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DESIGN AND EVALUATION OF SOLAR ENERGY POWERED GROUNDWATER PUMPING SYSTEM FOR IRRIGATION FARM IN IRAQ DESERT

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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BY

AHMED JABBAR GHAZI GHAZI

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By Ahmed Jabbar Ghazi GHAZI

August 2021

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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ABSTRACT

DESIGN AND EVALUATION OF SOLAR ENERGY POWERED GROUNDWATER PUMPING SYSTEM FOR IRRIGATION FARM IN IRAQ DESERT

Ahmed Jabbar Ghazi GHAZI

Master of Science in Electrical - Electronics Engineering

Advisor: Assoc. Prof. Dr. Fatih KORKMAZ

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August 2021

This thesis examines the design of a solar-powered groundwater pumping system to irrigate desert lands in Najaf, Iraq. The water pumping rate for the land to be cultivated was calculated as 83.4 m^3/day. We designed an irrigation system for the three agricultural crops that depend on soil and water sensors in their work. Where a land area of 12,500 m^2 was fed with water through two pumps, a well pump with a capacity of (5.5 KW) and a tank pump with a capacity of (0.78 KW), the number of solar panels required to operate the irrigation system was 27 solar panels, bifacial cells type, with a capacity of 390 Watts, Matlab Simulink's results and theory showed that the system can irrigate these lands, thus it will reduce the waste of electrical energy for the panels, and the purity of water and air which gives us a green and beautiful space.

2021, 82 pages

Keywords: PV Solar Panels, Pumping Station, Finite Element, Soil Moisture Sensor, Najaf, Iraq Desert

ÖZET

IRAK ÇÖL BÖLGESİNDE BULUNAN BİR ÇİFTLİK İÇİN GÜNEŞ ENERJİSİ İLE BESLENEN YERALTI SUYU SULAMA SİSTEMİNİN TASARIMI VE DEĞERLENDİRİLMESİ

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Bu tezde, Irak'ın Necef kentindeki çöl arazilerini sulamak için güneş enerjili bir yeraltı suyu pompalama sisteminin tasarımını incelemektedir. Sulanacak arazi için su pompalama hızı 83,4 m³/gün olarak hesaplanmıştır. Çalışmada, toprak ve su sensörlerine bağlı olan üç tarımsal ürün için bir sulama sistemi tasarlanmıştır. 12.500 m² arazi sulaması için 5,5 kW iki kuyu pompası ve 0,78 kW tank pompasının kullanımı durumunda, sulama sistemini çalıştırmak için gereken enerji ihtiyacı ve bu ihtiyacı karşılayacak güneş paneli sayısı hesaplanmış, systemin modeli Matlab Simulink program ile oluşturularak, teori ve sonuçları tartışılmıştır. Çalışma sonunda, sistemin bu arazileri sulayabileceği gösterilmiş olup, kırsal alan sulamalarında verimli ve etkili bir çözüm olabileceği gösterilmiştir.

2021, 82 sayfa

Anahtar Kelimeler: PV Güneş Panelleri, Pompa İstasyonu, Sonlu Elemanlar, Toprak Nem Sensörü, Necef, Irak Çölü

PREFACE AND ACKNOWLEDGEMENTS

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Today I think that I am fortunate to have my best friend who has given me support, encouragement and assistance in all matters of coordination in my dissertation Eng. Dr. Muhammad Abdul-Hussain AL-SHUWAILI, in addition to the engineer as an assistant teacher. Ahmed Al MUDHAFFAR, I will cherish the trust they have always given me.

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Ahmed Jabbar Ghazi GHAZI
Çankırı-2021

CONTENTS

LIST OF SYMBOLS

A	Ampere
C	Capacity
I	Current
Ω	Ohm
Q	Flow Rate of Water
L	Inductance
R	Resistance
V	Voltage
W	Watt
T	Temperature

LIST OF ABBREVIATIONS

AC Motor	Alternative Current Motor
Add	Amp-Hours Day
Aha	Amp-Hours Adjusted
CNTs	Carbon Nanotubes
COE	Cost of Energy
DA	Days of Autonomy
DC Motor	Direct Current Motor
DM	Design Margin
DOD	Depth of Discharge
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
Imp	Maximum power current
Iph	Photon current module
Irs	Shunt reverse current module
Is	Reverse current module
Isc	Short circuit current
KWh	Kilo Watts Hour
MPPT	Maximum Peak Power Tracking
MW	Mega Watts
NPC	Net present cost
PAMAM	Polyamidoamine
Pm	Maximum power
PM	permanent magnet
PV	Photo Voltage
PWM	Palls Width Modulation
Tc	Temperature Correction Factor
VI	Voltage and Current Characteristics
Vmp	Maximum power voltage
Voc	Open circuit voltage
WP	Watt Peak

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1. INTRODUCTION

Many farmers living in remote desert areas around the world, including my country, i.e., Iraq, are suffering from the problem of providing energy to the water pumping systems in those lands. Therefore, solar panels are the preferred alternative to supply electrical energy to the water pumping systems in remote and rural areas, as the solar panels provide a constant form of energy. Solar energy is renewable and guaranteed for a long time. The solar panels can be assembled in multiple places simultaneously. One of its most important advantages is that SPs are energy-friendly because it saves electricity and reduces maintenance and operating costs (Narale *et al*., 2013). Moreover, renewable energy is locally available and does not need to be imported, and this reduces the environmental impacts associated with transportation from outside the country (U.S. EIA, 2014) Hence, solar power plants are the recommended type of renewable energy to power the water pumping system.

The interest in renewable energies stems from the fact that they are one of the possibilities available for exploitation and optimization. Directing them is vital for the development purposes in areas of a large population to provide food due to the feasibility of their usage not only at the present time, but also towards the future. In contrary, the traditional energy resources, such as oil, are, in general, depleted. The increase in traditional energy consumption is offset by a decrease in the volume of the available reserves. With time, developments need more energy and it will not be sufficient to fill these needs through the traditional resource of energy. Consequently, the alternative sources must be developed to meet the future demands and lead to the possibility of using them, especially, in remote rural areas. This is due to the factors of (i) distance from the processing centers including effort, cost and time, (ii) indeed, the diesel systems need the expenses of fuel and maintenance and the greater the size of the load on diesel causes more expenses for fuel and maintenance. These expenses have become greater, as they can reach 60% of the cycle cost the overall life of a diesel system. Unlike solar cell systems, as they do not require major maintenance which make them suitable for remote areas in which qualified technicians are not available to repair and maintain generators it works with traditional fuel. Furthermore, solar cells are clean, non- polluting, and do not leave residues. Being sustainable gives them a special status in this field. Hence, paying more attention to solar energy in several areas is essential to reach more rural, aiming to improve their social and economic conditions. On the one hand, limiting the desertification gives the dispersal of the population over a vast area and reduces the isolation of many populated places. Hence, the search for alternative renewable energy becomes more rational, and this alternative can be represented effectively by solar energy.

Aiming to solve the problems of the pumping water in remote areas in the developing countries, which are without access to grid-connected power, by changing the pumping systems to directly coupled PV water pumping systems, (Kolhe *et al*. 2004) evaluated the performance of the permanent magnet (PM) powered Photovoltaic (PV) compact motor with a centrifugal pump of different density and a solar cell with different temperatures. Their analysis is useful for selecting the appropriate load and driver for water pumping applications in remote areas of developing countries.

Abu-Aligah (2011) compared the solar powered pumps and diesel pumps in terms of their costs and reliability based on the initial capital cost, operating and fuel costs. He made some estimation for choosing the appropriate system size and He listed the main components of the system and their uses. When comparing the cost and reliability between diesel pumps and solar powered pumps, he found that diesel pumps are low cost in the beginning and then very high operating and maintenance costs are expected, whereas, the solar pumps have high initial cost, but cost low operation and running expenses. In fact, the worst life of solar energy - Fuel costs $ 1.20 per liter, with an average consumption of 0.3 liters per kilowatt. Whilst, the worst life for solar energy the cost of fuel is 1.70 $ per liter, with a consumption rate of 0.7 liters per kilowatt. Table 1.1 and Table 1.2 show the differences between diesel pump and PV panels for the above scenarios.

Table 1.1 Comparison for solar and diesel water pumps (Abu-Aligah, 2011)

PUMP TYEP	INITIAL CAPITAL	OPERATING COST/YEAR	TOTAL NET PRESENT	PER KWh $
PV pumping	12.300 $	335 $	16.472 $	0.66 $
Diesel pumping	2.000 $	4.854 $	62.494 $	2.48 $

Table 1.2 Comparison for solar and diesel water pumps (Abu-Aligah, 2011)

PUMP TYEP	INITIAL CAPITAL	OPERATING COST/YEAR	TOTAL NET PRESENT	PER KWh $
PV pumping	12.300 $	335 $	16.472 $	0.66 $
Diesel pumping	2.000 $	12.525 $	158.094 $	6.27 $

It's obvious that solar-powered water pumps are highly recommended due to their cheap operation and maintenance costs and they are more reliable than the diesel-powered water pumps. Moreover; solar panels are useful for longtime operations as they operate the water pumps or charge batteries to work at cloudy conditions.

Dissabandara and Peiris (2013) mentioned a new invention of a 12-volts water pumping system which is portable with a 12-volt DC impeller pump powered by a rechargeable 12-volt battery, that is recharged by either 5-watt or 15-watt or larger solar panels.

Al-Waeli et al. (2017) utilized software applications to optimize energy systems based on numerical methods. They used HOMER software to simulate the utility of the PV system as this software can model the renewable and non-renewable system.

The REPS.OM and MATLAB softwares were used a base designed in Oman.

Researchers have calculated the optimum PV array/module, tilt angle, and the exemplary inverter measure for the PV system. REPS OM IA able to investigate the performance of a PV system for one year by simulating and optimizing the system. These studies were conducted in Sohar city in Oman. This area has about 8 -10.5 hours of daily sunshine at about 342 days.

The results of this study have noticed that the optimum system of REPS.OM seems higher HOMER which is based on COE and minimum NPC (Salam *et al.* 2013). This software is useful in such a way that it can be used for taking suitable decisions according to countries' climates as the calculations are the same. Having software corresponding to REPS.OM in different countries can help in adopting the design of the right system in low costs, and high efficiency.

Errouha *et al* (2019) searched for better control and optimization for the PV water pumping systems using an induction motor. They proposed a Fuzzy Logic Controller to improve the conventional Direct Torque Control and utilized a variable step size Perturb and Observe (P&O) to obtain the maximum power point from PV panels.

Singh and Saikia (2017) investigated a small project for automatic irrigation for horticulture purposes. This project contains two units: one to detect the level of the water tank and the other to measure soil moisture. They demonstrated the work of the current technologies such as Sensors, Arduino, etc. In this paper, they described the project framework and illustrated the project methodology.

