plentiful metal in a study that was conducted in 2012 by (Bag *et al.* 2012). This solar cell has an efficiency of power conversion of 10.1%. This cell has a gap of 1.04 eV, lower series resistance, a higher-minority-carrier lifetime, and a lower Voc deficit in comparison to the report greater band gap (Eg =1.15 eV; x = 0.4) cell with a like record efficiency. Additionally, this cell has a higher minority-carrier lifetime. The capability of adjusting the band gap of CZTSSe by changing the sulfur content (i.e., modifying x) makes it easier to investigate the reasons that are restricting performance in the most recent incarnation of CZTSSe devices.

In 2013, a group of researchers (Brammertz *et al.* 2013) reported on the structural, electromagnetic, and optical characteristics of solar cells based on Cu2ZnSnSe4 (CZTSe). These solar cells included an absorber layer that was manufactured via selenization of sputtering multilayers of copper, zinc, and tin. It has been shown that the doping density, which was determined using drive level capacitance profiling, has a correlation that is exponentially tied to the Zn/Sn proportion of the CZTSe absorber, which was determined using energy - dispersive x X-ray spectroscopy. In addition perhaps, the open-circuit voltage of the cells, the lifetime of the minority carrier, and the peak place of the fluorescence emission responding to the absorbing material all correspond to the doping level and, as a result, to the Zn/Sn ratio that is measured in the absorber.

The overall energy performance of a quasi single-glazed (PV) window for a typical workplace in Hong Kong was measured (Lin and Kin 2013). This investigation was conducted on the basis of heat capacity absorption, output power, and daylight illuminance in order to provide an assessment of its overall performance in terms of energy consumption. According to the results of the study, the thermal performance of the system is the most important factor in determining how much energy is saved across the board, while the amount of electricity used for lighting is the second most significant factor. The overall yearly power advantages for water cooled and air-cooled air-conditioning systems are around 900 kWh and 1300 kWh for air conditioning systems correspondingly. The installation of semi-transparent photovoltaic glass in windows can not only generate clean energy, but it can also cut down on the amount of energy that a building uses by lowering its cooling load and its demand for electrical lighting. This has unquestionably positive effects on both the environment and the economy.

Anjum and Haroon (2013), conducted a study to determine whether or not solar electric generation is economically viable in Quetta, Pakistan. In this study, the feasibility of a power plant that runs on photovoltaic cells was evaluated. In order to find the best site for the project location, the researchers compared the monthly average daily global solar radiation of eight cities in Pakistan. Quetta was selected as the location for a 10-megawatt (MW) plant. RET Screens modeling of the power station reveals that the one axis tracking approach has the potential to produce approximately 23.206 GWh of energy in a single calendar year. The projected PV plant has an overall price of $50 million, a debt ratio of 50%, and a discount rate of 9%; the cost of electricity generated by the plant is $0.157/kWh. According to the findings of the inquiry, the price of electricity generated by photovoltaic panels is currently around 30.8% higher than the price of electricity generated by the grid. The results of an examination of emissions showed that the proposed PV power station will prevent the generation of 17,938 tons per year of carbon dioxide. According to the results of the study, the proposed photovoltaic power plant cannot be constructed at this time when just economic concerns are taken into consideration. The results of a sensitivity analysis showed that if the capacity addition cost of the facility is approximately $35 million, then the price of electricity generated by a solar plant will be comparable to the price of electricity generated by the grid in the absence of any subsidies.

The optimal angle of inclination and direction of photovoltaic surfaces was investigated by (Farzad and Ali 2013), in Abu Dhabi, United Arab Emirates. We used an appropriate methodology and applied the total solar radiation that was measured on the horizontal plane in order to estimate the solar radiation that would be received by the inclined surface. Calculations of solar radiation were performed with the tilt angle changed from -20 degrees to +44 degrees and with the orientation changed from -90 degrees to 90 degrees. The annual optimum tilt angle, which was calculated to be 22 degrees, was very near to the latitude of Abu Dhabi, which was calculated to be 24.4 degrees, and the optimal alignment angle was in the direction of the south. The findings demonstrated that a change in the surface orientation away from the south reduced both the monthly and annual optimal tilt angles. Between June and December, the monthly optimal tilt angles on south-facing surfaces ranged from -9 degrees to 52 degrees. According to the findings of the calculation, it is recommended to make at least two adjustments to the tilt angle every year.

Steve and Hassan (2013) discussed the possibility of conducting an analysis of the technological and financial performances of integrating multiple photovoltaics as well as the values that these systems bring to the GCC society. The efficiency of photovoltaic (PV) systems has been demonstrated to decrease by 4-6% due to wide ranges of module temperature, and there is also a shift in the output power because of the high ambient temperatures, as evidenced by an in-depth and methodical modeling and study. As a direct consequence of this, the outputs of both vertical and horizontal Pv panels were discovered to be lower than the estimations that were based on the parameters of routine testing. According to the findings of this study, building integrated photovoltaic, also known as BIPV, systems are not economically viable in countries that are part of the GCC and therefore can compete against traditional electricity sources on the basis of unit cost. However, from the perspective of society, the incorporation of Photovoltaic systems into buildings would have a number of advantages for the countries that make up the GCC. These advantages include, to begin with, a reduction in the cost of capital attributable to centralized power plants and the transmission and distribution procedures; secondly, an increase in the amount of exported oil and natural gas that is used for the generation of electricity; and thirdly, a reduction in the amount of CO_2 emissions that are produced by conventional power plants.

Muhammed and Syed (2013) conducted research in Saudi Arabia to investigate the effect that dust collection has on the electrical output of solar photovoltaic modules. According to the findings of the study, solar photovoltaic modules might experience a drop in power of up to fifty percent if they are not cleaned for a duration of more than six months. A solar tracker can increase electricity output while at the same time reducing the influence of dust collection by up to fifty percent during off-peak hours.

The potential for putting photovoltaic systems on both horizontal and vertical building surfaces in metropolitan settings was calculated (Chun-Ming *et al.* 2013). This study examines the photovoltaic (PV) potential on vertical facades and rooftops in the research region in the West Downtown Area of Tainan Town in Taiwan. It was discovered that shade has a substantially greater impact on the vertical faces of buildings. The fact that twice as much electrical energy is produced on rooftops during the summer as during the winter is demonstrated by the average amount of power generated every unit surface area on rooftops. Even if the amount of electrical energy created by the per unit area on longitudinal surfaces is more in the winter, it is still only 1.1 times bigger than that generated in the summer. When taking into account the amount of electrical energy produced, the installation area for the southwest walls ought to be 1.5 times greater that of the mountaintops so that the same amount of electrical energy can be produced. This is the case in order for the southwest walls to generate the same amount of electrical energy as the rooftops. Rooftops, vertical facades facing southeast, southwest, and south directions, in that order, should be given priority when thinking about the installation of photovoltaic panels in the research region of this study as well as other geographical similar locations.

Felipe and Jan (2013), investigated the dirtying effects for photovoltaic systems in the state of California. During the course of 2010, changes in the energy conversion of 186 commercial and residential PV sites were measured during dry periods. These measurements were made in relation to rain events that were recorded at neighboring weather stations and made use of satellite data on solar resource availability. The overall rate of soiling loss was 0.051% per day on average, with 26% of the locations seeing losses of more than 0.1% each day. Larger soiling losses occurred in locations with shallow tilt angles (less than 5 degrees), although the variations between regions weren't really statically important.

Cu2ZnSnSe4 thin-film photovoltaic panels were produced (Oueslati *et al.* 2014) and placed on a soda-lime glass surface with a molybdenum (Mo) back connection. It was discovered that the building of a barriers here between absorbent and the back contact is what causes the degradation in the electrical performance. This was discovered via observation. Ti nitride (TiN), tungsten titanium (TiW), chromium (Cr), titanium (Ti), and aluminum are some of the materials that are employed as alternative back contact materials in order to combat deterioration of the kind described above (Al). It is possible to utilize this as a counter electrode. The most efficient device was found to be 8.8% on TiN, 7.5% on Mo, and 5.9% on TiW correspondingly. The TiN back contact has the lowest barrier value, which is around 15 meV, and is hence a suitable ohm contact.

Li *et al.* (2015) illstrated the effects of a prealloying procedure on the creation of MoSe2 and, therefore, on the performance of Cu2ZnSnSe4 (CZTSe). Solar cells are explored via the use of sputtering deposition and post-annealing techniques. During the ensuing high-temperature selenization process, the dense alloy layer, which is produced by a process known as prealloying that takes place at a low temperature, functions as a temporary se diffusion barrier. This temporary barrier has the potential to effectively restrict the production of thick interfacial MoSe2, which will work in conjunction with the following forming of compact CZTSe layer. It is possible to tune the thickness of the interface MoSe2 surface in CZTSe photovoltaic modules by changing the preannealing process that takes place during the selenization step. As a direct result of this, the resistor of CZTSe solar cells is brought down to a low level (0.6 cm2), which results in a considerable increase in the efficiency of CZTSe solar cells. It was discovered that a CZTSe solar cell with an efficiency of 8.7% could be manufactured.

High - performing kesterite (CZTSe) driven photovoltaic devices typically utilise an absorber/buffer heterostructure employing hazardous CdS produced through chemical bath depositing (CBD) as the buffer layer, according to research conducted in 2016 by M. Neuschitzer et al. This is because the conduction bands of the CdS buffer and the CZTSe absorber align in a way that is advantageously spike-like. The use of ZnS (O, OH) buffer layers is an interesting and potentially harmless option. This study presents a change of the thiourea content in the CBD of ZnS (O, OH) buffer layers and investigates the effect that this concentration has on the device performance of purified selenide kesterite heterostructure photovoltaic modules. In addition to this, the impact of the circumstances under which the buffer layer is deposited on light-induced metastabilities is examined. ZnS (O, OH) buffer that has been deposited with a high concentration of thiourea results in deformed illuminated JV curves, which is to be anticipated for devices that have an unfavorable high spike-like conduction band alignment between the buffer and the CZTSe absorber. It is possible to get less JV curve distortion by tinkering with the thiourea concentration. After light soaking, a device that has undergone a CBD process that has been tuned may achieve an efficiency of up to 6.5%, which is equivalent to the 6.9% effectiveness of a standard device that uses CdS as its buffer layer (Neuschitzer *et al.* 2016).

2016 saw a study published (Li *et al.* 2016) the photovoltaic efficiency of CZTSe thin-film solar cells is determined by a number of parameters, two of the most important of which are the defect states and the carrier density of the absorber layers of CZTSe. To improve the power efficiency of CZTSe solar cells to a more competitive level, fine-tuning the flaws and carrier density is a vital component. In this study, the phase characteristics, defective states, and carrier concentration of CZTSe thin film are very well controlled by carefully tweaking the ratio of Zn/Sn inside the range from 0.75 to 1.27. This allows for a wide range of possible values for these parameters. Measurements of capacity and voltage as well as admittance spectroscopy are used in order to describe the carrier density, the breadth of the depletion area, and the defect states of the CZTSe solar cells. The findings suggest that the defect states and carrier concentration of the CZTSe layer are highly responsive to the proportion of Zn to Sn in the layer. The statistical standards and policies of the photovoltaic characteristics of the

CZTSe photovoltaic modules with various ratios of Zn/Sn may be effectively described thanks to the combination of experimental findings and numerical simulation, which was performed. Both an increase in carrier density and a reduction in the number of deep level defects are connected to the rise in the value of the open circuit voltage (VOC) produced by CZTSe solar cells as the ratio of zinc to antimony rises. The narrowing of the depletion area width and the increased barrier imposed by the ZnSe phase are both to blame for the Zn-rich solar cells' precipitous fall in JSC. The Zn-rich photovoltaics suffer from a poor fill factor due to this barrier, which is the reason. In general, the CZTSe photovoltaic panels with a fixed ratio of Zn/Sn=1.02 had good flaws property and carrier density, which ultimately resulted in the greatest photovoltaic efficiency of 10.21%.

In 2018, the researchers reproduced the cells using the mathematical model of the experiments built (Mo/CZTSe/CZTS/CdS/ZnO/FTO) solar cell. They did this by using (CZTS) as the permeability layer, (CZTSe) used as the back surface layer (BSL), and (ZnO) layer as the window layer in addition to SCAPS-1D's experimental solar panels. When the (CZTS) absorbing layer is within (0.8 micrometers) thick, it was discovered that the cell transition efficiency increases by up to 6.42%. This conclusion was reached on the basis of the findings of the modeling. After adding the (CZTSe) layer as a BSL layer, the conversion efficiency rose, reaching (12.92%, JSC= 27.41 mA/cm2, VOC = 744.4 mV, and FF = 63.35%) (Khattak et al. 2018). This was achieved by obtaining the following parameters.

According to research by (Wang *et al.* 2019). Metal may increase the performance of chalcopyrite structured devices. On the other hand, such an alkali metal is often doped by diffusing sodium into the absorber layer made of beverage glass or by employing the vacuum approach. Doping sodium (Na) into a kesterite structure composite film is the focus of this investigation, which makes use of a soft chemical technique. It has been determined by the use of XRD, SEM, SIMS, and EDS mappings that the treatment with NaF aqueous solution gives a distinct Na source, which may enhance the development of the film as well as the distribution of the elements, particularly the distribution of the Se element. The participation of Na in crystallization at the early stage of the selenization process may enhance the interaction among CdS and CZTSe, which helps to prevent the exterior disintegration of CZTSe. This helps to suppress the exterior decomposition of CZTSe. The improved conversion efficiency of solar cells is enhanced from 6.3% with no such diagnosis to above 7.8% with such chemical treatment, and the best efficiency of 8.4% has indeed been attained for the 0.005 mol/L NaF allowed to treat CZTSe machine. Without such treatment, the average conversion efficiency of solar cells is 6.3%. This simple Na treatment in an aqueous solution provides a new perspective and also broadens the knowledge of the Natreatment on compound semiconductor solar cells, which will facilitate the manufacture of chalcopyrite solar cells that have good performance.