The induction motor is the main element of the pumping system. Control speed DC motors were used but they need a regular maintenance. To solve this problem, brushless permanent-magnet motor has been proposed. However, this motor is limited to low-power PV systems. So, AC motors have been employed as they are more efficient, maintenance-free and low costs as shown in Figure 1.1. (Rawat et al. 2016)

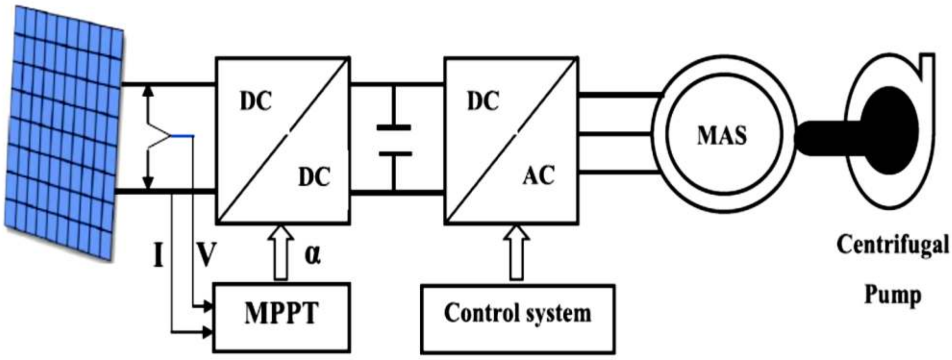


Figure 1.1 Description of the photovoltaic pumping system (Rawat et al. 2016)

When the system starts sensing the soil moisture value, if it is higher than the limit value, the motor then stops working and returns to the starting step. However, when the moisture is less than the threshold value, it starts the motor to pump the water and goes to the next step which senses the water level of the tank. In case the water is below the limit value, it keeps the motor pumping water. Contrary, if the water level is above the threshold, it shuts down the motor and shuts down the system. Figure 1.2, shows the block diagram in which both the soil moisture and water level sensors are connected to the microcontroller. The latter who shows as an input that gives the system status on the LCD as an output and a power supply providing both the microcontroller and the motor driver.

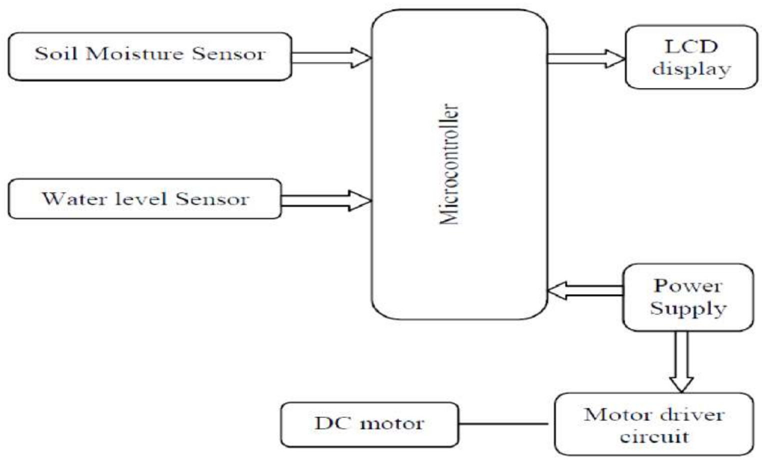


Figure 1.2 Block diagram of automated irrigation system (Rosly et al. 2014)

Reich *et al.* (2005) indicated that there is more than one factor that toned to be understood to estimate the performance when they are affected by different climatic conditions, including the effect of radiation and temperature on the solar cell, the incident light spectrum, and the performance of the unit. The translation equations in some parameters can depend on the radiation.

They can diverge from the experiments at every value of the radiation or when the temperature rises. Current-voltage curves (I-V) have been reported to be adopted based on linear interpolation or extrapolation. This is valid for more than one type of solar cells such as c-Si, a-Si, and thin-film crystalline silicon. Spanggaard and Krebs, (2004) discovered of the photoelectric effect of PV. They coated platinum electrodes with silver bromide or silver chloride which were lit in an aqueous solution. They discovered a light current. This is the photoelectric effect.

Historically, Spanggaard and Krebs, (2004) provided the first reports of photoconductivity to work on selenium in which the first organic compound was observed for photoconductivity. By Pochettino in 1906 and Vollmer in 1913. Scientist's interests have increased and have led to an increase in research on photoconductivity and related topics. In the early 1990s semi-conducting properties such as methylene blue was reported.

Photoconductivity was observed for the first time on anthracene, and it was studied extensively in the fifties. This indicates that the crystal structure was reached and determined precisely at an early date. There are readily available crystals, which are single crystals. These were of high purity. The first real investigation of photovoltaic was carried out on porphyrins and PCS, and this group of compounds became the most researched among dyes because they are easy to prepare, have high colors, and form crystalline membranes as shown in Figure 1.3.

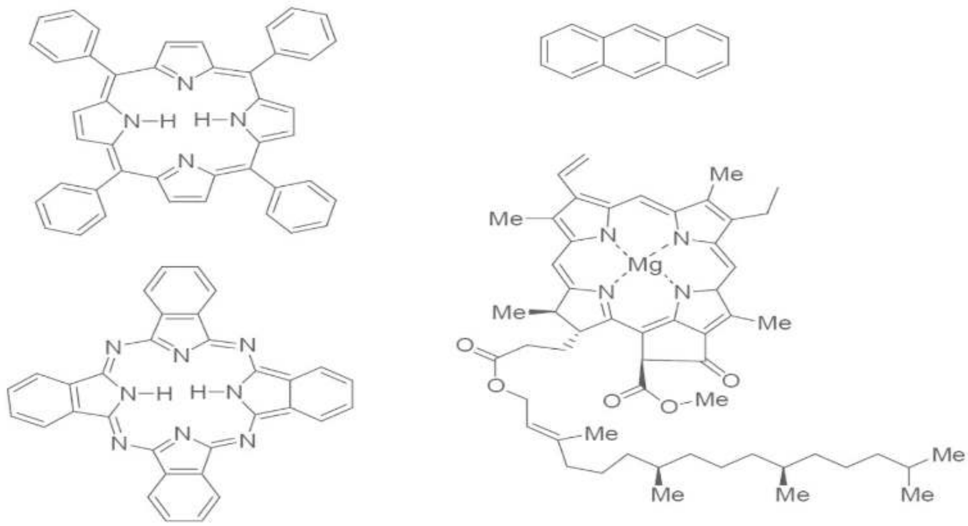


Figure 1.3 Development of organic and polymeric photovoltaics (Hung et al 1997)

Hoppe *et al*. (2005) investigated another way to generate, transmit, and store energy due to the increase in global warming on the planet, aiming to find a less harmful way. They need to acquire a large number of people to increase the spread of photovoltaics and make them a major source of renewable energy. One of difficulties is that the watt rate has to be reduced. They found a solution to the high price of manufacturing photovoltaics by manufacturing organic photovoltaics, and these cells can generate electricity at a lower price than solar cells made of crystalline silicon. To make these results come true they had to study the photoelectric properties of organic semiconductors.

Nabawy *et al*. (2020) presented Carbon Nanotubes (CNTs) that have different properties such as having high mechanical strength, high conductivity, high stability, and their carbon atoms are arranged in a hexagonal network. CNTs enter SWCNTs in which single sheets are wound and MWCNTs have multiple walls and DWCNTs and these are formed by rolling. Carbon nanotubes are used in sensors, solar cells, transistors, and other electronic materials. According to Singh and Saikia, (2017), smart irrigation has attracted the interest of many researchers about a decade ago. Their goal was to reduce the water waste, human efforts, water consumption and resource used.

Hoppe *et al.* (2005) indicated that the PV cells are usually in a solid state and consist of crystalline or amorphous silicon. Inorganic semiconductors were also produced. Now we can completely move away from ordinary solid semiconductor connections and replace them with bulk connections. Due to the fact of reduction in the traditional energy resources such as gas and oil, new types of solar cells have been developed since the world's energy needs will increase in the next 50 years.

Demadis *et al.* (2007) investigation of various water treatment by testing the inhibitors of water’s sparingly soluble electrolytes. That found mineral scale deposits for example phosphate, calcium carbonate calcium oxalate, barium and strontium sulfate, magnesium silicate, and other colloidal inorganic species, as well as colloidal inorganic species such as silica, face major challenges for process water applications. When silica is not handled, it forms hard, tenacious deposits that are difficult to extract and potentially harmful. Silica formation and deposition are not hindered by traditional phosphonate mineral scale inhibitors. Chemical cleaning is not without dangers, and it necessitates shutdowns. Corrosion of essential metal surfaces of industrial equipment is another concern. Finally, bio fouling is caused by the growth of microorganisms.

These studies are found the present the general scope of these problems as well as their solutions. It focuses on the use of engineered chemical approaches to inhibit (a) colloidal silica formation, (b) colloidal silica dissolution, and (c) metallic corrosion in water applications. Polyaminoacid dendrimers and polyethyloxazoline were used as silica inhibitors. Carboxymethyl inulin (CMI), Gene sol 40 (a patented mix of additives), and polyacrylic acid were the dissolvers tested for silica dissolution. Silica inhibition is a function of time and inhibitor dosage in theory (Meyers, 2004).

On the other hand, silica dissolution is affected by the dissolver's composition, time, and dosage in an unpredictably unpredictable way. Zinc ions and polyphosphate anions, which form protective films, have been used in tandem to prevent mild steel corrosion.

1.1 Problem Background and the Proses of Investigation

This research relies on finding solutions to a significant problem that affects the irrigation of desert areas and thus is divided into branches, and each branch has its own difficulty and solution.

The main branch is the problem of the water pumping system, which is divided into sub-problems related to pumping water to remote areas that results from the problem of supplying the water pumping system built in remote areas where there is no network. This problem leads us; first to think about the diesel pump and secondly the photoelectric pump. After comparing the two different methods of pumping we found that the PV pump is much better than the diesel-powered pump (Alshamani and Iqbal, 2017).

The main reason for using the renewable energy instead of fossil fuels is that it has a constantly increasing high cost including transportation and tough costs, along with its environmental pollution. Hence, some studies were carried out on the use of a PV water pumping system, which relates to analyzing the performance of a paired PV water pumping system. A direct evaluation was performed for (a) the economic and environmental aspects of the use of the PV system, (b) the active improvement of pumping water into the distribution system; (c) adding a control unit for improving and controlling the pumping system (Helmy E. and Gad, 2009).

Regarding the problem of materials that should be used in building photovoltaics, many different chemicals are available and each of them differs in its advantages and disadvantages. The materials are used depending on where the PV is built and its characteristics. A small version of the water pump system, which is portable and rechargeable, then, is discussed. The main feature of this work is to have a battery that is recharged using solar photovoltaic cells. To pump water to all parts of the farmland at a low cost and without causing any pollution to the environment, a PV pumping system instead of fossil fuels as an energy source is recommended (Korpale *et al*. 2016).

1.2 Geographical Location of Najaf

My country of Iraq includes nineteen governorates. I selected the Najaf governorate because its airspace and geographical location qualify it to install solar power stations, as Najaf is located on the outskirts of the western desert plateau of Iraq, southwest of the capital Baghdad, 160 km away from it show as Figure 1.4. The city rises 70 meters above sea level and is located on a longitude of 44 degrees and 19 minutes, and at a latitude of 31 degrees and 59 minutes. It is bordered from the north and northeast by the city of Karbala (which is about 80 km away from it), from the south by the Kingdom of Saudi Arabia, and from the south. From the east, the governorates of Diwaniyah and Samawah, while Anbar governorate is bordered on the west.

Figure 1.4 The location of Najaf (Kadhim and Al-Baaj, 2016)

The area of Najaf Governorate is (28,824) square kilometers, and this area constitutes (6.6%) of the total area of Iraq. (435,244 km2), and Najaf governorate includes three main districts, which are Najaf, Kufa and Al-Manathira, with an area of (626,437, 24461 km2) and the number of sub-districts. They are Al-Haidariya - Al-Shabaka - Al-Abbasiya - Al-Hurriya - Al-Meshkhab - Al-Qadisiyah.

1.3 Socio-Economic Context

The agricultural sector is considered a vital tool for the advancement of the comprehensive economic process in many countries of the world, and its importance lies in the fact that it represents the practical basis for facing the gap between production and consumption. Fruits, vegetables and grains, in addition to the availability of suitable conditions for raising bees, poultry and fish because the Najaf Governorate is located on the Euphrates River. Over the past years, it was considered one of the most prominent governorates in the country in the production of amber rice (the Mishkhab type), which is one of the finest and most elegant rice types in the world. The governorate is also famous for producing barley and yellow corn, as well as the spread of tomato and potato farms and palm farms in large areas of the governorate. However, the agricultural situation in the governorate has deteriorated significantly over the past six years for several reasons, most notably water scarcity, increased desertification, salinity, energy and fuel crisis, and weak government support for aspects of providing fertilizers and seeds, soft loans, and the failure of government legislation to provide protection for the local agricultural product. Refrain from agriculture and go to other work, such as volunteering in the ranks of the security forces to ensure a better and easier life than agriculture, which has become a tiring and cumbersome profession, which requires uniting efforts towards the establishment of agricultural planning that leads to restoring the prestige of this sector in the governorate and making it a tributary to provide the elements of food security and support the country's national product.

1.4 Research Problems

- High upfront costs for PV installations.
- Irregularity and blackouts due to cloudy days when PV cannot provide.
- Decrease in the performance of photovoltaic panels when in a stationary position.
- Industrial water problems such as: mineral corrosion, bio fouling.
- Scale deposits that affect the efficiency of the water pumping system.

1.5 Research Aims

- Irrigate the desert areas and rural by using photovoltaic water pumping system.
- Control the PV water pumping system using Arduino controller.
- Investigating in a solar battery charge system to be used in cloudy days.
- Energetic optimization of water pumping in distribution.
- Evaluating the environmental and economic aspects using PV water pumping systems.
- Comparison between diesel and PV water pumping system.

1.6 Research Importance

- Use of renewable energy sources such as solar panels instead of traditional energy sources.
- Using modern irrigation methods for agricultural lands through water and soil moisture sensor.

1.7 Methodology

In this thesis, a mixture of quantitative and qualitative Finite Element analyses is used to design and evaluate a novel irrigation system that suitable to use in deserts, especially the Iraqi desert. First, we study the previous research that depends on the photoelectric water pumping system. Analyzes have then been made to this research such as results, theories and comparisons that help in choosing the right and most suitable components for the proposed novel system considering the highest efficiency, and feeding crops in controlled method to water usage employing a soil sensor.

The Finite Element simulation was done to choose the most suitable engine used in the system. The factors considered in the simulation are: (a) the location of the built plate; (b) the optimal position of the plate, which is the basis for choosing the number of hours to obtain the necessary sufficient power, and estimating the energy dissipation in the system according to the characteristics of VI; (c) choosing the number of suitable batteries to compensate the tank pump with electric power in dusty days and in the Earth's initial operating hours.

1.8 Construction of the Thesis

1- This study has been divided into five chapters, which are: The general introduction is included in the first chapter. This chapter explains why the topic was chosen, the study's dilemma, the hypotheses, the purpose, the construction, and the methods used to achieve the desired results.

2- In the second chapter, detailed information is given on the main topic of the thesis. Photovoltaic panels, types, areas of use, and terrestrial applications of PV systems are illustrated. Also, the methods used in studies are reviewed in the literature and the advantages and disadvantages of these studies are highlighted.

3- In chapter three, the study's theoretical information, system used, method used, calculations and formulas are explained in detail.

4- In the fourth chapter contains the study models, the explanations of the blocks and the sub-models used in the model, the results obtained, and the interpretations of the results in the thesis.

5- In the fifth chapter the purpose of the thesis is briefly stated. The results obtained are presented in general terms and informative information are also provided to those who will work on this issue in the future.

2. TYPES OF SOLAR PANELS AND THEIR APPLICATIONS

2.1 Introduction

Photovoltaic solar power has many advantages that make it one of the most promising renewable energy sources on the planet. It is non-polluting, has no moving parts that may fail, needs little maintenance and no monitoring, and has a 20-30-year life cycle with low operating costs. It's particularly unusual in that it doesn't necessitate a large-scale installation. Remote areas can easily generate their own electricity by building small or large a system according to their needs. Solar power generators are easily delivered to residences, schools, and businesses, requiring no additional construction or land area to assemble, and operating in a clean and quiet manner. More solar energy a solar cell, also known as a photovoltaic cell, is an electrical system that uses the photovoltaic effect, a physical and chemical phenomenon, to transform light energy directly into electricity. First, it's a type of photoelectric cell, which is characterized as a device with electrical characteristics that change when exposed to light, such as current, voltage, or resistance. Photovoltaic cells capacity can be added as cities expand. Photovoltaic modules, also known as solar panels, are made up of solar cells, which are the building blocks (Lakatos *et al*. 2011).

Solar cells are classified as photovoltaic regardless of whether they are powered by sunlight or artificial light. They are used as photodetectors (infrared detectors, for example), detecting light or other electromagnetic radiation in the visible range, or measuring light intensity.

A photovoltaic (PV) cell must have three basic characteristics to function:
1. Light absorption that results in electron-hole pairs or exactions.
2. The isolation of opposite-type charge carriers.
3. Separate carrier extraction and transfer to an external circuit.

Solar cells are usually given the name of the semiconducting material that they are made of. In order to absorb sunlight, these materials must possess certain characteristics. Some cells are made to withstand sunlight that reaches the Earth's surface, while others are made to be used in space. Solar cells may be made of a single layer of light-absorbing material (single-junction) or multiple layers of light-absorbing material (multiple-junction) (Luceño-Sánchez *et al*. 2019).

2.2 The Major Types of Solar Panels

Three main types of solar panels are available, shown in Figure 2.1, which are monocrystalline, polycrystalline and thin-film. Each type has its own set of benefits and drawbacks, and the best solar panel type for your installation will be decided. (Mohammad Bagher, 2015).

Figure 2.1 Types of solar panels (Purusothaman et al. 2014)

Solar cells are constructed from a semiconducting material that converts light into electricity in order to generate electricity. Silicon is the most common semiconductor material used in the solar cell manufacturing process (Petrovska-Delacrétaz *et al.* 2009).

Cells made of silicon wafers include both monocrystalline and polycrystalline solar panels. Wafers are arranged into rows and columns to form a rectangle, and then covered with a glass sheet and framed together to create a monocrystalline or polycrystalline panel shown in Figure 2.2.

Although all types of solar panels use silicon cells, the composition of the silicon itself differs between monocrystalline and polycrystalline plates. Monocrystalline solar cells are made out of a single, pure silicon crystal. Alternatively, polycrystalline solar cells are made up of silicon crystal fragments that are fused together before being cut into wafers in a mold.

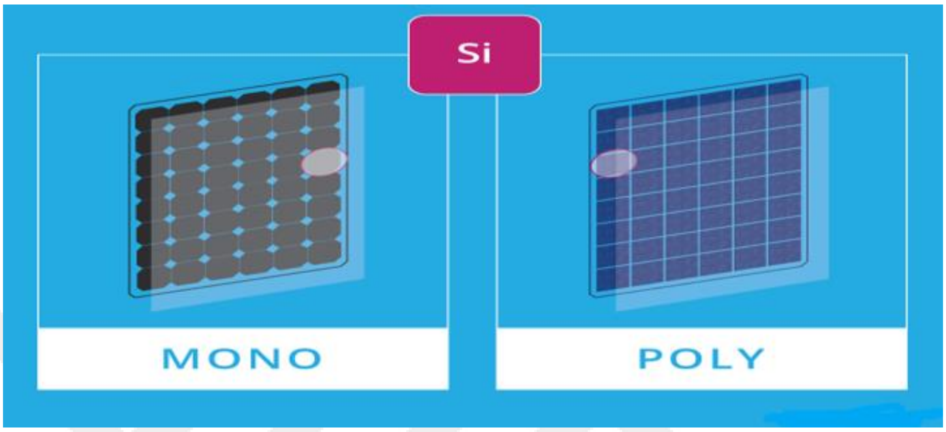


Figure 2.2 Solar plates, monocrystalline and polycrystalline (Taşçioğlu et al. 2016)

2.3 Monocrystalline solar panels

Monocrystalline silicon also known as single-crystal silicon, single-crystal Si, mono c-Si, or simply mono-Si is the most common type of silicon chip used in today's electronics. Mono-Si is also used in the production of solar cells as a photovoltaic, light-absorbing material. It's made of silicon, and the whole solid's crystal lattice is continuous all the way to the edges and free of grain boundaries. Mono-Si can be rendered intrinsically, with only very small amounts of other elements added to change its semiconducting properties, or doped, with very small amounts of other elements added to change its semiconducting properties.

The Czochralski method is used to develop silicon monocrystals into ingots up to 2 meters long and weighing several hundred kilograms. For further processing, these cylinders are cut into thin wafers of a few hundred microns. Single-crystal silicon is probably the most important technological material of the last few decades the silicon (Heywang and Zaininger, 2004). Because its inexpensive availability has been critical for the production of electronic devices that have underpinned the current electronic and informatics revolution. Other allotropic types of silicon include non-crystalline amorphous silicon, which is used in thin-film solar cells, and polycrystalline silicon, which is made up of small crystals called crystallites, as shown in Figure 2.3.

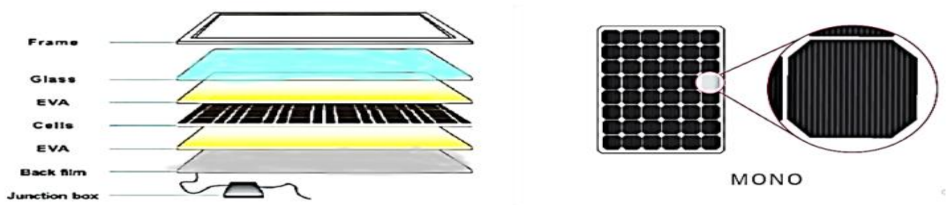


Figure 2.3 Monocrystalline solar cell structure (Mohammad Bagher, 2015)

It's most definitely a monocrystalline panel if you see a solar panel with black cells. Because of the way light interacts with the pure silicon crystal, these cells appear black. While the solar cells themselves are black, their back sheets and frames have a range of colors for Monocrystalline solar panels. Monocrystalline usually have the highest efficiencies and power capacity of all panel types. Monocrystalline solar panels can achieve efficiencies of more than 20%, whereas polycrystalline solar panels usually achieve efficiencies of 15 to 17%.