Zhang *et al.* (2020) stated that, the highest conversion efficiency for such solar cells is still a significant distance away from the highest efficiency of Cu-based kesterite solar cells, which is around 9 percent. This same manufacturing of kesterite CZTSe photovoltaic modules through an electrodeposition offers an appealing methodology for the low-cost and environment-friendly energy supply. The use of a nanocrystalline Cu–Ge alloys layer at the bottom of metal catalyst led to the development of a 10.54% efficient CZTSe solar cell with a 0.28 cm2 active sized area and no antireflection layer. It has been discovered that the existence of Ge elements near the base of the film may facilitate the downwards dispersion of Sn element. As a consequence of this, the distribution of Sn is generally homogenous throughout the annealing process. As a consequence of this, the development of defect clusters that are unwanted is suppressed, as well as the band alignments of the CdS/CZTSe interaction is adjusted. The end consequence of this is an improvement in the energy conversion of CZTSe slender solar cells from 6.74% to 10.54%, which is the greatest efficiency that has been recorded for electrochemically manufactured CZTSe solar cells.

Kasem *et al.* (2021), constructed a quadrupole cell in the year 2021 whilst also adding a porous layer of (ZnO) to the bilayer cell to create a cell constituted of (CCTS / CdS / ZnO) strands, accompanied by a porous layer of (AZO) to generate a compartment with four layers that is identical to the working cell. This process resulted in the construction of a quadrupole cell. The study aims to increase the efficiency from 1.80% to 7.7%, and it does so by using an absorbing coating that is 5 micrometers, a (CdS) buffer layer that is 0.2 micrometers and permeability layer that is (ZnO and AZO) at 0.2 microns thick. After all is said and done, the output of the finished cell is as follows: (VOC = 0.638V, JSC = 25.47mA/cm2, FF = 47.32%, = 7.69%).

2.3 Dust Deposition on the PV Panel

Photovoltaic (PV) panels are negatively impacted by particulates. This leads in power dissipation, which reduces the process performance, in addition to global temperatures, which further reduce the overall system performance and lifespan. This is in relation to both time and location, both chemical properties, concentration, and development of a dusty deposit on the Panel surface vary dramatically. Styszko and his colegue (Alaa 2009), examined particle deposits on the Photovoltaic top glass cover is evaluated throughout the quasi period within one of the most contaminated cities across Europe, Krakow. The association between time-dependent droplet formation and smog with particulates was analyzed. Dust deposited on two or more identical Photovoltaic panels during variable exposure times (between One day through One week) and specimens of totally colloidal matter (TSP) on silica fibre filtration to use a small volume sample were obtained over the course of 5 weeks during the non-heating season. During the study period, the concentration of TSP varied between 12.5 and 60.05 g m3, while the concentration of PM10 at the Voivodeship Inspectorate of National Environmental Road station, located 1.2 kilometers from the TSP sampler, varied between 14 and 47 g m3. For one-day exposure periods, the dusty deposit volume on a PV surface ranged from 7.5 to 42.1 mg m2, while the measured weeklong particle deposit density ranged from 25.8 to 277.0 mg m2. The volume and intensity of precipitation as well as the relative humidity have a considerable impact on the deposited dust. In the absence of precipitation, the rate of dust accumulation reaches roughly 40 mg m2day1 and was at least two times greater as flows calculated based on PM10 and TSP concentrations, indicating that other factors such as electrostatic forces greatly influence dust deposition.

Due to the fact that soiling is a problem that is unique to each location, the authors of (Khansaa 2010) study perform controlled experiments for the very first time in order to determine the properties of a dust sample taken from a desert region in Iran as well as the effect that this dust affects the energy effectiveness of solar solar panels. Experiments on the characterisation of dust are carried out with the assistance of an electron microscope, X-ray fluorescent, and elemental analysis. The use of scanning electron tests, which have received a relatively low level of consideration in solar dirtying investigations, will assist researchers in conducting more accurate inquiries into these phenomena. By conducting tests on a variety of dust samples, one may determine the general correlations between losses brought on by dust deposit as well as the deterioration of solar output characteristics, which are necessary for electrical assessments. The findings of the elemental analysis revealed that the dust samples are predominantly made up of silicon, aluminum, and calcium. Experiments conducted inside have shown that dust particles may range in size from 0.4 to 31 micrometers and can have a variety of forms. It was observed that the conversion efficiency, photovoltaic normalized maximum power, open-circuit current, and short-circuits current all reduced through 98.2% (semi), 98.13% (quasi), 20.63% (linear fashion), and 98.02% (quasi), respectively, when the dust density was increased from clean cell to almost dark shading conditions. This was observed when the dust density was increased from clean cell to almost dark shading conditions. In addition, the findings demonstrated that the soiling process does not have a major influence on the fill factor as a consequence of the uniform dust dispersion over the PV module.

The collection of dust particles causes a degradation in the efficiency of solar cells and leads to significant losses in the amount of electricity produced as a consequence of the sun's irradiance being scattered by the impacts of the panel surface. Because of that, a study conducted by Saidan and a team (Mehleri *et al.* 2010) that they consider Baghdad, the capital of Iraq as a region of interrest. In the city of Baghdad, in the country of Iraq, this research analyzes the effects that dust buildup has on photovoltaic solar modules. In order to achieve this goal, an experiment has been carried out to determine the extent of the losses brought about by the collection of dust on the top of three photovoltaic solar modules that are otherwise similar. Within a carefully monitored and regulated trial environment, the panels have indeed been put such that they are subjected to the elements directly. After then, measurements of the amount of dust that has accumulated on the modules have been collected on a daily, weekly, and monthly basis, respectively. A very sensitive aerosols measuring device was used in order to research and take measurements regarding the dust density as well as the size and shape of aerosol particles and fibers. A solar simulator was used as the light source, and both the module that had been dusted and another identical module that had been cleaned were then subjected to continuous radiation and temperature. When compared to the identical parameters of the clean module, the dust that was deposited on the surface of the photovoltaic solar modules exhibited a drop both in the short-circuit current (Isc) and the output power. When solar modules are exposed to dust for one day, one week, and one month, respectively, the average deterioration rate of their efficiencies is determined to be 6.24 percent, 11.8 percent, and 18.74 percent, respectively. The calculated outcomes of an updated version of the authors' theoretical model match well with the findings of the experiments that were carried out more recently.

Anthony *et al.* (2011) discussed the environmental circumstances in which photovoltaic cells are installed have a significant impact on their performance, with dust being the one that has the most bearing on overall performance. This study's primary objective was to determine the extent to which the efficiency of a photoelectric modules was negatively impacted by the presence of dust deposition under the climatic conditions that prevail in the city of Baghdad in Iraq. The components of the dust that had gathered were analyzed after being collected for a period of two months. In addition, the influence of the primary three components on the performance of the PV module was investigated individually, and the results were compared to naturally collected dust. The impact that particle particulates (PM), calcium (CaCO3), and soil had on the performance of the PV module was analyzed using ascending blocks of each substance. The efficiency of the Photovoltaic panel suffers significantly as a result of the deposition of dust, which causes a large drop. The components of the deposited dust play an important part in influencing the pace of decline in the amount of energy that is created as well. The accumulation of dust raises the temperature increase of the photovoltaic, which in turn leads to an increase in the amount of energy that is wasted.

The research looked at several different kinds of PV cleaning products that were readily accessible in the area to see which ones were the most effective. When a PV module is contaminated by natural dust and PM, the produced energy loss may be minimized by cleaning the module with sodium solution. However, the impact of this cleaning method is restricted when applied to dirt and $CaCO_3$. It is recommended that high-pressure water be used to remove $CaCO_3$ and dirt from photovoltaic panels, and then the surface of the PV should be wiped off with a cloth or a brush to prevent these things from adhering to a top of the PV.

Chaichan in another study (Benghanem 2011) also examined the performance of the solar cell noticeably suffers if there is a buildup of dust just on cell's outer surface. The research has led to the investigation of the influence of pollutants including dust on the performance of solar cells in four distinct locations of Iraq, each of which has its own unique characteristics. Baghdad, an agricultural region near Mahmoodia, the desert route between Karbala and Najaf, and the city of Fao were the locations that were investigated. The contents of dust samples taken from the places specified were analyzed, and a significant amount of silica was discovered to be present; this demonstrates the influence of the desert on the dust found in Iraq. Clay and silt minerals, which may be traced all the way back to the rich valley of Mesopotamia, were detected in unambiguous amounts in dust samples from Baghdad and Mahmoodia. Dust samples from both Fao and Baghdad were analyzed, and the results indicated a high level of pollution caused by the burning of fossil fuels. The samples included significant amounts of particulates (PM), lead, and sulfur. In the course of conducting practical tests to measure the current, voltage, and energy of a solar cell, a discernible drop in the values of these parameters was observed. The research derived appropriate periodic cleaning periods and cleaning procedures for each different kind of dust based on the sorts of components that were found in the dust samples.

3 ENVIRONMENTAL IMPACT AND THE PHOTOVOLTAIC DEVICES

This chapter introduces solar energy, photovoltaic (PV) technology, and the primary elements that determine PV module performance to lay the groundwork for the thesis's more specialized themes.

3.1 Solar Radiation

Solar energy is by far the most significant source of energy that can be harnessed by planet Earth and the people who live on it. Without it, there is no possibility of life existing. It is the source of energy that fuels the process that occurs during photosynthesis. As such, it is accountable for all of the biomass that can be found on the surface of the world and is the source of fossil fuels, which are the byproducts of photosynthesis that occurred millions of years ago and are now buried beneath the surface of the globe. The sun's rays are responsible for the winds that blow across the earth, the evaporation of water into water vapor that causes precipitation, waves, and the ocean's ability to generate thermal power. In point of fact, the sun is the source of all of the many sources of energy that are utilized by man, with the exception of nuclear energy, geothermal energy, and tidal power. The generation of electricity can be accomplished through the usage of each of these distinct types of solar-derived energy. Nevertheless, solar can also be harnessed in its purest form to directly produce electrical power. It is possible to accomplish this goal in the simplest way possible by drawing heat from the sun's rays; but it is also possible to generate electricity directly from light by making use of an electrical component known as a solar cell. Both approaches are valuable for the generation of power from renewable sources (Aldo *et al.* 2009).

Every second, the Sun produces a staggering quantity of energy. Energy from the sun is radiated out into space. Only a small fraction of solar energy actually reaches Earth's atmosphere because of the huge distance between the Earth and the Sun (149.6 x 106 km). The amount of energy from the sun that reaches Earth's surface is called the solar constant, and it is equal to 1367 W/m^2. Some of the sun's rays are absorbed by molecules and dust in Earth's atmosphere (diffuse radiation), while others are redirected straight to Earth's surface (direct beam radiation) (Kempe 2006). The equivalent to the quantity radiation reaching a horizontal surface, also known as global horizontally radiation (Park *et al.* 2013), is a combination of direct beam radiation corrected for the incidence angle and diffuse radiation.

Figure 3.1 shows that AM is the inverse of the cosine of the vertical position between both the Sun and also the zenith.

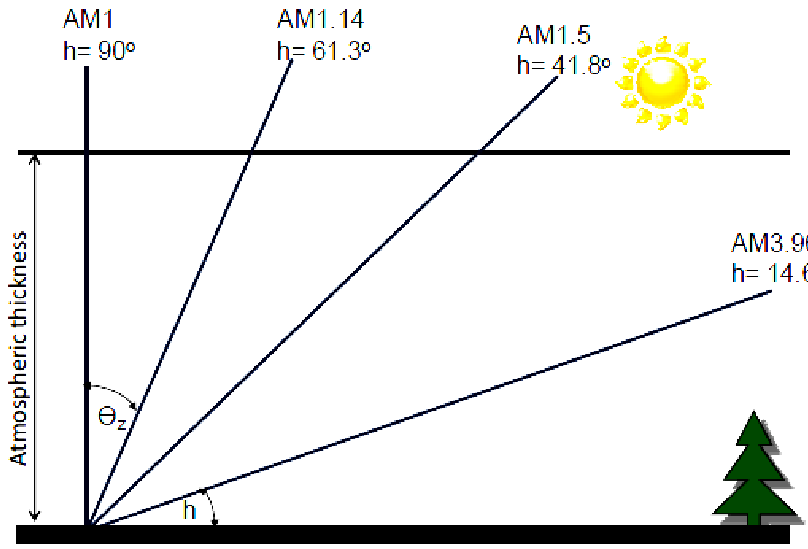

Figure 3.1 A picture showing Air Mass variation along with solar elevation (h) and zenith angle (Θz).

The AM-solar elevation relationship shown in Equation (3.1)

$$\boldsymbol{AM} = \frac{\mathbf{1}}{\boldsymbol{Cos}(\mathbf{90}-\boldsymbol{h})} \tag{3.1}$$

The sun releases 3.8 x 1023 kW worth of energy into the atmosphere every second. The majority of the energy that is emitted by terrestrial radiation is absorbed by oceans and seas. During any given year, the extraterrestrial radiation is typically three times more than the terrestrial radiation. Because of physical and socioeconomic constraints, the quantity of the remaining 1.5 x 1017 kW that is intercepted by land may only be used to a certain extent (Karwan 2009).