Monocrystalline solar panels tend not only to produce more power than other types of panels because of their performance, but they also have higher wattage modules. Most monocrystalline solar panels come with a power capacity of more than 300 watts (W), some of which now reach 400W. On the other hand, polycrystalline solar panels appear to have lower wattages. This does not mean that monocrystalline and polycrystalline solar panels are not physically the same size - in fact, with 72 or 96 cell variants each, all types of solar panels appear to come with 60 silicon cells (usually for large-scale installations). Monocrystalline panels, on the other hand, can generate more electricity for the same number of cells (Ahmad *et al*. 2016).

2.3.1 Polycrystalline solar panels

Polycrystalline silicon, also known as polysilicon or poly-Si, is a polycrystalline type of silicon with a high purity that is used as a raw material in the solar photovoltaic and electronics industries. A chemical purification process known as the Siemens process is used to make polysilicon from metallurgical grade silicon. The distillation of volatile silicon compounds and their high-temperature decomposition into silicon are also part of this process. A fluidized bed reactor is a new refinement approach that is gaining popularity. Upgraded metallurgical-grade silicon (UMG-Si) is also produced in the photovoltaic industry, which is purified using metallurgical rather than chemical methods (Xue et al. 2021).

Polysilicon has impurity levels of less than one part per billion (ppb) when manufactured for the electronics industries, while polycrystalline solar grade silicon (SoGSi) is usually less pure. The majority of the money came from a few companies in China, Germany, Japan, Korea, and the United States, including GCLPoly, Wacker Chemie, OCI, and Hemlock semiconductor, as well as the Norwegian-based REC.GCLPoly, Wacker Chemie, OCI, and Hemlock Semiconductor from China, Germany, Japan, Korea, and the United States, as well as the Norwegian-based REC, accounted for the majority of the global output of around 230,000 tons in 2013.

As shown in Figure 2.4, polycrystalline solar cells appear to have a bluish hue to them, unlike monocrystalline solar cells, since light reflects in a different way from a pure monocrystalline silicon wafer from the silicon fragments in the cell (Taşçioğlu *et al.* 2016).

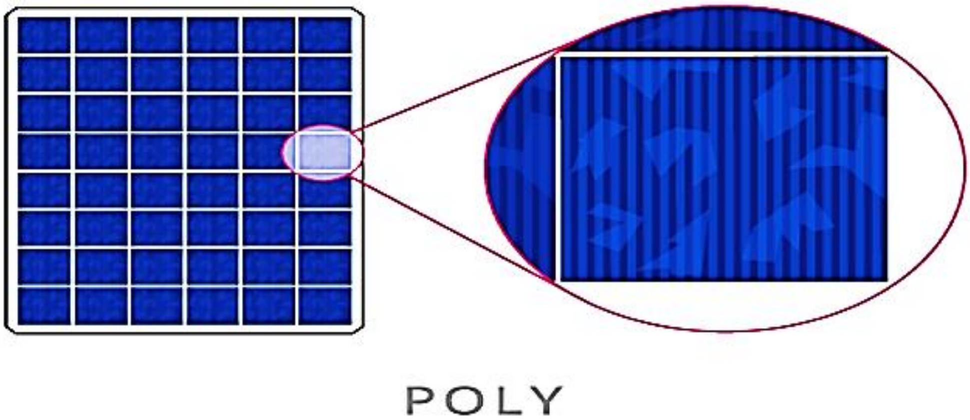


Figure 2.4 Polycrystalline solar structures (Krebs, 2009)

Similar to monocrystalline, polycrystalline panels for back sheets and frames have various colors. The frames of polycrystalline panels are most often silver, and either silver or white are the back sheets.

Usually, polycrystalline solar panels are cheaper than solar monocrystalline panels. Since the cells are made up of silicon fragments rather than a single, pure silicon crystal, this is the case. These enable a much simpler method of producing cells, thereby costing producers and ultimately end consumers less.

2.3.2 Thin-film solar panels

As shown in Figure 2.5 a thin-film solar cell (TFSC), also known as a thin-film photovoltaic cell (TFPV), is a second-generation solar cell created by depositing one or more thin layers of photovoltaic material on a substrate such as glass, plastic, or metal. Thin-film solar cells, such as cadmium telluride are commercially available (a-Si, TF-Si) (Alexander H. Ip, *et al.* 2012).

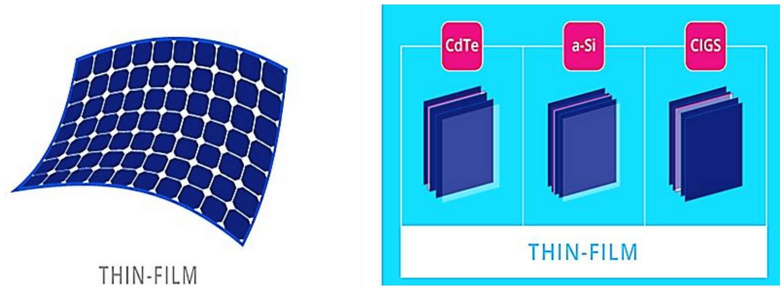


Figure 2.5 Thin -film solar panel structure (Sambo et al. 2014)

Thin-film solar panels tend to be lower than monocrystalline or polycrystalline varieties in performance and power size. Efficiencies vary depending on the type of material used in the cells, but they are typically about 11 percent.

Unlike the uniform 60 monocrystalline and polycrystalline solar panels, Thin-film technology comes in a number of sizes, including 72 and 96 cell variants. As such, the ability of power from one thin-film panel to another would depend largely on its physical size. Monocrystalline or polycrystalline solar panels would, on average, have a higher power capacity per square foot than thin-film panels.

Finally, another common form of thin-film technology is Copper Indium Gallium Selenide (CIGS) panels. All four components of the CIGS panels are mounted between two conductive layers (i.e., glass, plastic, aluminum, or steel) and electrodes are placed on the front and back of the material in order to absorb electric currents (Kirchartz *et al.* 2016).

Through the above, Table 2.1 shows the most important advantages and disadvantages of solar panels.

Table 2.1 The advantage and disadvantages of the solar panels

PANEL TYPE	ADVANTAGES	DISADVANTAGES
Monocrystalline	High efficiency/performance	Higher costs
	Aesthetics	
Polycrystalline	Low cost	Lower efficiency/performance
Thin-film	Portable and flexible	Lowest efficiency/performance
	Lightweight	
	Aesthetics	

2.4 Bifacial Solar Panels

Bifacial solar cell is a type of solar cell that has two faces. In comparison to monofacial solar cells, bifacial solar cells have the ability to absorb additional sunlight through the back surface, which is a significant benefit. Additional solar radiation absorption through the back surface of the design of an adequate rear surface reflector is a key challenge in the effective use of bifacial solar cells. For residential applications, the effect of an external rear surface reflector for bifacial solar cells has been investigated. the bifacial solar cell results in increased electrical power generation like wall reflection, window capture of reflected radiation, and terrestrial reflection in parking lot the presence of an effective reflector is important in such applications in order to significantly increase solar radiation incident on the rear surface (Richardson *et al.* 2017).

The bifaciality parameter, which is defined as the ratio of rear surface efficiency to front surface efficiency:

$$Bifaciality = \; Rearsurface\ efficiency\ \div\ Frontsurface\ efficiency \qquad (2.1)$$

This definition is based on the premise that solar radiation strikes both the rear and front surfaces at the same rate (Guerrero-Lemus *et al.* 2016).

Some solar panel manufacturers produce solar panels with half-cut cells, although not as popular as 60, 72, or 96 cell panels, effectively doubling the number of solar cells inside the panel. Using a laser cutter, half-cut solar cells are monocrystalline or polycrystalline solar cells that are cut in half. Solar panels will experience marginal gains in performance and longevity by cutting the solar cells in half. Solar panels come in a number of price points.

2.4.1 Bifacial PV panel applications

Bifacial PV panels and modules provide a unique advantage for space systems and similar applications. Under this title, some studies on this subject are given and information about the importance of this subject is given. While examining these studies, direct citations were made to the studies of the researchers.

When photovoltaic cells were first produced, they were only suitable for high-budget applications like space systems due to their expensive costs, writes Hardingham on Mars, solar cells are still used to fuel rockets, satellites, and remote-controlled vehicles. Because of the value of high reliability, this is to be predicted, space applications necessitate extremely stringent quality management and manufacturing requirements. Because of the weight and space constraints on spacecraft, solar cell performance is also critical (Taylor *et al.* 2001).

After a few years, bifacial solar modules were commonly used in solar tracking systems. The main aim was to increase the system's efficiency by inserting tracking the light or putting a cheap reflectors to the surface. Following the discovery of the natural albedo array, the emphasis shifted drastically. Since then, researchers have researched bifacial solar systems in order to better understand their maximum efficiency and benefit from their use. Building integrated PV (BIPV) systems is a more modern application. In this scenario, the concept is to use solar panels instead of conventional building materials.

2.3.1.1 Space systems applications

Bifacial panels in space have a poor lighting absorbance, a lower working temperature, a higher power/weight ratio, a higher sunlight absorving from the Earth's albedo (Macdonald *et al.* 2005).

The International Space Station is still using 10kW bifacial space arrays, which have seen a 10-20% increase in capacity (Letin *et al*. 2000).

Comercial and Pesqueros (2014) presented the findings of a study on bifacial panels for space systems in 2012, demonstrating that the panels can supply 15-45 percent energy increase on LEO spacecraft than normal traditional Si cells. A 25 percent equivalent efficiency was presented. Space bifacial cells were produced using a combination of thermal P diffusion for n+ layer doping and B ion implantation for n+ layer doping. The findings showed that bifacial cells absorb less infrared light than monofacial cells, allowing them to work at lower temperatures in space as shown in Figure 2.6.

Figure 2.6 Bifacial type PV panels of ISS (Mohammad Bagher, 2015)

2.3.1.2 Solar Concentrators and Trackers

Polar axis solar tracker and/or monitoring concentrator are often mounted on high support structures, to avoid contact of the rotating panel array with the ground, according to Danish Solar Energy. In contrast to fixed panel arrays or even roof-mounted panel modules, it increases back-side energy collection. The energy gain may be in the range of 10-15% for traditional albedo 0.3. The airflow around the panels, as well as the resulting cooling, has been enhanced (especially in comparison with roof integrated modules). Bifacial PV modules, which are invisible to infrared radiation, have a lower operating temperature than monofacial PV panels (around 5-9°C). Solar trackers and monitoring soft concentrators, for example, benefit from it because PV panels are gathers more solar lightings than on traditional panels. On a tracker, the temperature of bifacial Si PV panels is normally about 5-8°C lower. When the bifacial cells must be placed close to a wall, the panel can gather to achieve radiation on the back side of the panels by integrating reverberator into the panel itself (Guerrero-Lemus *et al*. 2016). A semi-circular reflector centered on each side of each row inside the panel, as shown in Figure 2.7, is the simplest integrated reflector.

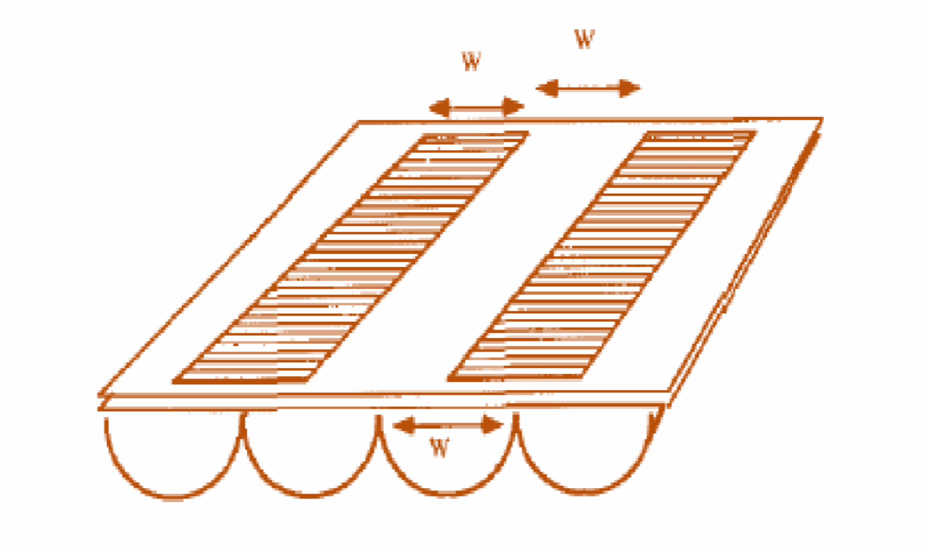


Figure 2.7 PV's with cylindrical reflectors (Edmonds, 1990)

Uematsu *et al*. (2003) launched a static concentrator flat plate solar panel with bifacial PV and V-groove reflector in 2003, as seen in Figure 2.8. It is a low concentrator, and the concentration ratio is influenced by the distance between the bifacial PV and the V-groove reflector.

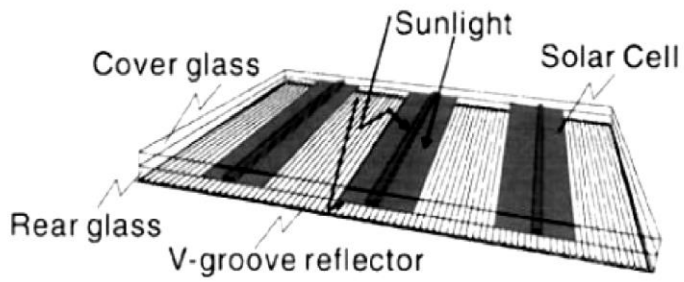


Figure 2.8 Scheme of static concentrator flat solar panel (Ooshaksarei, et al. 2011)

2.3.1.3 Albedo Array for Terrestrial Applications

Many parameters affect the rear side contribution may be attributed to lighting situations, such as position of sun, ratio of diffused/global radiation , and underlying surface albedo; or to panel and device parameters, as back/front performance, panel inclination, and distance between rows, standalone/field system, and panel position above underlying surface, among others (Eisenberg and Jucker, 2012).

Macdonald *et al*. (2005) discovered a much more easy and efficient way to take advantage of the advantages of bifacial cells in the early 1980s. The discovery came about by chance, when outdoor measurements of a particular bifacial BSF panel showed an apparent efficiency of around 20%. Mirrors and concentrators were no longer needed because collecting albedo, whether natural or artificially enhanced, was much easier.

2.3.1.4 Building-Integrated Photovoltaics

Building-Integrated Photovoltaics (BIPV) are photovoltaic materials that are used to replace typical construction materials in areas of the building envelope such as the roof, skylights, or facades, according to Figure 2.9. As a main or auxiliary source of electrical electricity, they are gradually being integrated into the design of new buildings. Current houses, however, can be retrofitted with BIPV modules. The initial cost of integrated photovoltaics can be reduced by reducing the amount spent on construction materials and labor that would usually be used to create the portion of the building that the BIPV modules replace. BIPV is one of the parts of the photovoltaic panel area with a very high growth rate because of these benefits. (Heinstein *et al*. 2013).

Figure 2.9 PV roof application example (Mohammad Bagher, 2015)

2.3.1.5 Vertical Module, Photovoltaic Noise Barriers

Use of vertical solar panels as noise barriers, Photovoltaic noise barriers (PVNB) along highways and railways has enabled to implementation the most cost-effective application of grid connected PV with the added benefits of large-scale plants such as overall installed power about 100 kW and eliminating the need for additional space, according to Nordmann et al., (2000). PV on NB was first proposed in Switzerland. The technology benefits from widespread interest and goodwill.

According to Faturrochman et al. (2018) the 8 kW Aubrugg plant which is shown in Figure 2.10, is the world's first PVNB bifacial plant and is situated near Zurich, on a north–south motorway flyover. The modules are bifacial prototypes that function as sound reverberators. The morning sun shines on one side and the afternoon sun shines on the other. In principle, the annual yield should be equivalent to, if not greater than, that of a south-facing tree. The back surface has a slightly lower efficiency due to the cell design and manufacturing process. As a consequence, the annual output is lower than one would expect from a completely symmetric bifacial array.

Figure 2.10 Example of bifacial technology in Zurich (Asnaashari et al. 2015)

Finally, noise limitation barriers and vertical establishing of bifacial panels showed a novel use for these devices. In this case, the increased power output would be determined by their spatial location. Nonetheless, as opposed to monofacial structures, the results will still be stronger.

2.5 Determinants of the Efficiency of Solar Panels and Their Applications, Including Agricultural Areas

Elobaid *et al.* (2015) explore a variety of ways for determining the maximum amount of energy delivered by PV cells. It turns out that the literature has included at least 19 different ways, some of which date back to the first approaches. Shade, Photovoltaic (PV) efficiency is affected by a variety of factors including solar deformation, heat, and matrix orientation (Patel *et al.* 2008). Photovoltaic umbrellas are frequently blocked-in part or fully by nearby towers, residences, fleeting clouds, telephone, trees, and utility poles. The situation is particularly critical in the case of big PVs, such as those utilized in distributed power generation schemes in partially shaded areas. Photovoltaic properties become more complicated when there are multiple peaks. It is, however, critical to comprehend and forecast in order to obtain the full amount of energy. This thesis introduces a MATLAB-based modeling and simulation approach for developing and evaluating approaches for tracking the new maximum energy point. It can be used to investigate the properties of the P-V and I-V of the PV group under irregular distortions caused by partial shading, in particular for partially shaded situations. The proposed models may easily be swapped out with electronic power transformer models, which is a very handy feature. It can also be used to look at the effects of 30 shading on PV panels and whether or not they exist. Another situation where the advanced tool can be used is when it was determined that the number of PV modules in an array (the number of units in series and parallel) has a substantial impact on the overall available power under partially shadowed situations. The sample was confirmed experimentally, and the significance of this research was demonstrated through the use of various illustrations.

Aribisala (2013) continuing proclamation of worldwide energy independence on a local and national level. Renewable energy is becoming increasingly popular as a solution to the country's expanding energy demand as the country's population continues to grow at a fast pace. But also, on environmentally sustainable ways to meet this requirement, and in the spring of 2010, he participated in the design project of a 5kW solar power system. The project included the design and construction of solar panels, as well as related accessories such as a solar inverter and a solar array. Choosing successful solar cells for creating panels at a fair cost while staying within our budget was one of the primary obstacles, we faced during the project's first phase. The subject of efficiency design was not well understood not only in the competitiveness of solar cell production, but also in the overall system efficiency of the entire solar system. As a result, this work is now available, exploring the thesis and expanding its scope beyond the project's scope to look for various ways to improve the performance of photovoltaic solar systems, from solar cells to solar cell assembly and tracking array systems, as well as DC-AC reflection system techniques.

Singh (2013) covers a wide range of solar energy sources, including solar heat, photovoltaic solar energy, solar thermal power, and solar fuel, all of which provide humankind with a renewable and environmentally sustainable energy source that is plentiful and comprehensive.

Solar technology that is economical, comprehensive, and clean is being researched from the beginning in order to attain long-term benefits. As a result, a lot of experts have looked into the history of solar energy from the beginning. Additionally, efforts are being made to enhance knowledge of present and future difficulties concerning the development of high-quality, trustworthy solar energy systems.

The amount of energy produced by photovoltaic panels is strongly dependent on the weather. (Iftikhar *et al*. 2018). In fact, a grid-connected system requires a quick response to variations in solar light and temperature. Due to the maximum limit in the characteristics of P-V and I-V, the PV array's properties will become more complex under partially shadowed situations. In addition, complex algorithms can be utilized to address some of the faults in traditional Maximum Power Point Tracker (MPPT) methods. The electricity generated by the solar panel is sent down the shade to the grid via a two-stage conversion system consisting of a DC-DC booster converter and a DC-AC adapter. Climatic conditions are complex.

They can monitor maximum power with ease and precision. Salem and Farhan, (2014) created a computer-based rotational control that he used to operate the solar tracking system via computer simulation. The control system was crucial in obtaining the maximum amount of power from the solar cells. The pushback method is being investigated to pay for neural network feeder training, a concept that correlates to the base weights. A tiny constant or a series of adaptive steps is used to set the learning rate. And to use this constraint to show some of the algorithm's convergence effects, which include both weak and strong convergence, as well as to prove the weight limits in the online training technique. Theoretical findings are supported by simulation findings.

Patel and Agarwal, (2008) demonstrated a number of approaches to achieve MPPT and showed that if the potential shading pattern of the PV array is understood, then the simulation model can be used to build the most efficient PV matrix layout to extract the maximum power.

Due to limited non-renewable energy and growing energy consumption, solar energy appears to be an alternative to non-renewable energy because it does not require power, is clean, and can be converted to many types of energy (Li *et al*. 2015).

Since irrigation coincides with the seasonal increase in incoming solar energy, using solar energy to run agricultural water pumping systems has the advantage of increasing the water needs of remote areas. When properly built, these PV systems can also save money in the long run and have a smaller environmental footprint than traditional energy systems. This is determined by the type of pump, which is determined by the depth of the available water supply. Despite the positive offset, centrifugal pumps and broad heads are favored. As seen in Figure 2.11, she is most widely used for this.

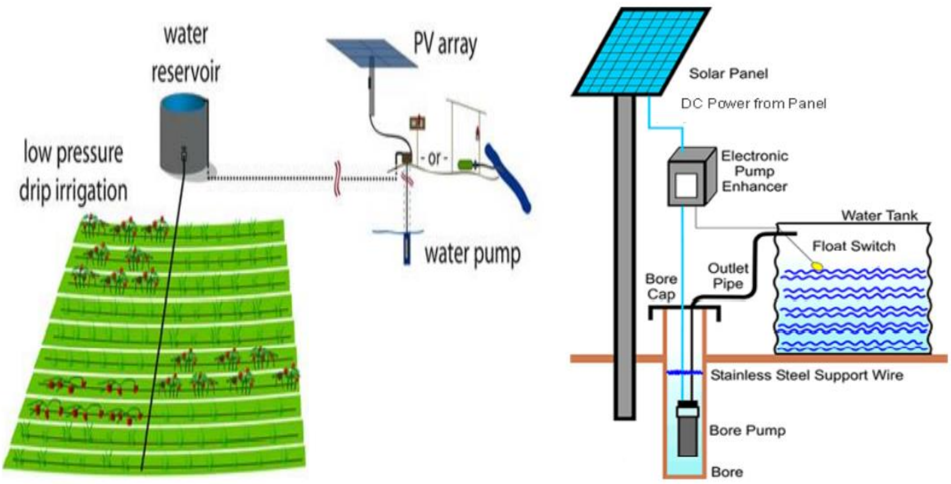


Figure 2.11 Solar PV irrigation system components (Shinde and Wandre 2015)

Solar-powered water pumps are commonly assumed. It is a costly and ineffective technology. Pumping enough water is not a long-term solution. However, solar water pumps have come a long way in the last 25 years, and there are now solar pumps on the market that build on previous technology, such as submersible pumps with up to 200 m heads and pumps that can pump larger volumes of water, such as 10,000 L/day at 100 m and 20,000 L/day at 50 m. Dual systems will double the above efficiency.