AM0 stands for the alien spectrum, while AM1 describes a condition in which the Sun is exactly perpendicular (Park *et al.* 2013). AM1.5 is a reference AM value that is used for PV system global standard testing. This value designs an estimated annual scope for mid-latitude sites with the Sun at a solar elevation angle of 41.8 degrees (Kempe 2006) (as well as an extra configuration of clear sky); For examples, Figures 3.1 and Figure 3.2 because our work is mainly focused on accumulating dust particles, we will not be conducting any additional research on this subject for the entirety of this thesis. (Gueymard 2004). It has been shown that particles suspended in the air can reduce the intensity of the sun spectrum.

Different wavelengths of solar energy reach Earth Figure 3.2 Spectral Irradiance (E) are the wavelength-specific radiation power per unit area (Dhere and Raravikar 2001) the path length and optical transmittance parameters determine how the atmosphere affects spectrum irradiance, which attenuates exponentially with distance. Air Mass (AM) is the ratio of actual distance to shortest path.

Many of the commercially available solar radiation meters measure the integral of spectral irradiance across a certain wavelength range. With this information, they can determine the irradiance. Irradiance is the power density of solar radiation (G). Taking the integral of the irradiance over a given time period yields the energy density, also known as irradiation, with a value of either MJ/m^2 or kWh/m^2. Long-term research and evaluation of PV systems sometimes make use of the irradiation value, which can be written as the annual cumulative irradiation (in $kWh/m^2/year$) (Chaichan and Kazem 2016).

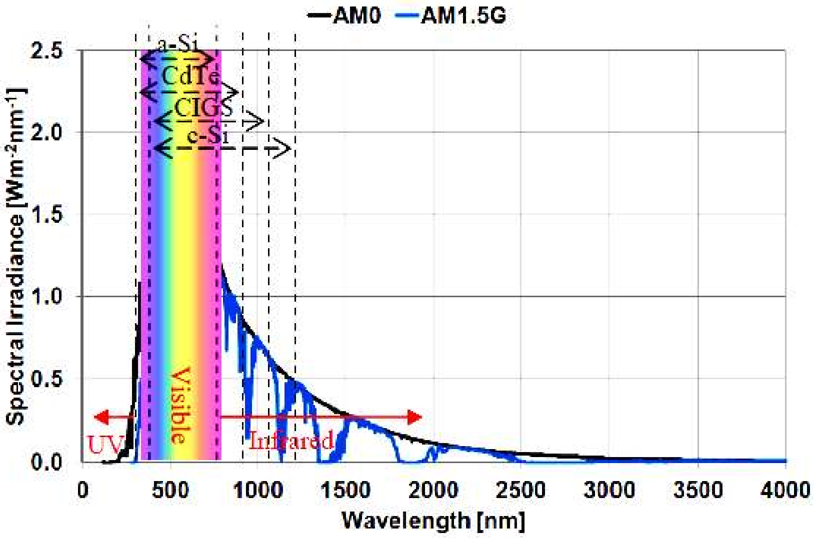

Figure 3.2 Irradiance AM0 and AM1.5 over the spectrum measured at 1000 W/m2 in accordance with the IEC60904-3 standard (Thongpao et al. 2010). The spectrum of wavelengths that are usable by various PV module technologies is denoted by the region that is labeled at the very highest point of the graph.

The sun is generally connected with three different energy conversion processes. These processes are:

i. Heliochemical: This refers to the process of photosynthesis in its most fundamental form.
ii. Helioelectric: This effect is utilized frequently in photovoltaic cells (i.e., Photovoltaics).
iii. Heliothermal: This refers to the process of converting sunlight into thermal heat, and it is used in concentrated solar energy (CSP) plants (Ahmed and Ramesh 2011).

3.2 Spectral Response

The amount of energy stored in the solar spectrum can be deduced from the rate of vibration of the photons that make it up. Equation (3.2) describes the relationship between photons and the production of energy, and this energy is referred to as the photon energy E.

$$\boldsymbol{E} = \frac{\boldsymbol{hc}}{\boldsymbol{\lambda}} \tag{3.2}$$

Where h denotes the constant of Planck, c denotes the speed of light, and $\boldsymbol{\lambda}$ denotes the wavelength. As a consequence of this, the energy potential at various wavelengths across the spectrum is distinct from one another. The term "spectral response" refers to the percentage of photon at every wavelength that contributes to the creation of the short circuit current in a photovoltaic device (SR).

Integrating the product of the external SR and the desired spectrum yields the short circuit current (Isc) of a PV device, as shown in Equation (3.3).

$$I_{sc} = \int SR(\lambda)E(\lambda)\,\mathrm{d}\lambda \tag{3.3}$$

3.3 Performance Parameters for Photovoltaic Devices

PV modules use solid-state technology to convert light into energy. Solar photons (irradiance) are used to power PV devices. The energy of an electron can be transferred to an electron and turned into an electron hole pair thanks to the valance and charge transfer of the semiconductor material, commonly known as the Band Gap. When an electron is stimulated to a higher energy level, it leaves the valence band, creating a hole at the lower energy level. This free-moving, excited singlet-state electron in the bandgap can be trapped by using a p-n junction constructed from doped semiconductors. Doping impurities (from group 13 or 15 of the periodic table) with the silicon, for instance, produces a p-n junction in crystalline silicon. Group 15 doping, which results in N-doped material, involves the introduction of an extra electron into the lattice for each atom of the chemical that is being doped. When group of 13 elements are doped into silicon, they displace one electron (a hole) for every atom of doped component within the lattice, producing a material with a p-type dopancy. As an n-doped layer diffuses into a p-dopant wafer, a p-n junction forms. Here, between two different semiconductors, a concentration of holes and electrons drives the electron to go from the n-type material to the p-type material. As shown in Figure 3.3, this causes the formation of the depletion area, also called the space charge region, where there are few free charge carriers. This is because the electrostatic force between the two sides of the junction promotes drifting current and a diode charge flow that opposes the dispersion of electron hole pairs while balancing it until equilibrium is reached (Park *et al.* 2013).

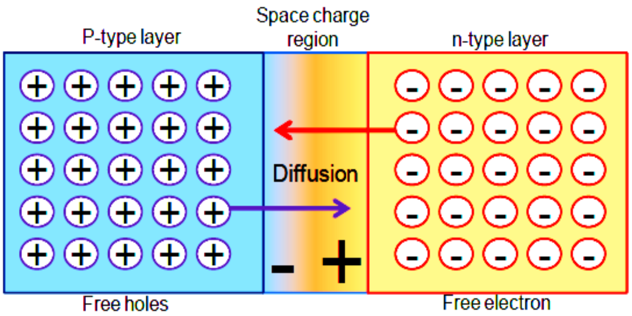

Figure 3.3 p-n junction space-charge zone formation due to electron-hole drift.

PV devices are solid-state devices whose estimation can be made using a simple diode equation. Diode I-V curves stand in for those of a PV device when used in a low-light setting. As shown in Equation (3.4), it allows current to flow in the direction of the positive bias but entirely blocks the flow of the current that is caused by the negative bias.

$$I_D = I_0\left(e^{\left(\frac{qv_j}{nkT}\right)}_{-}1\right) \tag{3.4}$$

Here saturating current in a diode (Io) and diode ideality factor (n) are two related concepts. The latter exemplifies the collection of both drifting current (with a value closer to 1) and dispersed current (value closer to 2). Particle atomic charge, q, is equivalent to 1.602x1019 Coulomb, while the Boltzmann constant, K, is equal to 1.381023 J/K. Both T and Vj are numbers; T represents the device's temperature in Kelvin (K), while Vj is the voltages across diode junctions. While the diodes equation provides a fantastic approximation of the electrical behavior of a perfect PV device, it falls short when applied to actual devices. The change adds a discussion of the series and shunt resistance that represent the parasitic and ohmic losses, respectively, in the circuit.

3.4 Impacts of Temperature

Temperature has a direct impact on PV devices. The device's functional band gap decreases as the temperature rises. Because less energy is required to produce electron hole pairs as the temperature rises, the band gap narrows as well as the dark saturating current will increase (increasing recombine) (Park *et al.* 2013). As a result, open-circuit voltage drops. Accordingly, as shown in Figure 3.4, as the temperature rises, the open circuit voltage of the PV device will drop while the short-circuit- current will slightly increase. The linear relationship between the Voc and temperature illustrates in Equation (3.5).

$$v_{(OC)} = \frac{kT}{q} ln\left(\frac{I_{sc}}{I_o} + 1\right) \quad (3.5)$$

The influence of temperature on the Photovoltaic module can be summed up as a minimally high effect perfect negative relationship to open circuit voltage and positive linear relationship to short circuit current. Both of these relations are linear.

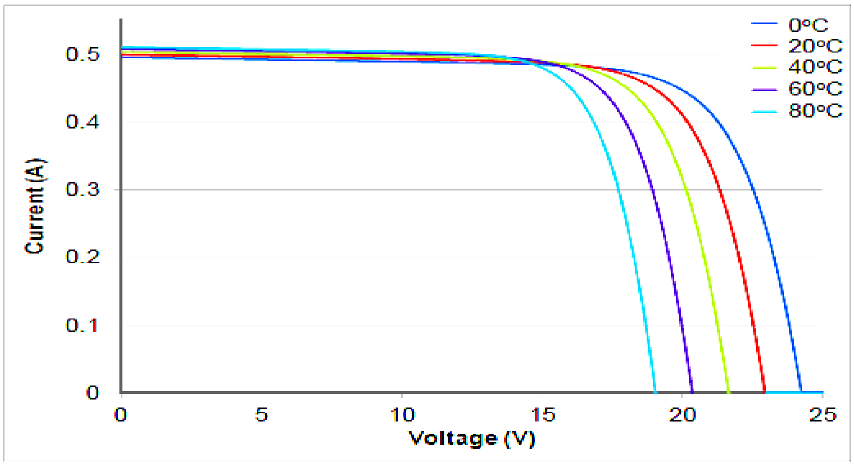

Figure 3.4 Temperature Impact on PV Panel performance.

3.5 Impacts of Irradiance

Irradiance, in its most basic form, refers to the strength of the solar irradiance that is received by the planet. It is measured in watts per square meter (W/m^2), and the STC value for it is 1,000. The values of the irradiance range anywhere from 0 to 1,250 W/m^2. Full sun, also known as peak sun, can be seen in many terrestrial sites, which corresponds to a value of 1,000 W/m^2 (Ryan 2010).

Short-circuit current (I_{SC}) and open-circuit voltages (V_{OC}) of the solar cell both rise in proportion to the amount of irradiance received by the cell. The relationship between irradiance and the current flowing via a short circuit is very close to being linear.

The sun is a ball of extremely hot gaseous material with a size of 1.39 million kilometers and a distance from the planet that averages 149.6 million kilometers. Solar energy can be broken down into two categories, as follows (Garg and Prakash 2000).

3.5.1 Solar radiation from beyond earth's atmosphere

Alaa (2009) stated that the term "extraterrestrial solar radiation" refers to the solar radiation that strikes a surface perpendicular to the light of the sun but is not absorbed by the atmosphere of the earth. It is necessary to take into account two different causes of variance in extraterrestrial radiation. The first one is because of the shifts in the radiation that the solar emits, and the second one is because of the shifts as measured in terms of the distance that separates the sun and the earth. The later variation causes a modification in the interplanetary radiation flux that is somewhere in the region of 3 percent. Equation (3.6) and the accompanying Figure 3.5 both illustrate how the amount of alien solar radiation varies depending on the season.

$$Gon = Gsc(1 + 0.033cos360n365\ ) \tag{3.6}$$

Here, Gsc is the solar constant and Gon is indeed the extraterrestrial irradiation, calculated on the plane parallel towards the irradiance on the nth day of the year (Benghanem 2011). The average amount of energy emitted by the sun in one timestep on an area measure that is orthogonal to the rays that it emits and located outside the atmosphere of the Earth is the value that is referred to as the solar constant Gcs. This object has a value of 1367 W/m2 (Lorenzini et al. 2010). Figure 3.5 shown the sun's radiation changes from beyond the planet throughout the year.

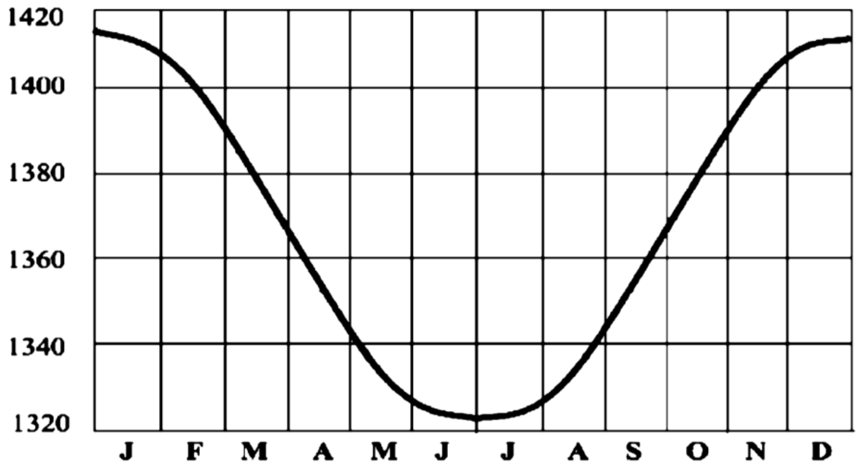

Figure 3.5 Radiation from the sun that comes from beyond earth that varies throughout the year (Duffie and Beckman 2010).