From what was mentioned in the previous references, the advantages and disadvantages of using solar panels can be summarized in Table 2.2, and reversed in using these panels to reclaim agricultural land in desert and rural areas.

Table 2.2 The advantages and disadvantages of using solar panels according the types

NO	TYPE	ADVANTAGES	DISADVANTAGES
1	Solar radiation	Solar pv rely on solar radiation to produce electrical energy.	Its decrease affects the production of electrical energy.
2	Temperature	Solar pv depends on temperature to produce electrical energy.	Rising temperatures affect the life of solar pv energy.
3	Wind	Wind helps us cool solar pv	High winds cause damage to the bases of the solar pv structure if they are not fixed well.
4	Solar pv	It has a long life, does not cause noise, and is easy to install. All of these specifications depend on the type of panels chosen and the manufacturer of them.	Expensive, needs space if the demand for energy is high, its productivity decreases on cloudy and dusty days.
5	Diesel	Its initial cost is appropriate, ease of operation, and not require large areas to install it.	Its life is less, it requires regular maintenance, it causes noise and gases.
6	MPPT	Through it, the maximum energy of solar panels is obtained, with an increase of up to 30%.	Expensive, and he needs to install a place that is not affected by external circumstances.

3. DESIGN OF THE NEW PUMPING SOLAR SYSTEM

3.1 Introduction

In ancient times people used to live mainly on plants, they always changed their place so they are near water for drinking and agriculture. Nowadays people are still depending on agriculture in food, medicine, clothing or even decorations and furniture. Irrigation of plants has many ways first and easiest one is rain-fed farming as it does not involve any man effort other methods are artificial method as: Irrigating surfaces where water is spread by gravity over and through the ground, and no mechanical pump is involved. Localized irrigation, where water is distributed through a piped network under low pressure and applied to each plant.

Drip irrigation is a form of localized irrigation that delivers drops of water at or near the root of plants. Evaporation and runoff are reduced in this method of irrigation. Sprinkler irrigation in which water is spread from a central position in the field or from sprinklers on moving platforms through overhead high-pressure sprinklers or weapons. Center pivot irrigation, where a system of sprinklers that travel in a circular pattern on wheeled towers distributes water. This method is prevalent in flat areas of the U.S. Sub-irrigation, through a system of pumping stations, canals, gates and ditches, where water is spread across the land by raising the water table. In areas with high water tables, this method of irrigation is the most effective (Kim and Evans, 2009).

Manual irrigation, by manual lab our and watering cans, where water is spread throughout the land. This scheme is extremely lab our intensive. In the past these methods could only be done if the land is near water source or in raining areas if that is not the case there is an option of building artificial lakes through canals or that area would be considered not eligible for agriculture (Dowell *et al*. 2016).

3.2 Problem Definitions

We have land located in the noble province of Najaf in the State of Iraq in isolation and not close to any source of water or near any electrical source, and we want to apply a small part of that land to grow different types of crops. The area is in the desert and rain rarely falls around which makes it difficult to find water to irrigate the land. The area of the land is about 42,000,000 million square meters, which is a big area that depends in its cultivation on artesian wells using electric pumps that are working by generators diesel, so we decided to take a model of that land with an area of 12,500 square meters. There is Near it is a well, the depth of the well is 93 meters and a diameter of 13 meters in a circular motion and 72 m level water, but due to the outbreak of Covid-19 disease we were prevented from implementing this project in practice, so the calculations were done theoretically and the results were extracted using the Matlab/Simulink simulations. We need to build an irrigation system to provide the full needs of the land with water depending on the type of crops we will grow. Since we are not near any electrical source, we will be using solar energy to power this system.

3.3 Methodology

In the problem definition section, we discussed the problem we are facing which is the shortage of water and energy sources for the Earth. To operate the irrigation system, we will be using solar energy which is more than enough to supply all of our electricity needs. We need to draw water from the well to the surface and for this we will use the AC centrifugal pump that supports pumping from great heights. A reservoir will be set up to store all the water that is pumped from the well or from the rain to irrigate the ground through a DC pump. This tank is dug into the ground and covered with a thick plastic cover 30 meters long, 10 meters wide and 1.5 meters deep. The type and number of solar panels in the land to be planted, as well as the selection of the capacity of both the well pump and the tank pump, is determined through the Grundfos Product Center program. We use batteries to store power only tank pump for when there is no sun or it is blocked by clouds, so we need a charging regulator to keep the voltage stable on the battery and cut the power on it when it is fully charged and also use the battery when there is no power from the PV array. The output voltage of the PV array is a DC volt so when we are using an AC pump, we will need an inverter to change the DC voltage to AC voltage (Lakatos *et al.* 2011).

3.3.1 Project working flowchart

The project work plan represents three crops for three soil moisture sensors, to which water is supplied from the tank by a DC pump that operates on dusty days from battery voltage, the tank is supplied with water by a borehole pump, sensors and pumps operate at the command of the Arduino circuit. Figure 3.1 shows the process of irrigation of crops at during and night the day.

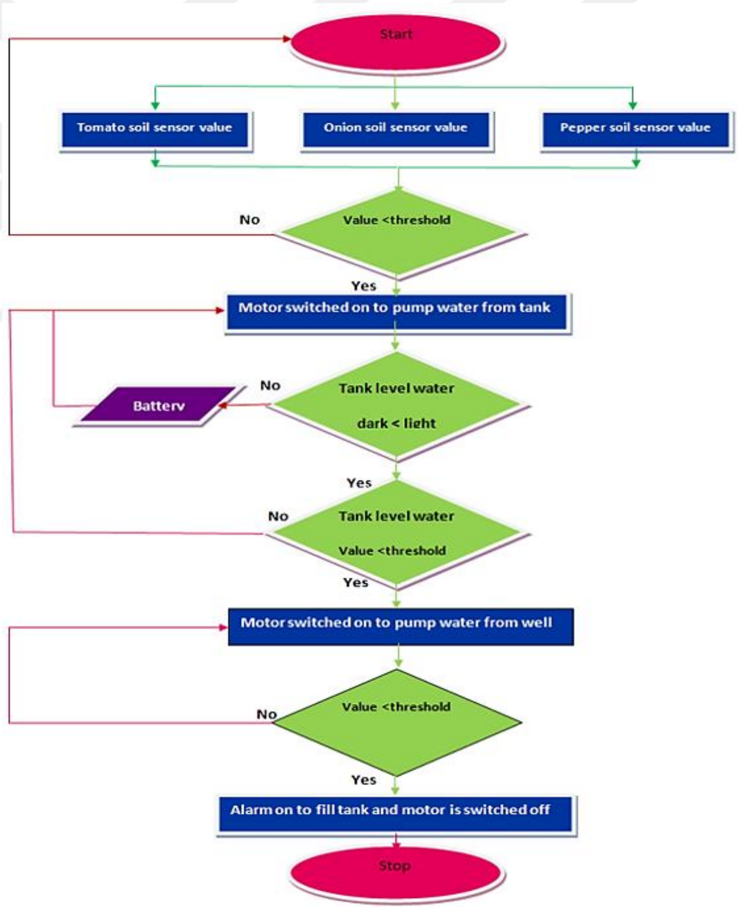


Figure 3.1 Project working flowchart (Jansen and Schulz, 2017)

3.4 The Solar Radiance in Iraq

Iraq is considered one of the countries with high levels of exposure to solar radiation, where the average daily incident solar radiation ranges from 850 W/m² in the summer to 450 W/m^2 in the winter. Solar energy is widespread. Figure 3.2 shows solar energy in Iraq.

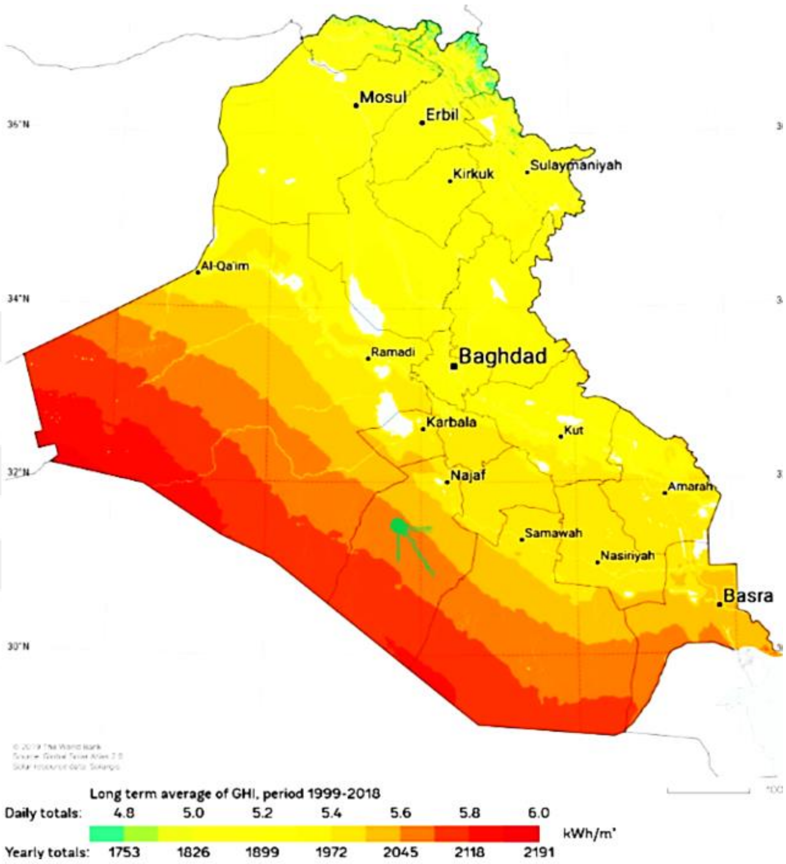


Figure 3.2 Global solar radiation map of Iraq (Ahmad et al .1983)

Table 3.1 also shows the period of exposure to solar energy in Iraq to the monthly and annual rates of real daily solar radiation (hour/day)

Table 3.1 The monthly and yearly rates for the actual day solar radiance (h/day) for Iraqi stations for the period 1982–2013 (Chaichan and Kazem, 2018)