3.5.2 Solar irradiation on the surface of the earth

When alien solar radiation travels through an atmosphere, some of it is dispersed, a portion of it is collected by water vapor and air vapor, and some of it is reflects back into space. The portion of the radiation that originates straight from of the solar disc and, as a result, travels through space without being absorbed or dispersed by the atmosphere to arrive at the surface of the earth as a beam is referred to as the solar irradiation or beam irradiation (Newton 2007). Diffuse solar radiation is the term used to describe the portion of the sun's rays that are dispersed through the atmosphere and eventually make their way to the surface of the planet. There is the possibility that some of the irradiance that reaches the ground will be reflected back toward the receiver. This property, known as albedo, is highly dependent on the characteristics of the ground's surface as well as the angle of incidence (Stefan 2006). Therefore, the direct, diffuse, and albedo components of the global solar radiation that is absorbed by photovoltaics may be broken down into their respective categories using the diagram below (Newton 2007). Figure 3.6 illustrated the photovoltaic cells on earth receive solar radiation from the sun through the atmosphere.

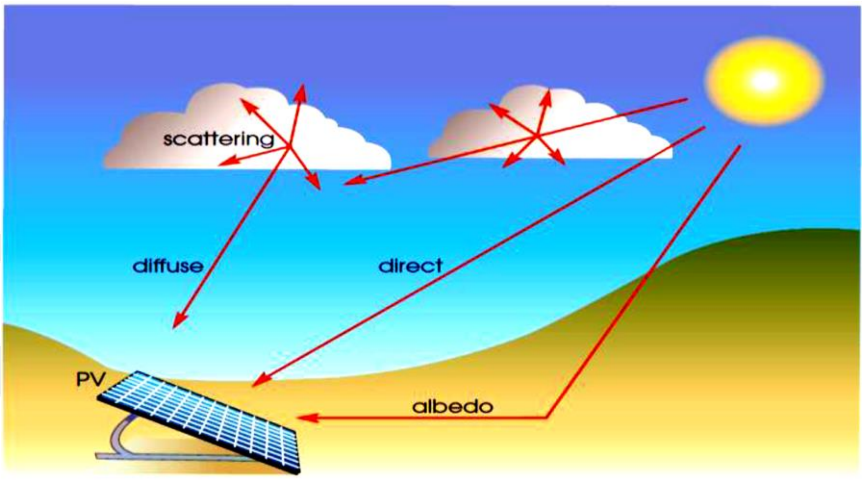

Figure 3.6 Solar radiation from the sun to photovoltaic cells on earth by way of the atmosphere (Oueslati *et al.* 2014).

3.5.3 Difference in the distance between the earth and the sun

If the output of the sun were always the same, therefore the amount of sunlight that reached the world would only be affected by the distance that separates the sun and the earth. This distance shifts during the course of a year as a result of the elliptical nature of the earth's orbit, which may be quantified by the earth's eccentricity value.

Since the amount of irradiance causes the PV device to generate more photocurrent, we can expect that the amount of photocurrent generated by the PV device will vary in a linearl manar with the amount of irradiation, as illustrated in Figure 3.7. It is possible to notice a logarithmic relation between both the voltage across an open circuit and the irradiance when both Io and T are treated as variables.

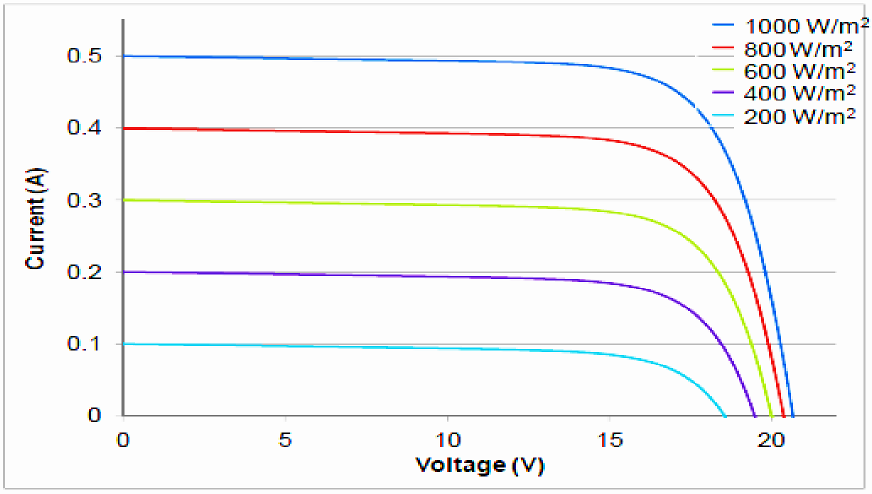

Figure 3.7 Irradiance impact on the performance of the PV module

3.6 Dust Impact on Photovoltaic Panels

At the very least, the use of solar energy is negatively impacted by sand dust, which is a factor present in the majority of the world's dry regions. When dust particles are created on PV panels, they will be interfered with the quality of lighting by reducing the amount of incoming light and dispersing the light that is available. The composition of the particles, their density, and the size distribution of the particles all have a role in the degree to which they interact (Deutsche 2013). Particles collide with a surface because of the force of gravity, the electrostatic charge, or the influence of mechanical forces. After the depositionprocess, the particles are kept in place in addition to gravity and electrostatic forces by the fluctuation of electric voltage near the surfaces (charge-double-layer), surfaces power impacts, and capillary impacts (García *et al.* 2011). To a lesser extent, the surface's roughness and structure also contribute to the increase in surface friction that occurs between the surface and the particles.

Dust is prevalent in essential places. The location has an effect on both the particle size and its content (Richard 2008). Dusty weather conditions have a tendency to be more severe in some locations than they are in others. For instance, throughout the months of March through August in Iraq, there is dust in the air on certain days during daytime hours. It makes it more difficult to see clearly on days when there is a lot of dust in the air (Figure 3.8) (Kimber *et al.* 2006). At some point, dust will congregate on exposed surfaces, resulting in the formation of a thin coating of collected dust. According to some reports, the buildup of dust may be influenced by a variety of factors, including gravity forces, wind speed and direction, electrostatic charges, and the amount of moisture present on the surface (Kazem *et al.* 2013). The gravitational impact, the size of the particles, and the speed of the wind are the three characteristics that have the most influence (Hammond *et al.* 1997). Dust deposition is enhanced by low wind speeds, although high wind speeds may aid in the removal of dust provided the wind is blowing in the right direction (Hanif *et al.* 2012).

As shown in Figure 3.9, the random buildup of dust on the surface area of the PV module may form patches with different concentrations of dust particles. This phenomenon can be seen in some areas. These patches range in size, shape, and position, and they contain varying amounts of dust. Small, random locations on the photovoltaic module may experience partial shadowing from incoming solar radiation as a result of variations in dust deposition, which may lead to varying transmission of light into the module and so contribute to these variations.

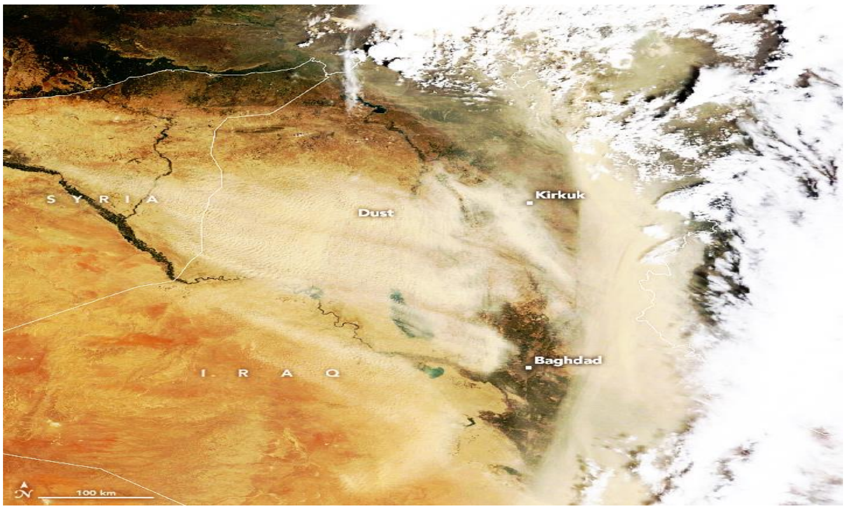

Figure 3.8 Dust storm in Iraq

A series of severe dust storms has been affecting Iraq and other regions of the Middle East since the beginning of April 2022. Because poor air quality caused by airborne dust may make asthma and other respiratory disorders worse, thousands of people have been sent to hospitals as a result of two significant storms that have occurred in the previous two weeks.

Orange clouds covered the sky over a number of Iraqi cities, including Baghdad, Najaf, and Sulaimaniyah, and visibility plummeted to just a few hundred meters. During the dust incidents, a number of airports were forced to shut their doors, as did schools around the country. The provincial governments of seven of Iraq's 18 provinces have closed their government offices, and some governors have proclaimed states of emergency.

The Medium Resolution Par with other developed, or MODIS, is an instrument that can be found on NASA's Terra and Aqua satellites. It was used to gather the natural-color photos that are shown on this page. The picture that can be seen to the top right was acquired from Aqua MODIS on May 16, 2022; the photo that can be seen to the bottom right was obtained by Terra MODIS on May 5.

Dust storms are most prevalent in Iraq during the late spring and summer months. These storms are caused by seasonal winds such as the "shamal," which comes in from the northwest.

These powerful seasonal winds sweep through a wide variety of dust-generating sources. According to research conducted by The World Bank, the region between both the rivers Tigris and Euphrates in northern Iraq is home to the region's largest concentration of dust sources.

According to reports from various news outlets, Iraq has been struck by at least eight dust storms over the course of the previous six weeks. Researchers have discovered that there has been an increase in the number of dust occurrences that occur in Iraq. In recent years, the nation has been dealing with drought conditions, changes in land use and overuse, all of which have contributed to an increase in the amount of loose soil that is accessible to be carried into the atmosphere. The World Bank identified Iraq as one of the nations that is most susceptible to the effects of climate change and desertification. Figure 3.9 shown the amounts of dust that have accumulated on various PV modules that have been put in Iraq in an inclined arrangement.

Figure 3.9 Amounts of dust that have accumulated on various PV modules that have been put in Iraq in an inclined arrangement.

It would seem to be a common sense as dust does have a direct effect on solar PV modules by degrading their overall performance. It has been found that dust has a progressive influence on various meteorological indices such as relative humidity, rain, as well as ambient temperature (Hammond *et al.* 1997). Dust that has settled and dust that is airborne both have the effect of reducing the quantity of solar energy that is incidental on the top of a Photovoltaic panel (Mani and Pillai 2010)

3.7 Photovoltaic System Maintenance

In general, a PV system would require very little maintenance; nevertheless, it is necessary from time to time to clean the panels, and the battery capacity must be maintained on a regular basis.

3.7.1 Cleaning of the panels

When there is a discernible accumulation of soiling deposits on the PV array, we will need to wash it. However, there is really dust just on units when they are in a desert environment. In this particular scenario, it is essential to clean on a more regular basis. In most cases, we utilize a de-mineralized cleaning solution that is heated to room temperature in order to avoid any instances of glass shock or hard-water stains. In addition, we need to clear the dust and filth out of the electric junction box as well as the DC-to-AC inverter (Djamila and Ernest 2012).

3.7.2 Maintenance of battery

We have to control batteries for any imperfection, especially corrosion or leakage and if necessary, adding electrolyte and equalizing charging (Djamila and Ernest 2012).

3.8 Solar Panels Operations

When a photon is absorbed by a solar cell at or around a p-n junction, an electron-hole pair is produced as a byproduct of the absorbed photon (EHP). The EHPs that were produced in inside p-n junction would be evaluated first, following by a EHPs that were produced outside the junction, but were still relatively close to it. Both of the electric charge will be subject to the influence of the electric field that is already present inside the junction in the event that an EHP is produced within it. Because the field is oriented from the n-side of a connection to the p-side of a joint, the region would cause the electron to be swept swiftly towards to the n-side of a junction, and the field will cause the hole to also be sweeping immediately toward the p-side of the intersection, as illustrated in figure 3.10. The optically generated carriers, once outside of the junction region, get to be a part of the charge transfer of the respective regions, which causes excess concentration levels of majority carriers to appear at the edges of the junction. Once the optically generated carriers leave the junction region, they get to be a part of a positive ions of the respective regions. Since the concentration of majority carriers has only been increased close to the junction, the surplus conduction band then diffuses away from the junction and toward the exterior contacts. The introduction of excessive majorities of charge carriers on either of the junction's sides produces either a voltage difference between the material's terminals on the outside or a movement of current through the circuit that surrounds the material, or both, depending on the circumstances. If an external wire is linked here between n-side of the materials as well as the p-side of a material, a flow IO will flow through the wire from p-side to the n-side. This will occur if the p-side of the material is linked to the n-side of the material. This current will have a magnitude that is directly proportional to the amount of EHPs that are produced in the junction area (Roger and Jerry 2004).

Light has to enter the junction area of the solar cell and be successfully absorbed for it to be possible for electron-hole pairs to be generated in an effective manner. During the process of absorption, the total amount of energy will remain unchanged photons with energy represented by the equation E=hv, which must be more than or equal to the bandgap of the semiconductor (h > Eg) (Adrin 2011).