Station	Jan	Fab	March	April	May	June	July	August	Sep	Oct	Nov	Des	The average
Sulaymaniyah	4.8	5.2	6.7	6.4	9.4	11.3	11.3	11.5	10.4	7.9	6.8	4.8	8.0
Arbil	4.9	5.5	6.8	8.5	8.4	11.2	11.3	10.9	9.8	8.1	6.3	4.9	8.0
Kirkuk	5.2	6.2	7.1	7.7	9.3	11.3	11.2	11.2	10.2	8.4	6.7	5.2	8.3
Mosul	4.6	5.6	6.7	7.9	9.8	11.0	11.9	11.3	10.3	8.1	6.3	4.6	8.2
Najaf	6.4	7.3	7.9	8.4	9.4	11.4	11.5	10.9	9.8	8.4	7.3	6.4	8.72
Khales	5.3	6.2	7.1	7.9	9.3	10.9	10.1	10.6	9.5	7.3	6.7	5.3	7.99
Baghdad	6.1	7.2	7.9	8.6	10.0	11.4	11.3	11.1	10.1	8.2	7.1	6.1	8.7
Al-Hella	6.2	7.2	7.5	8.5	9.6	11.7	11.6	11.3	10.0	8.2	7.2	6.2	8.7
Al-Diwaniyah	6.4	7.3	7.9	8.3	9.4	11.6	11.7	11.3	10.3	8.5	7.1	6.4	8.9
Al-Hay	6.5	7.5	7.9	8.5	9.6	11.7	11.6	11.4	10.2	8.4	6.9	6.5	8.87
Al-Samawa	6.9	7.7	8.1	8.7	9.2	11.3	11.9	11.6	10.2	8.9	7.6	6.9	9.0
Al-Amara	6.2	7.3	7.4	8.7	9.8	11.8	11.5	11.6	10.3	8.1	6.9	6.2	8.8
Al-Nasiriyah	6.5	7.4	7.6	8.2	9.1	9.9	10.1	10.0	9.6	8.1	7.2	6.5	8.32
Al-Basra	6.6	7.6	7.9	8.5	9.6	11.3	11.1	10.9	10.3	8.9	7.6	6.6	8.9
Al-Rutba	6.5	7.4	8.1	8.7	10.0	11.3	11.8	11.6	10.5	8.7	7.6	6.5	9.1

3.5 Calculations of Water Flow for Agricultural Crops

The area of the land is 12500 m^2, the depth of the well is 93 meters, and tank volume is 450 m^3. First of all, we need to calculate the flow rate of water using the Equation (3.1).

$$Q = \frac{quantity\ needed\ daily}{number\ of\ peak\ hours\ daily} \tag{3.1}$$

To calculate the amount of water needed for crops per day, we need to know the agricultural area for each crop using an Equation (3.2), and the crops are: tomatoes 50%, onions 30%, pepper 20%.

$$Crop\ area = total\ agricultural\ area\ \times crop\ ratio \tag{3.2}$$

Area for tomatoes = 12500 x 0.50 = 6250 m^2 = 1.544 acres

Area for onions = 12500 x 0.30 = 3750 m^2 = 0.927 acres

Area for pepper = 12500 x 0.20 = 2500 m^2 = 0.618 acres

Therefore, according to Table 3.2, we can calculate the daily water consumption for each crop from the application of the Equation (3.3).

$$Crop\ Type\ = Area\ Crop \times Consumption\ m^3/day \tag{3.3}$$

Table 3.2 The amount of water (m^3/day) for agricultural crops (NASR SOLAR, 2020)

CROP	CONSUMPTION (m^3/day)
Banana	65
Rise	45
Mango	15 to 40
Potato	31.5
Sugar Cane	30
Onion	26
Cotton	22
Pepper	21
Corn	19
Wheat	18
Barley	17
Bean	16
Sunflower	16
Pomegranate	5 to 13
Tomato	30

Tomatoes needs 1.544 x 30 = 46.32 m^3/day

Onions needs 0.927 x 26 = 24.102 m^3/day

Pepper needs 0.618 x 21 = 12.978 m^3/day

Total amount of water needed every day = 83.4 m^3/day

To calculate the pump flow rate, we use Equation (3.1), noting that the peak hours of the sun in Iraq are about 5 hours.

Q (m^3/min) = 83.4 ÷ 5 ÷ 60 = 0.278 m^3/min.

After completing the water flow calculations for the three agricultural crops, we used a special program to determine the type and number of solar panels in the land to be planted as well as choose the capacity of both the well pump and the tank pump, a program (Grundfos Products Center). shows us the location of the installation of solar in Figure 3.3.

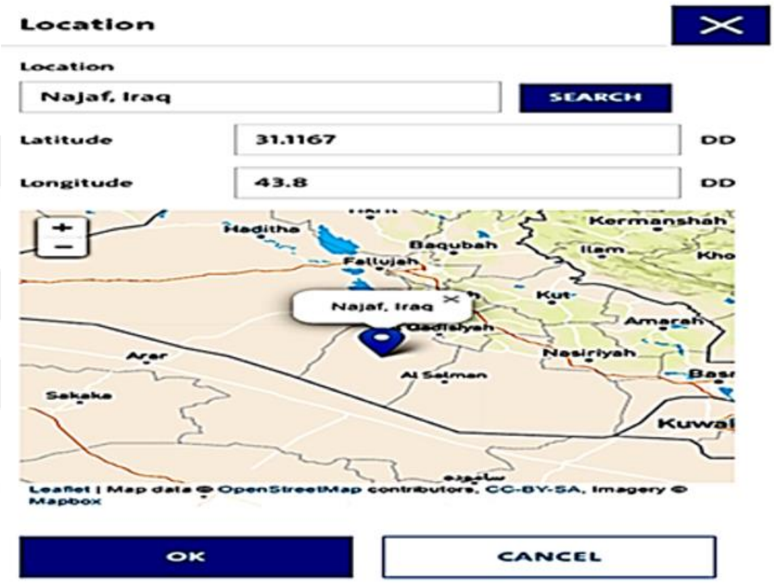


Figure 3.3 Determine the location of the agricultural land (GRUNDFOS PRODUCTS CENTER, 1945)

3.5.1 Sizing results

Specifications of the pumps and solar panels suitable for the location of the land to be cultivated:

Well pump: SP 17-9, 1 x 12A01009

Tank pump: CRNF 10-01 A-CA- G-E-HQQE, 1 x 98415326

Solar module: NN 390W, x 27

Number of solar modules in series: 9, in parallel:3

Total friction loss in pipes: 2.539 m

Total head: 74.54 m

Cable length (pump): 82 m

Cable size (pump): 6 mm^2

Cable loss (pump): 4.1 %

Total water production per year: 43000 m^3/year

Avg. water production per day: 117.9 m^3/day

Avg. water production per Watt per day: 12.6 l/Wp/day

Water produced in month for sizing: 127.4 m^3/day

3.5.2 Specifications of the well pump

Product number 12A01009, submersible borehole pumps, designed to pump groundwater, are Grundfos SP. Both stainless-steel pumps are Grundfos SP, and are available in 3 grades of material. The pumps are ideal for boreholes in sizes from 4 inches to 6 inches and 8 inches to 10 inches. The pump motor sizes are available in the range of 0.37-250 kW.

3.5.3 Quotation

Submersible borehole pump, ideal for smooth water pumping. It can be mounted horizontally or vertically. All steel parts are made of EN 1.4301 (AISI 304) stainless steel, which ensures high resistance to corrosion. This pump carries authorization for drinking water. The pump is equipped with a sand shield motor of 5.5 kW MS4000, mechanical shaft seal, water-lubricated journal bearings and a volume competition. The motor is a submersible type of canned motor that offers good mechanical stability and high performance. Suitable for up to 40 °C temperatures. The motor is equipped with a Grundfos Tempcon sensor that allows temperature monitoring by using power line contact in conjunction with the MP204 control panel (Rawat *et al*. 2016). All the specifications and drawings and curves of Well pump are shown in Appendix 1.

3.5.4 Specification of the tank pump

CRNF 10-01 A-CA-G-E-HQQE
Product number 98415326, suitable for

- Solar water solutions
- Community water supply
- Livestock watering
- Solar boosting and water supply solutions

Renewable MG Flex vertical multistage pumps for solar, wind and AC power sources. Fits for both AC and DC voltages. Quotation CRNF 10-01 A-CA-G-E-HQQECRIF, CRNF, is a multi-stage vertical, centrifugal pump. This (non-self-priming) inline pump is ideal for in-pipe systems and is designed to be placed on a frame. The pump's MGF motor is ideal for supplying both DC and AC. No more motor protection is required as the motor electronics integrate motor protection. The Maximum Power Point Tracking (MPPT) program enables a solar panel-connected motor to work efficiently. The P1 engine is 1250 W, with a maximum speed of 3350 rpm. All the specifications and drawings and curves of tank pump are shown in Appendix 2

3.5.5 Specification of the N type monocrystalline bifacial dual glass solar panel

This solar system not only has the function of a solar power system, but also has an additional utility function. The solar system will automatically switch to take the solar energy from the battery to power the load while the main power is off, if the solar power is insufficient and the power is turned off, it can switch to the main power automatically and connect to the electricity grid with the main power, Table 3.3 and Table 3.4, show the performance parameters electrical and general performance parameters of the specifications of those solar panels that were used in this thesis.

Table 3.3 Electrical parameters of the N-Type monocrystalline bifacial solar panel

N type monocrystalline bifacial dual glass solar panel / 390W / 72cells / 24V	
Electrical performance parameters	
Test condition: irradiance=(1+0.1BiFi)1000W/m^2, ambient temperature=25°C, AM=1.5	
Model	DDG(N)390
Maximum power (Pm/Wp)	390
Maximum power voltage (Vmp/V)	37.5
Maximum power current (Imp/A)	10.40
Open circuit voltage (Voc/V)	46.60
Short circuit current (Isc/A)	10.92
Module efficiency (%)	19.9
Electrical performance parameters (NOCT)	
NOCT: irradiance=(1+0.1BiFi)800W/m^2, ambient temperature=20°C, AM=1.5, wind speed=1m/s	
Maximum power (Pm/Wp)	290
Maximum power voltage (Vmp/V)	34.60
Maximum power current (Imp/A)	8.39
Open circuit voltage (Voc/V)	43.40
Short circuit current (Isc/A)	8.81

Table 3.4 General parameters of the N-Type monocrystalline bifacial solar panel

Mechanical performance parameters	
Cell Nos & array	72 (6*12)
Diode Nos	3
Junction box	IP68, split
Cable	4mm^2, 300mm, length custom
Weight(kg)	28
Dimension (L*W*H) (mm)	1974*992*6 (junction box thickness 23mm)
Packing	30pcs/carton, 22cartons/40HQ, 660pcs/40HQ
Temperature coefficient (STC)	
Temperature coefficient of Voc	-0.300%/°C
Temperature coefficient of Isc	+0.048%/°C
Temperature coefficient of Pm	-0.380%/°C
Quality parameters	
Working temperature range (°C)	-40~+85
Power tolerance (W)	0~+5
Maximum system voltage (V)	DC1500
System maximum protection current (A)	15
NOCT(°C)	45±2°C
Front/rear static loads(Pa)	5400/2400
Bifacial factor	≥85%
Hot spot	100% hot spot free

Specifications of panel can be listed as,

- High power output: 30-year linear performance warranty, more than 30% additional power gain.
- Zero LID & PID: No LID, more power generation. No PID, stable power generation.
- Fire safety performance: Higher fire safety class to minimize fire risks.
- Outstanding module performance: Higher power output, even under low light conditions. Excellent low irradiation performance and below -0.38% /℃ temperature coefficient of power.
- Wider applications & more flexible installed angle: No water-permeability and high wear resistance, can be widely used in high-humid, strong wind & sand areas and not limited to traditional slope installation.

There are several types of bifacial solar panels depending on their capabilities. Figure 3.4 shows the type used in our study, with a capacity of 390 W.