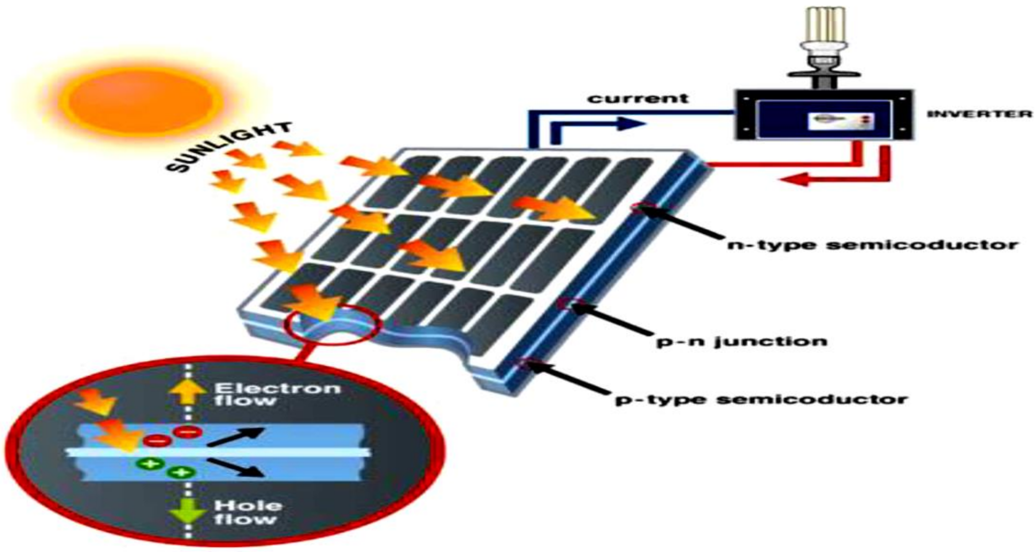

Figure 3.10 Solar cell operation.

4 RESULT AND DISCUSSION

4.1 Introduction

In order to conduct the test, a solar panel array with a total capacity of 360 watts is mounted on a metal platform. In order to investigate the influence of a wide range of environmental factors, measurements of electric parameters such as voltage and current were taken. The effect that fog, dust, filth, and direct sunlight had on the energy discount was tested and assessed. The influence of dust or dirt may be assessed by comparing the performance of a panel when it is exposed to dirt with the performance of a panel that does not contain dust or any sort of filth. In this study, the measurements include a silicon panel with a surface area of about 2 m2, an MTS inverter that was put into use for the purpose of determining the size of generating the voltage, current, and temperature, as well as anything linked with the solar panel. In the city of Kirkuk, the trial check was carried out. Throughout the course of the measurements, the temperature of the surrounding air varies from 15 to 50 degrees Celsius. The solar photovoltaic panel was analyzed, and the characteristics, such as power and ambient temperature that were necessary for the evaluation of the structures were measured at regular intervals of ten and a half hours, beginning at eight in the morning and ending at six in the evening. Using the inverter, we were able to get readings on both the temperature of the surrounding air as well as the amount of incident solar energy. Table 4.1 shown the Specifications of the PV module

Table 4.1 Specifications of the PV module

Parameter	Value
Model	Tata BP 184459
Average power	360 W
Open circuit voltage	12V
Short circuit current	2A
Number of cells	60
Dimensions	2*1*0.1 m^3
Weight	25 g

4.2 Experimental Setup

During this portion of the study, an entire solar system was constructed. It had a capacity of one kilowatt, three solar panels, and two batteries with a capability of two hundred amp-hours and three hundred and sixty watts. All of this information is included in Table 4.1. The measurements and data were collected with the help of a smart MTS invertor. The practical element and the facts that were earlier taught about it are shown in Figure 4.1 and Figure 4.2. Regardless of whether there is lighter shade or dust on portion of a panels as well as the cells, the remainder of the panel will not be affected as a result of the panel division into two parts. This means that the first part does not affect the second part and vice versa. It should be mentioned that the solar panels are divided, and this is what can be done excellent to collect the most possible energy. The readings were obtained using the method depicted in Figure 4.3. A laptop has been used, and a program was installed on the laptop to start taking the measurements directly from the inverter that was attached between both the batteries and the solar panels. This allowed the readings to be obtained in a timely manner.

Figure 4.1 Solar panel (360 W) of each panel (Front side)

Figure 4.2 Solar panel (360 W) of each panel (Back side)

Figure 4.3 Full Solar system showing the invertor device and the batteries

4.3 Experimental Preperation

After creating all of the necessary equipment for the solar power system so that it could be worked on and monitoring its performance for a number of months throughout the year, we established the necessary needs to extract data from the solar energy system so that it could be processed. Because we will be collecting data for a number of months, and the time intervals between readings must be extremely tight in order for us to identify the real output of the solar system, we picked a laptop that was manufactured by HP and was known for its high level of efficiency. Downloading a piece of software. Figure 4.4 allowed for the creation of a tool that can facilitate communication between the laptop and the solar system (electric inverter). Following that, we began collecting the data and regularly uploading it to the server.

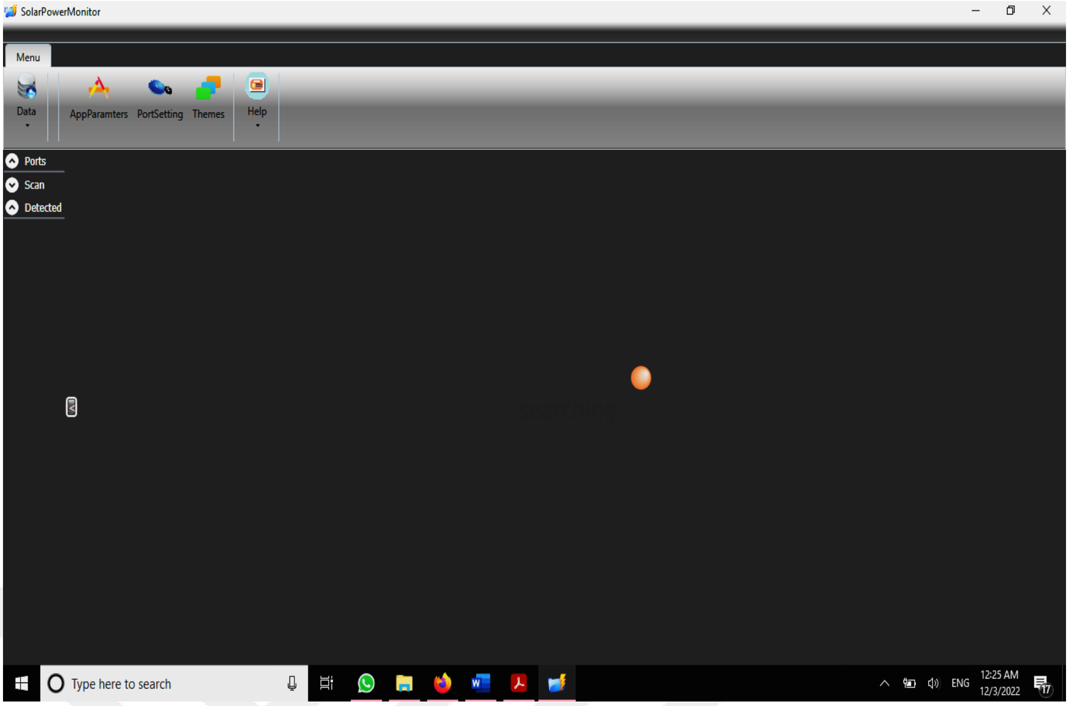

Figure 4.4 Solar Power monitering system software(solar monitor).

4.4 The Findings

The findings of the power analysis were derived using data gathered over a period of six months in a row. These findings represent the Power that was acquired over the course of a period of six months, beginning in the month of March and continuing through the month of August; statistics were gathered for each day of each month during that time period.

It is important to keep in mind that the data for each day was gathered over the course of ten hours each day, beginning at eight in the morning and continuing until six in the evening.

By looking at the figures that are provided below, one can see that the graphs of any shape do not follow a regular pattern. For the month of March, for instance, the graph begins with a few values and then either increases or decreases until the last day. Additionally, the value of the Power (the Y axis) either increases or decreases according to the days, and this is all due to the fact that weather conditions change throughout the month. For those days, wet days, overcast days, and dusty days were recorded in the months of March, April, and May respectively. Dust or dust storms might even cause work to be interrupted on certain days. This can be quite frustrating. It enables us to understand the primary factor that contributes to the unstable nature of the power curves shown in the first three pictures, which respectively represent the months of March, April, and May.

As for the curves in the last three figures, which represent the months of June through August, the curves appear to be almost stable and oscillate around almost constant Power values because the weather conditions in these three months are very similar to one another. Also, there were no exceptional weather conditions, such as dust, in these three months; however, the temperature rose significantly in July and August. This is the only difference between these three months.

The data in the Table 4.2, Table 4.3, Table 4.4, Table 4.5, Table 4.6, and Table 4.7 show the average amount of power obtained during each day of the month. Also, Figures 4.5, Figure 4.7, Figure 4.9 Figure 4.11, Figure 4.13, and Figure 4.15 show the average power of the day in each month corresponding to each table. In this experiment, we recorded the real data for each day of the month, in Figure 4.6, Figure 4.8, Figure 4.10, Figure 4.12, Figure 4.14, and Figure 4.16. It appears from the Figures that each vertex is the maximum power of the day but in this experiment, we calculated the average of each day.

Table 4.2 Average data of March

Day	Watt	Day	Watt	Day	Watt
1	47.38277	11	176.8392	21	217.453
2	38.07544	12	170.9164	22	205.6074
3	42.30604	13	177.6854	23	209.838
4	47.38277	14	170.9164	24	205.6074
5	21.99914	15	170.9164	25	194.6078
6	42.30604	16	175.9931	26	188.6849
7	95.61165	17	159.0707	27	207.2996
8	105.7651	18	146.3789	28	216.6069
9	154.8401	19	175.147	29	170.9164
10	166.6858	20	202.2229	30	148.0711

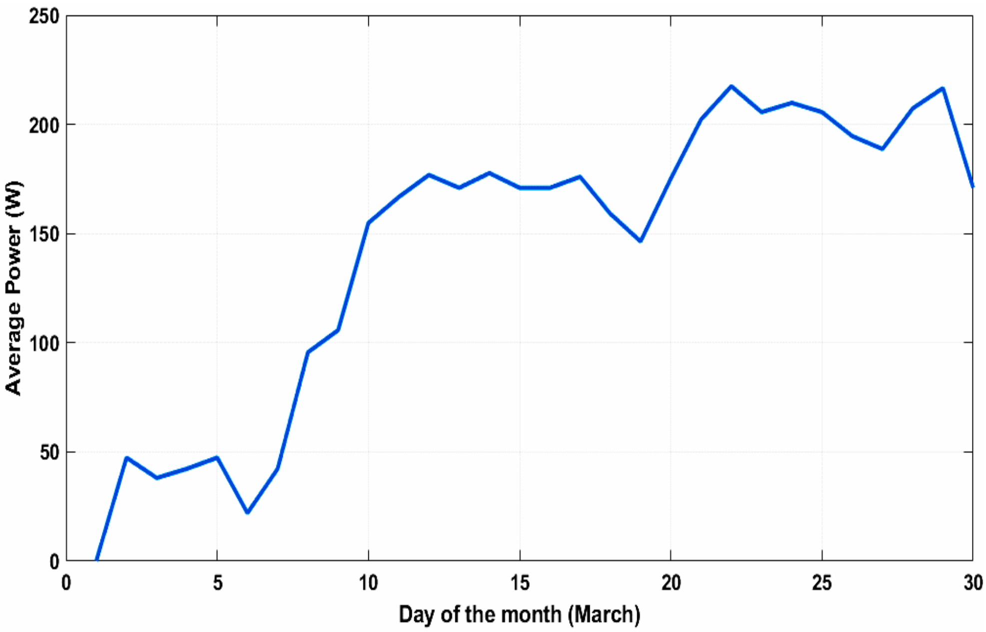

Figure 4.5 Average power of March

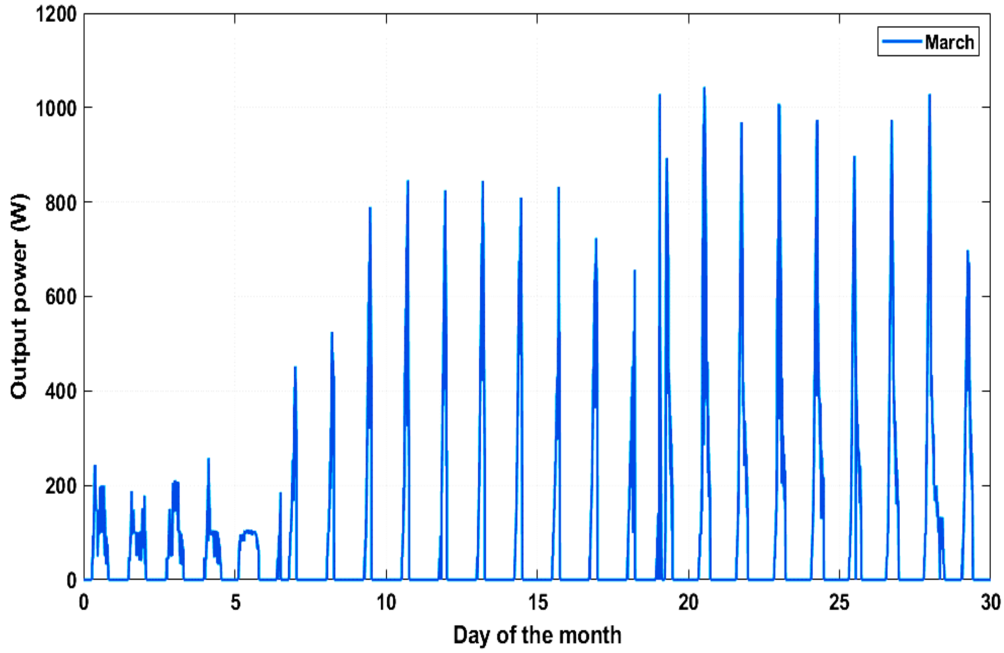

Figure 4.6 Power of March

Table 4.3 Average data of April

Day	Watt	Day	Watt	Day	Watt
1	158.2597	11	133.4514	21	209.5871
2	158.2597	12	151.416	22	196.7553
3	165.9588	13	178.7906	23	195.0443
4	136.0178	14	180.5016	24	200.1771
5	206.1653	15	183.9234	25	185.6343
6	208.7317	16	176.2243	26	197.6107
7	197.6107	17	178.7906	27	133.4514
8	205.3098	18	186.4898	28	108.6431
9	28.2301	19	165.1033	29	112.0649
10	29.08556	20	189.0561	30	124.6829

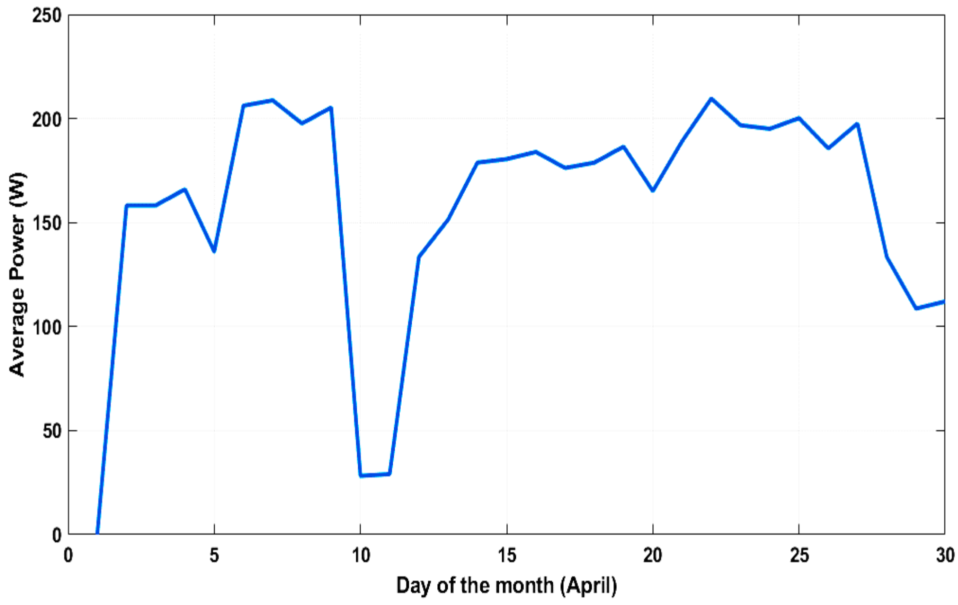

Figure 4.7 Average power of April

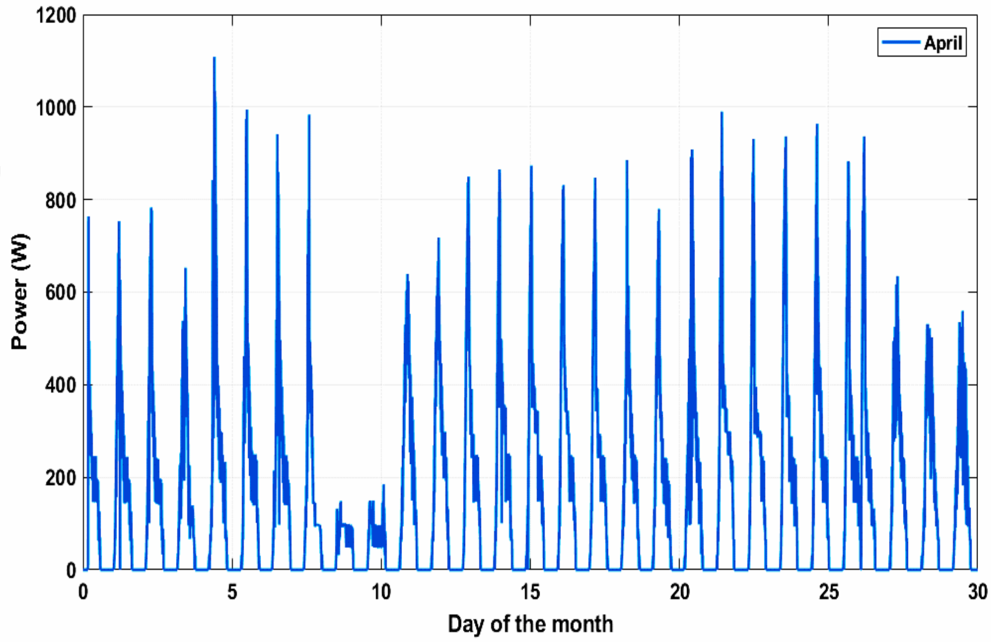

Figure 4.8 Power of April

Table 4.4 Average data of May

Day	Watt	Day	Watt	Day	Watt
1	204.0863	11	203.2066	21	88.8479
2	181.2145	12	196.1691	22	85.32917
3	210.244	13	84.44949	23	77.41203
4	194.4098	14	43.10443	24	90.60727
5	200.5675	15	34.30761	25	101.1635
6	196.1691	16	30.78888	26	109.0806
7	186.4926	17	33.42792	27	109.0806
8	191.7707	18	197.9285	28	109.0806
9	199.6879	19	143.3882	29	102.9228
10	207.605	20	130.193	30	95.88536

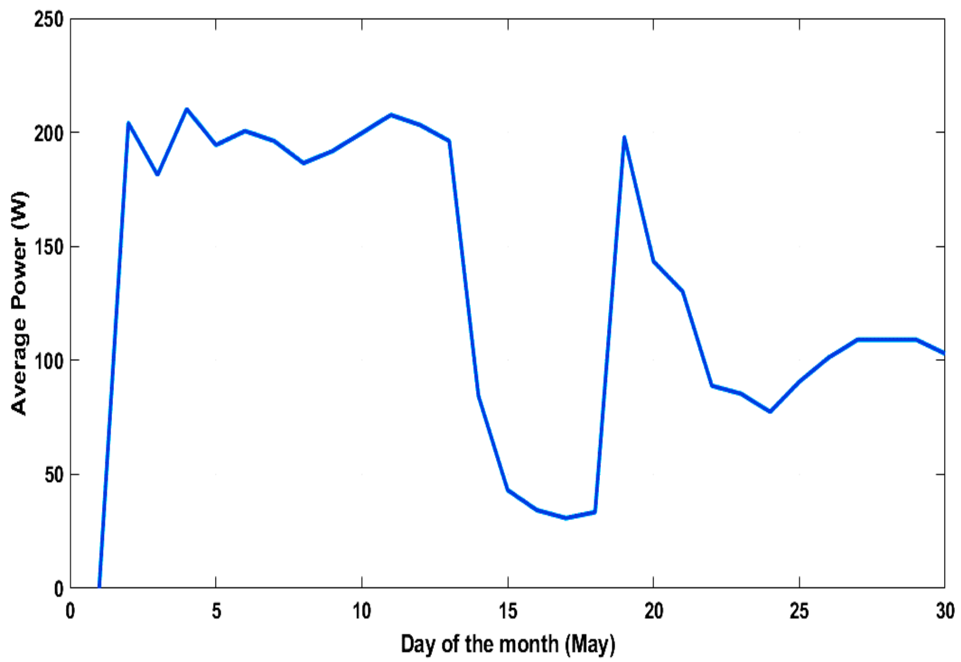

Figure 4.9 The average power of May

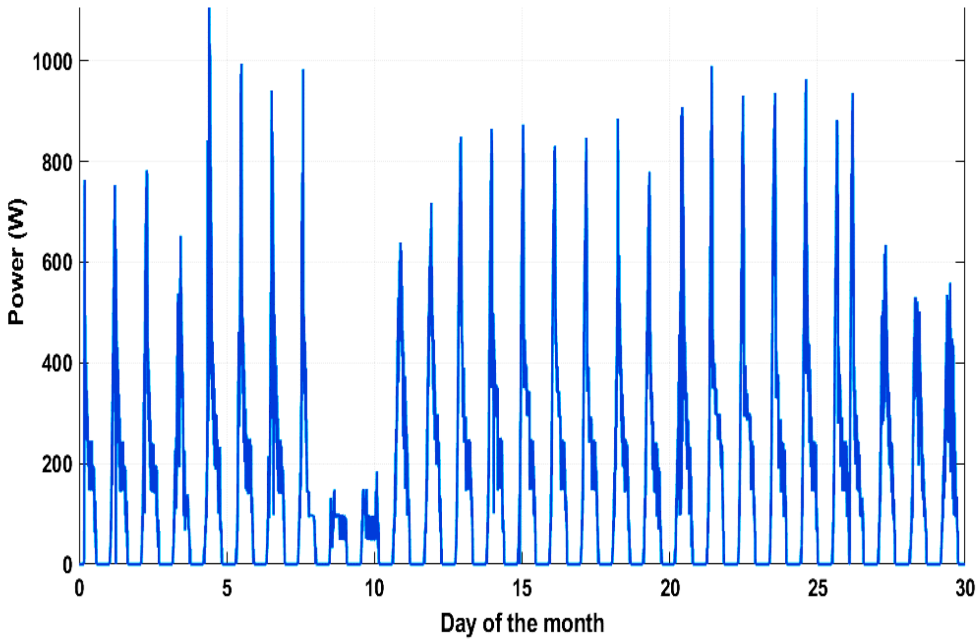

Figure 4.10 The power of May

Table 4.5 Average data of June

Day	Watt	Day	Watt	Day	Watt
1	205.0368	11	205.0368	21	210.3395
2	182.9423	12	211.2233	22	200.6179
3	213.8746	13	195.3152	23	204.153
4	195.3152	14	203.2692	24	203.2692
5	205.9206	15	199.7341	25	199.7341
6	198.8503	16	188.245	26	198.8503
7	187.3612	17	198.8503	27	198.8503
8	196.199	18	210.3395	28	205.0368
9	208.5719	19	196.199	29	205.0368
10	193.5477	20	205.9206	30	197.0828

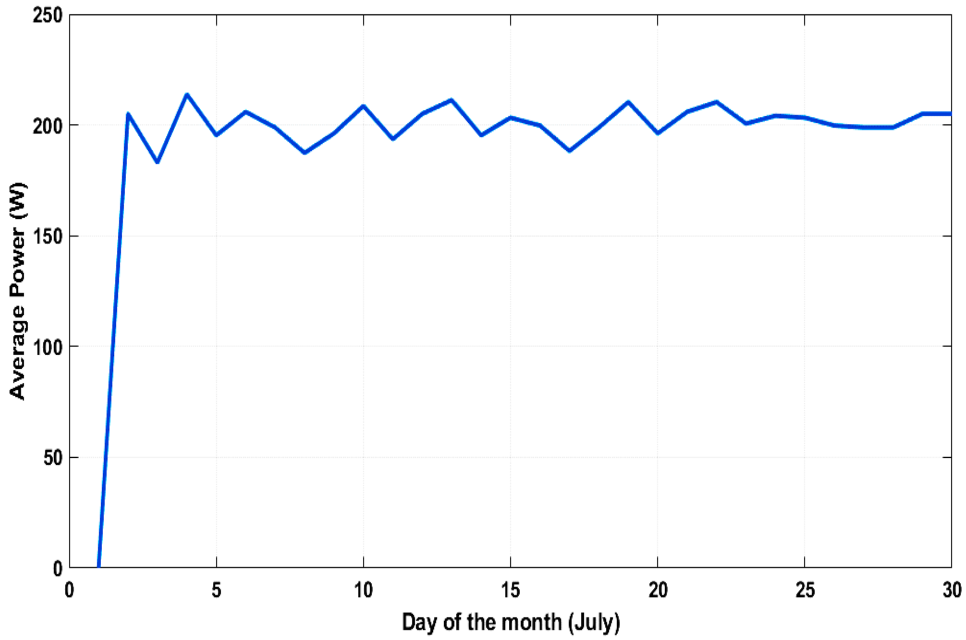

Figure 4.11 The average power of June

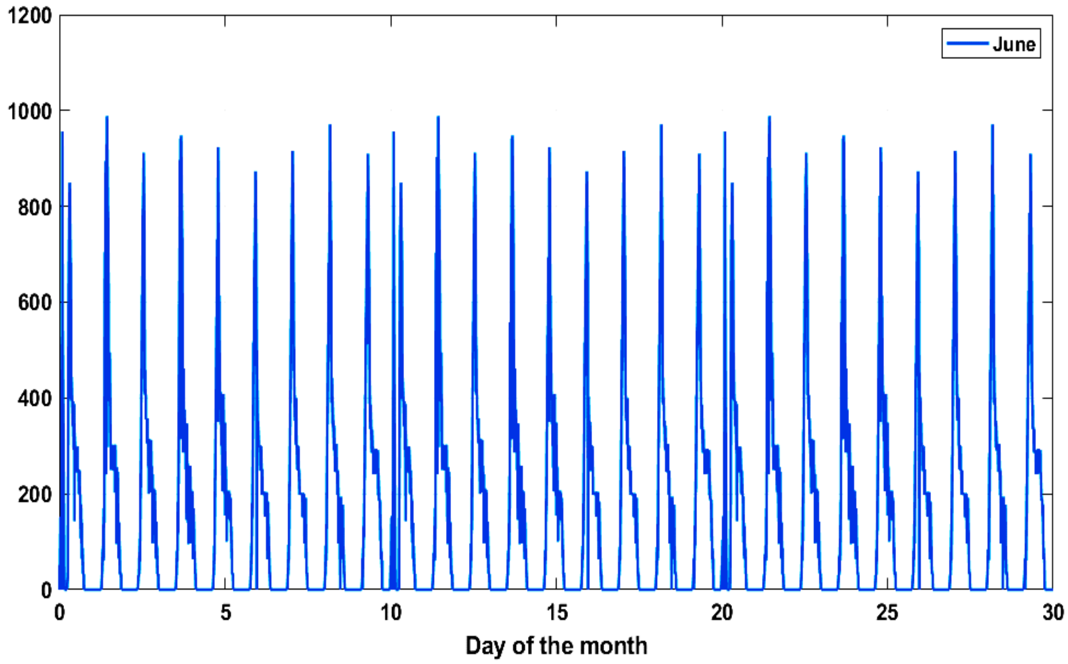

Figure 4.12 The power of June

Table 4.6 Average data of July

Day	Watt	Day	Watt	Day	Watt
1	204.5812	11	205.4631	21	201.054
2	183.4177	12	212.5176	22	212.5176
3	211.6358	13	195.7631	23	198.4085
4	196.6449	14	204.5812	24	200.1722
5	204.5812	15	201.054	25	201.054
6	199.2903	16	189.5904	26	201.054
7	188.7086	17	195.7631	27	189.5904
8	197.5267	18	203.6994	28	195.7631
9	209.8721	19	201.9358	29	207.2267
10	195.7631	20	201.9358	30	202.8176

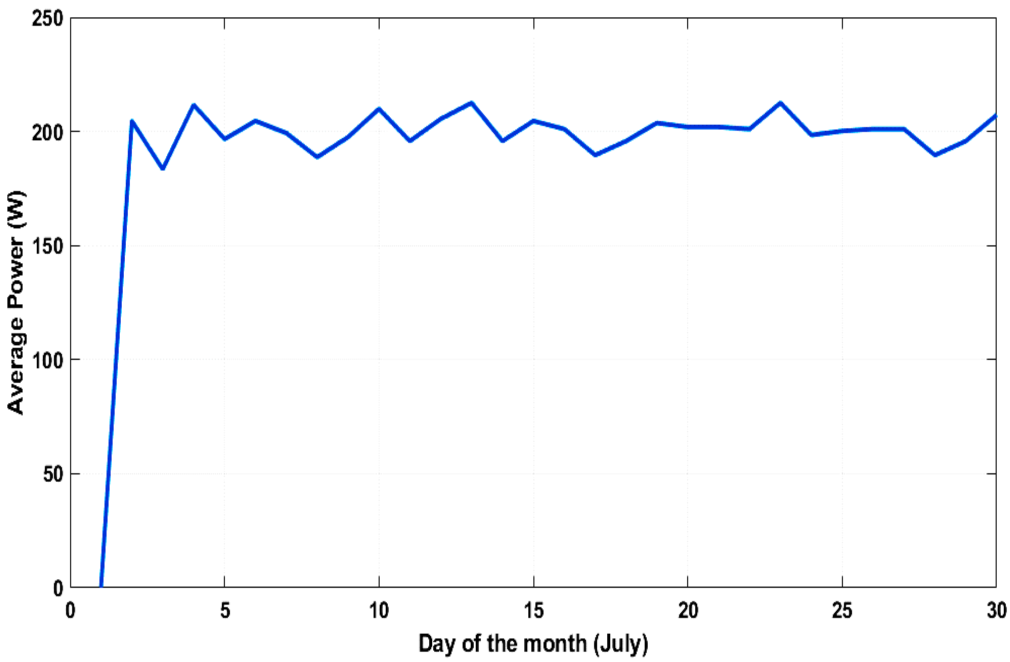

Figure 4.13 The average power of July

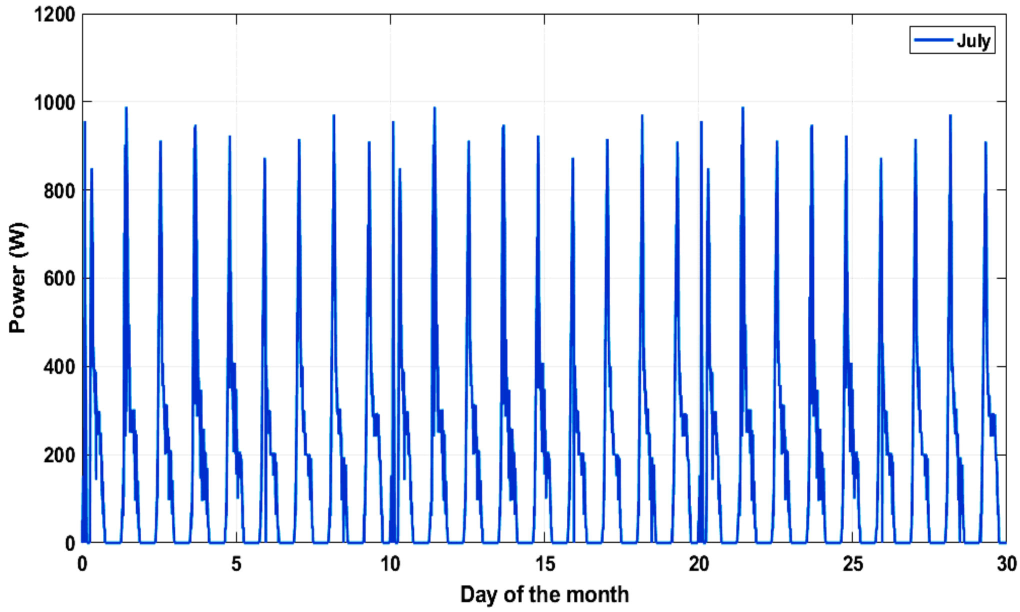

Figure 4.14 The power of July

Table 4.7 Average data of August

Day	Watt	Day	Watt	Day	Watt
1	181.1301	11	185.5479	21	181.8664
2	210.5822	12	212.0548	22	211.3185
3	193.6473	13	195.1199	23	193.6473
4	203.2192	14	201.7466	24	204.6918
5	198.0651	15	198.8014	25	196.5925
6	186.2842	16	187.0205	26	185.5479
7	196.5925	17	195.8562	27	198.0651
8	209.1096	18	209.1096	28	192.911
9	194.3836	19	194.3836	29	196.5925
10	206.1644	20	206.9007	30	195.1199

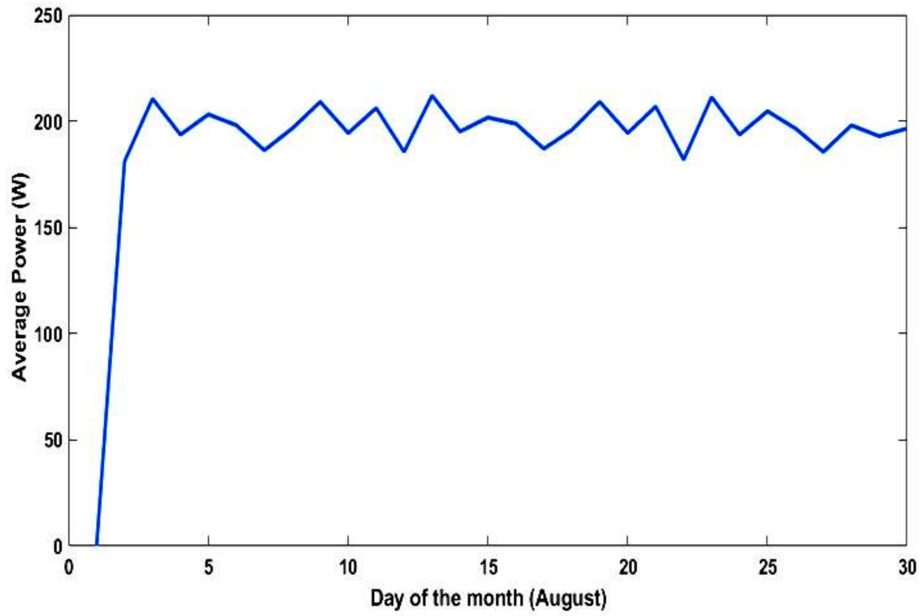

Figure 4.15 The average power of August

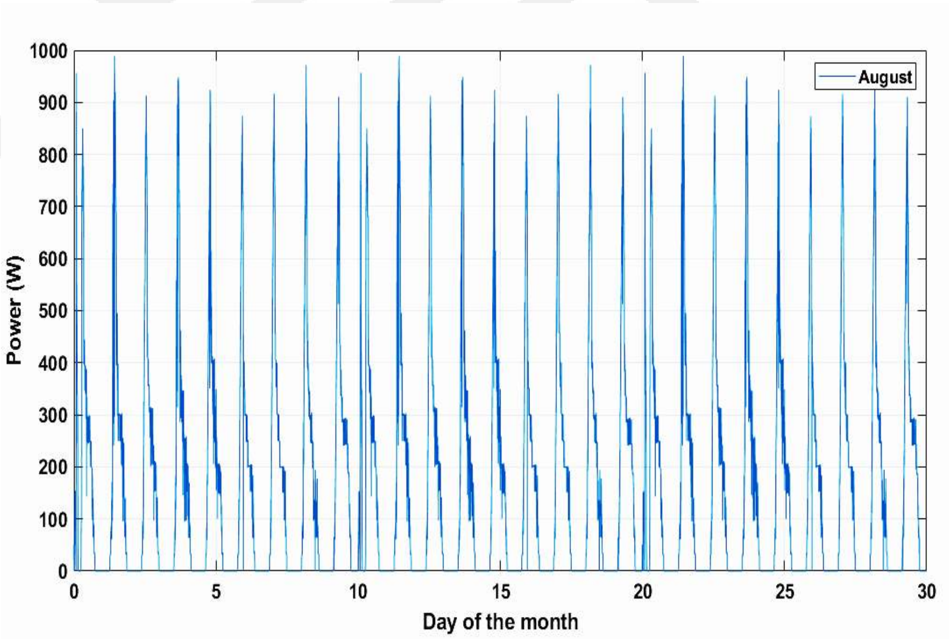

Figure 4.16 The power of August

Through the Figure 4.5, it becomes clear to us that the first days of the month were subjected to intense dust weather and it was varied between rain showers and cloudy in the rest of the month's days in addition to that this month has few days of dust in the middle of the month or in parts of the day. Therefore, the amount of energy obtained was insufficient or somewhat low, as shown in the figure. In addition, it can be seen that the energy obtained in the later days of the month has increased as a result of the improvement in the weather, meaning that the weather has become somewhat clear.

In Figure 4.7, the same happened in the month of April, but the weather conditions were in the days of 9 and 10 of April 2022. The performance of the system went back because the city of Kirkuk had been subjected to very dusty storm. In addition, quite a few days were rainy or cloudy in the middle of this month. Worth noted that the last four days of this month the city was subjucted to a variety of weather conditions such as dust and cloud.

In Figure 4.9, the dusty days were in the days between 13 to 17 of the months of May that can be seen from the figure, where the power in this span was very low because it has the day of 16 was very dusty even the goverment in the city of Kirkuk announce of cancelation of thre regular govenorate activity. From the figure, once can notice that the span 21-23 it was so dusty especially in the day of 23. The performance of the system was enhanced after this span but at the last day of this month the curve went down becuase of the dust.

Figure 4.11 and Figure 4.16 represent the month of June through August respectively where the power generated from the sun was almost consistent during the days.

In Figure 4.17, we are comparing the six plots in one to give more intention about our results. From the figure, one can see that there are lots of variation in the values that is because of the weather condition differences during the months changing from the rainy to cloudy to sunny and we have many dusty days during the selected months.

From Figure 4.17, which is the final form of comparison between the energy obtained during the months of testing, it turns out that the energy obtained from solar cells is greatly affected by the environmental, atmospheric, and physical conditions to which the solar systems are exposed. On the contrary, the clear atmosphere can produce very high energy that reaches the energy of the inverter used in the solar system.

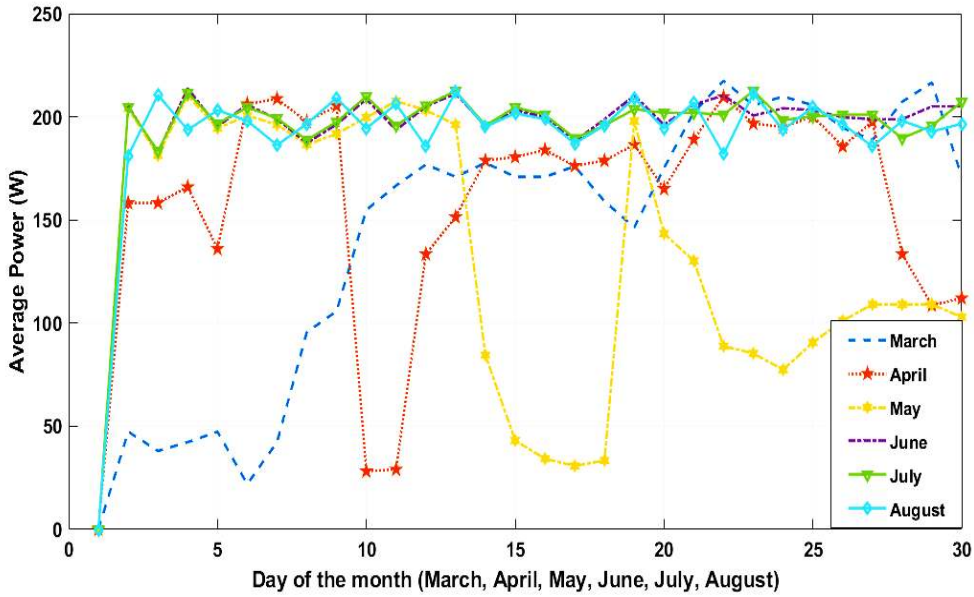

Figure 4.17 Comparison between the average powers in 6 months

In the Figure 4.18, the reader or researcher will be able to see the data that was taken directly from the sun, which represents the energy obtained and according to the months mentioned previously.

In the end, it is necessary to know the average energy obtained during the month, which is as mentioned in the Table 4.8.

Table 4.8 Average data of each month

March	April	May	June	July	August
143.6495	157.4525	130.2781	194.3459	193.9995	191.0346

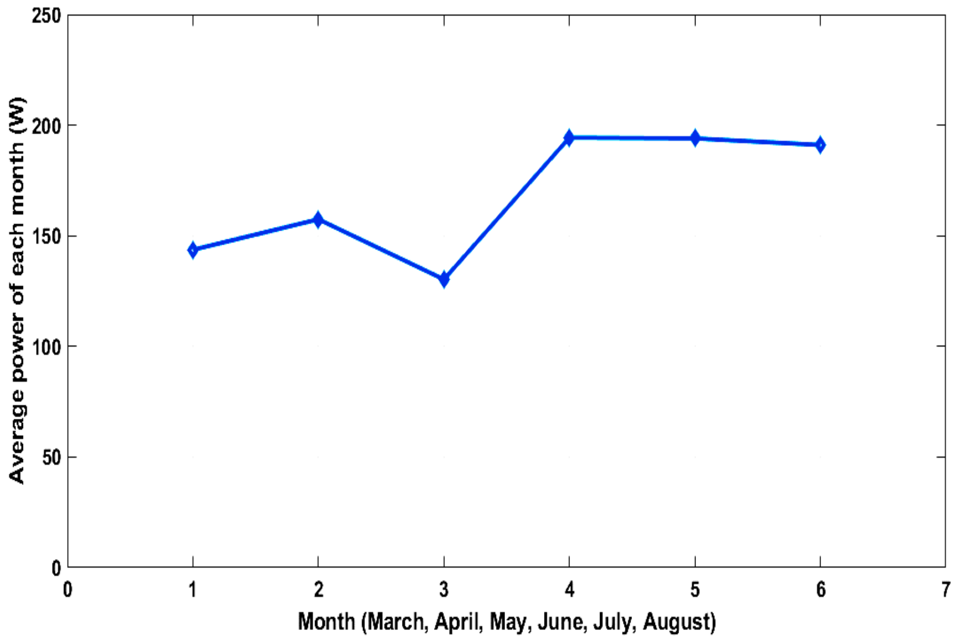

Figure 4.18 Average of each month

4.5 Power Consumption

In this section of the thesis, we measured the percentage of electrical energy consumption for a house over a period of six months in order to compare it with the amount of production of the solar energy system that we connected to the house.

We would like to point out that the house has a total area of 100 square meters and a building area of 70 square meters and contains two bedrooms, a living room, and a kitchen, in addition to the bathrooms. This house depends on electrical energy, electrical appliances that consume little electrical energy have been selected, in addition to the selection of economical light bulbs throughout the house. This house has an air cooler, 5 fans, a fridge and freezer, and 2 TVs, both of which are operated only for urgent necessities as well as we have three air conditioners, at least one of them is used especially in the hot weather. In addition, the family owns some electrical appliances that are of little use, such as the electric iron, vacuum cleaner, washing machine, dishwasher, in addition to other devices, such as chargers, according to the family's needs. As for the lighting, the residents of the house depend, as we said, on the economical bulb, and the bulbs are lit as needed, day and night. The refrigerator and freezer are operated continuously, and the fans are operated according to the presence of the family in the room and according to the air temperature, as is the case in the air cooler. As for the TV, it is turned on according to the presence of the family. It means that the electrical appliances are operated as needed. As for other devices, such as the mixer, iron or water pump, they are used once every two days for a short period of time as needed.

This was done in order to determine whether or not the solar energy system was worth the investment. The data was collected throughout the months of March, April, May, June, July, and August by using the official bills comes from the governorate electrical company. We compared them in order to determine the degree to which the house draws upon the available electrical power from the public grid. Temperatures fluctuate throughout the year in Iraq and, more specifically, in the city of Kirkuk. Since most of the months are not particularly warm, it is necessary to make use of electric energy for activities such as lighting and cooling, and some of the months are extremely chilly. For example, the months of March and April. It is almost hot in the month of May, the temperature is higher in June, and it is extremely hot in the months of July and August.

The amount of energy that is used by the house is represented by this section of the chapter. The data presented below makes it abundantly clear that the months of March and April have the lowest amounts of electrical energy consumption. This can be attributed to the fact that the temperature in those months is either slightly cold or moderate to some extent, and as a result, the use of electrical energy in those months can be greatly utilized for lighting or electrical appliances. For example, a refrigerator or freezer is required for daily use. As for the subsequent months, the amount of electrical energy consumption is high or large to some extent, and it may exceed the reasonable limit. This is because the majority of homes have cooling devices, and in some cases, there may be more than one cooling device. As a result, the amount of electrical energy consumption is high during the months in which temperatures are higher than the reasonable limit.

Table 4.9 shows the average power consumption during the month. From the table, once can see that the power consumption of the month is varied depends of the season. On March the consumption is low because the weather is good and on April is getting high and higher on May and son on until August. Figure 4.19 illstrated the average power consumption during the month

Table 4.9 Average power consumption during the month

March	April	May	June	July	August
2.911578 KW	4.081848 KW	5.231025 KW	6.689956 KW	6.30921 KW	6.329726 KW

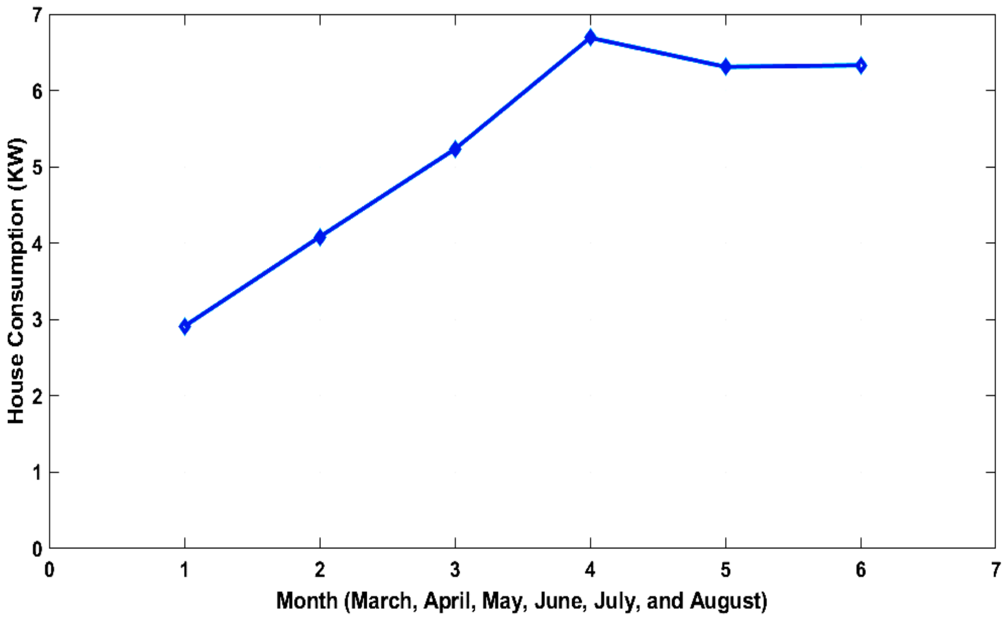

Figure 4.19 Average power consumption during the month.

4.6 Conclusion of the Results

1. Through the previous figures in this part of the thesis, it becomes clear to us that the lowest consumption of electrical energy in the house chosen in this study is 3,000 watts (3 KW) as a result of the real consumption in this house.The highest consumption is 6,000 watts (6 KW) in the summer as a result of the presence of

cooling devices and auxiliary devices for that. Comparisons can prove that the system that was used is not enough to enable the family in this house to operate any device at any time.Through this, another system should be installed to replace the current one, the size of which is six times the current system.

2. Through the above, and based on the system we used to conduct practical experiments, we must have 18 panels and 8 batteries to handle the consumption of this house.

3. In addition to the above conclusion, one can conclude that we can reduce the amount of the panels in the system because the recent system was built three years ago. In the meantime, we can have panels with more power such as 680 W in each panel. In this way, we can reduce the number of panels to half of the previous system. It means that we will have 8 panels in total.

4. By reducing the number of panels will gain two advantages:

- The total cost will be less becuase the cost of two 680 W panels is less than the total of four 360 W panels according to the markets.
- The area in which the panels installed will be less because the number of the panels is less comparing if the 360W is used. Worth noted that the area of the panels (360 and 680) is comparable.

5 CONCLUSIONS AND RECOMMENDATION

In conclusion, this study examined a variety of characteristics that were thought to be significant to the performance of solar energy systems. The performance of solar energy storage devices continues to be significantly impacted by environmental conditions to a significant degree. These environmental consequences include shading, dirtying, and variations in solar irradiance, and monitoring the sun, which refer to the direction and tilt angle of the PV module. Tint is one of the most significant environmental aspects.

Customers represent one of the most important factors that contribute to the solar industry's constant need for innovation. After the consumer has a solar-powered incandescent bulb or radio, they challenge the companies to innovate so that they can supply solar-powered products such as a solar-powered television or refrigerator. For example, the above advancement can be especially compared to an electricity leaderboard that starts with just a power staircase, progressively tries to climb up to solar appliances, and then goes further up to distribution networks that have the adequate facilities that can provide power for schools, hospitals, and industries. This energy ladder may begin with an energy ladder.

Businesses that are in the act of actively innovating within the solar energy system are also companies that provide credit financing. Therefore, they are including the people in an economy by giving the people access to their products that are both effective and inexpensive. In doing so, they are bringing the people into the economy.

Solar rooftop projects are now being encouraged by governments in regions all over the world that have an abundant of solar energy. This is done so that each household and commercial facility can be a proud producer as well as a user of the renewable radiation. The excess power generated by solar energy can be recycled directly into to the traditional attached grid by many state utilities around the world, which in turn allows the benefits of this technology to be passed on to households and industrial facilities. These technologies have been used by many states' utility companies around the world. Because of this configuration, conventional utilities will need to generate less power in order to meet the demands of the grid, which will ultimately result in less consumption of fossil fuels.

5.1 Impact of Dust on Photovoltaic Panels

An investigation was conducted to determine how dust buildup on the surface of a PV module affected its performance. There was found to be a connection between the collection of dust and a decrease in the performance of the module. It has been established that a variety of factors contributed to the decrease in the performance of the module. The amount of solar irradiance that reaches the PV module is affected by the dust particles' composition, size, and concentration through absorption and scattering. It has been determined that these are the primary causes of decreased performance and focus in the workplace. It has been established that the scattering effect has an effect not just on the magnitude but also on spectrum attenuation. Because of the diverse range of particle sizes present in the dust, a greater quantity of light is deflected at wavelengths shorter.

Regarding the dust effect on the PV modules, the work that is provided in this thesis provides a deep insight that was not carried out in prior studies. In specifically, the attenuation effect that dust has on the spectrum irradiance is the focus of this specific insight. This impacts not only the PV readings but also the system designers, as it suggests that in the same environment and dust concentration, technologies with larger band gaps will be more negatively impacted than technologies with smaller band gaps. When installing photovoltaic (PV) installations in a form of dust, it is necessary to use a technology-selective approach to choosing the panels to use in the installation.

5.2 Dust in Measurement

Researchers studied the impact of dust buildup and its relationship to dust concentration, tilt angle, and the spectrum attenuation effect by collecting long-term measured data in the field. A non-uniform thermoelectric distribution was detected during outdoor tests, although no damage was attributed to localized heat sources by the end of the measuring devices' cycles. Rain has a significant impact on the rate at which dust accumulates on the surface of the modules, where an increase in the amount of precipitation produces a greater cleanup influence.

It is possible to draw crucial conclusions based on the findings of the inquiry that are described in this thesis, including the following points:

1. The best way to construct an optimal system might be accomplished by determining which type of energy is created by the system.

2. Electrical engineers who are interested in maximizing yield but do not wish to make an investment in continuous tracking can benefit from the conclusion reached in point 1, which can be seen above.

3. When it comes to panels that are placed on roofs, it is advantageous to raise the panel over the surface of the roof. This is because roofs in the Kirkuk region (and generally in Iraq) are built of panels of concrete staggers, which get extremely hot during the summer season. PV-panels have their efficiency and, as a result, their output power decreased when the temperature was high.

4. The province of Kirkuk is the site that was looked at for the purpose of this research. It is not essential to clean the panels throughout winter, but once spring arrives, a monthly cleaning program is required. As we get closer to summer, a weekly and sometimes even a daily cleaning schedule is required.

5.3 Suggestion for the Further Researches

On the basis of the encouraging findings that were achieved from in this preliminary resource assessment, the city of Kirkuk may be able to utilize electricity generated by solar panels in the near future as a source of energy that will provide a supplemental power supply. The following initiatives are proposed to be carried out in the future in order to get a deeper comprehension of this body of work and to contribute to its advancement:

1. Keeping the project going so that measurements may be taken for a number of years in a row so that a more accurate evaluation can be made.
2. Making the measurement process easier by utilizing automated data records to monitor the voltage and current for solar panels, in addition to the environmental conditions.
3. The climatic variation in the region of Kirkuk should be researched by utilizing automatic data records that are installed in the area of work since it has a significant impact on the quantity of electricity that can be generated by solar panels.
4. The idea might be advanced by integrating the charging of storage batteries and the measurement of the level of charge in the batteries (or electrical energy). The battery's discharging and charging cycles are also crucial variables that require further research to be done on.
5. Employing various electrical loads, such as lighting fixtures, electrical motors, water pumps, and so on and so forth to make a project comparable to the one that was recommended in point number four, but this time.
6. The battery's discharging and charging cycles are also crucial variables that require further research.

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