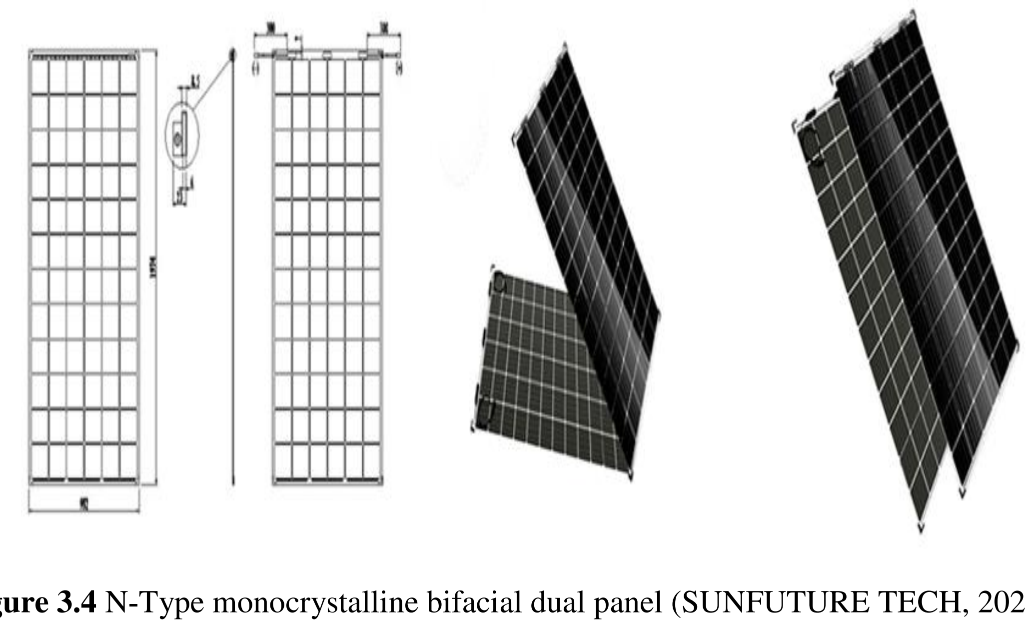


Figure 3.4 N-Type monocrystalline bifacial dual panel (SUNFUTURE TECH, 2021)

3.6 Sizing of Battery Bank

The number of batteries suitable to support the operation of the tank pump in exceptional circumstances is calculated according to the following Equations (3.4 - 3.8):

$$Aha\ = \frac{Ahd \times Tc \times DA \times DM}{DOD} \tag{3.4}$$

Here, Aha - Amp-hours adjusted (600Ah), Tc - temperature correction factor (1), DA - days of autonomy (1.3), DM – Design margin (1.05), DoD – Deep of Discharge (%50). Amp-hours day can be calculated as,

$$Ahd\ = \frac{Tp}{Vb} \tag{3.5}$$

while, *Tp* – total power (Wh) and *Vb* – battery bank voltage (V). Number of batteries in parallel can be calculated as,

$$NoBp = \frac{Aha}{Bcc} \tag{3.6}$$

NoBp and *Bcc* are number of batteries in parallel and battery current capacity. Number of batteries in series can be calculated as,

$$NoBs = \frac{Vs}{Vb} \tag{3.7}$$

Vs and *Vb* are indicates system and battery voltages. Total number of batteries,

$$TNoB =\ NoBp + NoBs \tag{3.8}$$

Table 3.5 shows the technical parameters of the lithium battery used in the system.

Table 3.5 The technical parameters of the lithium battery

LITHIUM POWER BANK	
Model	24V200AH
Normal battery voltage (Vdc)	25.6V
Normal capacity (WH)	5120WH
Voltage window (Vdc)	22.4-29.2V
Float charge voltage (Vdc)	27.6V
Max continues discharge current (A)	150
Max pulse discharge current (A)	200A30Sec
Max continues charge current (A)	100

After we apply the above laws through the available data for the tank pump, the number of batteries used in the irrigation system is shown in Table 3.6.

Table 3.6 The number of batteries used in the irrigation system

NUMBER OF BATTERIES	
Number of batteries in parallel	3
Number of batteries in series	2
Total number of batteries	6

From the table of specifications of lithium batteries, we choose a battery capacity of 25.6 V, 200 A, 5120 Wh.

Therefore, we need to put 2 batteries in series and then connect them to another 3 batteries in parallel, then the system can support up to 6 × 5.12 = 30.72 kWh power which is above what we need (27 kWh) assuming cloudy or dusty conditions for a while continuous up to 30 hours.

The specifications of the LI-Batteries are shown in Appendix 3.

3.7 Cost, Advantages and Disadvantages between PV System and Diesel System

Table 3.7 shows the cost differences over 25 years of generating the same power between the solar PV system and the diesel system, while Table 3.8 illustrates the advantages and disadvantages of these systems. Table 3.7 shows us that the cost of generating 10.53 kW by solar energy is economically feasible, as the cost is - $1.95/day paid for the costs of the system compared to the generator that operates on conventional (gasoline) energy, which costs $11.73/day and is paid daily, this is without calculating the cost of the back-up generator price, as well as not calculating the transportation cost of the casino, oil, and periodic maintenance in addition to depreciation. And the costs involved in treating or removing the effects of pollution caused by generators as a result of burning fuel and environmental pollution from plants, animals, soil, and water, as well as their impact on human health.

Table 3.7 Cost difference between PV system and diesel system calculated in this thesis

SYSTEM TYPE	SYSTEM COST/$	GENERATOR OPERATING COST OF (10.53KW)					PV OPERATING COST OF (10.53KW)	SYSTEM COST PLUS ANNUAL OPERATING COST /$	OPERATING LIFE OF THE SYSTEM		SYSTEM COST OVER 25 YEARS/ $	SYSTEM COST OVER 25 YEARS ÷ OPERATING LIFE OF THE SYSTEM /DAY
		Kazulin		Oil		Kazulin and Oil						
		Daily /$	Monthly/$	One Weekly/ $	Monthly/$	Annual/$	The Cost of 6 Lithium Batteries Every Ten Years/$		Year	Day		
Solar PV	9700	------	-------	-------	--------	--------	2700	12400	25	9106	17800	1.95 $
Diesel	4500	7.6	228	17	68	3552	---------	8052	6	2185	106800	11.73 $

Comparisons between PV panels and diesel systems conducted in this research are given in Table 3.8.

Table 3.8 Comparisons between PV panels and diesel systems conducted in this research

PUMPS TYPE	**ADVANTAGES**	**DISADVANTAGES**
Solar PV	You need little follow up	The initial cost is relatively large
	Its service life is great	You need to store water on cloudy or dusty days
	Its maintenance process is very limited and inexpensive	
	No noise and pollutants emitted	You need specialized technicians to maintain it
	Easy installation	
Diesel	Quick and easy to install	You need to monitor and supply them with fuel constantly
	It can be moved from one place to another	It needs costly maintenance
	Its base price is relatively low	Its useful life is small
	Widely used	It produces noise and pollutants for the environment

4. FINITE ELEMENTS ANALYSIS OF CIRCUITS AND THEIR RESULTS

4.1 Mathematical Model Photovoltaic Module

A photovoltaic module is made up of parallel-connected photovoltaic cells. This cell is essentially a p-n junction fabricated in a thin film semiconductor such as silicon that allows light energy to be transformed into electricity. When a cell is exposed to light energy, the photon that reaches it is absorbed by semiconducting material, allowing the electron to flow and produce electricity, as shown in Figure 4.1.

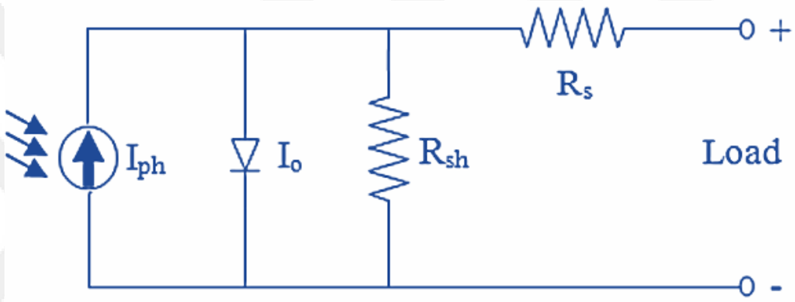


Figure 4.1 The circuit represents the PV cell

The photocurrent of the cell is represented by the current I_{ph}. The PV saturation current is represented by I_o, and the intrinsic shut and series resistances of the cell are represented by R_{sh} and R_s, respectively. Since the value of R_{sh} is very high and the value of R_s is very small, all values of R_{sh} and R_s are often ignored to simplify the analysis. PV cells are wired together to form a module that is normally covered in glass and framed together to achieve high voltage and current values. The modules are then linked in parallel-series configurations to create a PV array. The mathematical model of a PV panel is shown in the following equations:

For PV module photo current,

$$I_{ph} = [I_{sc} + K_i (T - T_r)] \times \beta/1000 \tag{4.1}$$

while, I_{ph} (A), I_{sc} (A), K_i (0.0017 A/C°), T (K) and β (W/m²) denotes photo-current, short-circuit current, short-circuit current of cell at 25°C and 1000W/m^2, operating temperature and solar irradiation, respectively. For PV reverse saturation current,

$$I_{RS} = I_{sc} / [exp\,(qV_{oc}/N_s kAT) - 1] \quad (4.2)$$

while, q – electron charge, V_{oc} – open circuit voltage (V), N_s – number of cells connected in series, A – ideality factor and k – Boltzmann's constant.

For PV saturation current, I_S,

$$I_S = I_{RS}[\frac{T}{T_{REF}}]^{\,3} \, exp\,[\frac{q \times E_g}{Ak}\,(\frac{1}{T} - \frac{1}{T_r})] \quad (4.3)$$

For PV output current, I_{pv},

$$I_{pv} = I_{ph} - I_s \times \left[exp\left(q \times V_{pv} + I_{pv}R_s/N_s kAT\right) - 1\right] \quad (4.4)$$

Here, R_s − series resistance (Ω). Regarding the technical data of the photovoltaic panels shown in Table 4.1, they were used in the design of the irrigation system.

Table 4.1 Technical data of photovoltaic panels used in irrigation system design

Test condition : irradiance = (1+0.1BiFi)1000W/m^2, ambient temperature=25°C, AM=1.5	
Model	DDN(N)390
Maximum power (Pm/Wp)	390
Maximum power voltage (Vmp/V)	37.5
Maximum power (Imp/A)	10.40
Open circuit voltage (Voc/V)	46.60
Short circuit current (Isc/A)	10.92
Total number of cells in series	9
Total number of cells in parallel	3

In Matlab/Simulink simulations, the N form bifacial dual glass solar panel 390 W PV module was chosen as a guide. The model is built using equations (4.1 - 4.4), which include temperature dependence on the photocurrent source, diode saturation current, and a series resistance based on the Shockley diode equation.

PV cells transform energy directly into electricity based on solar radiation and temperature, resulting in both I-V and P-V performance characteristics. Figure 4.2 - Figure 4.8, depict the modeling process in Simulink, along with the steps involved.

4.1.1 Step 1. Temperature conversions

Modelling of temperature conversions from degrees Celsius to Kelvin is given in Figure 4.2.

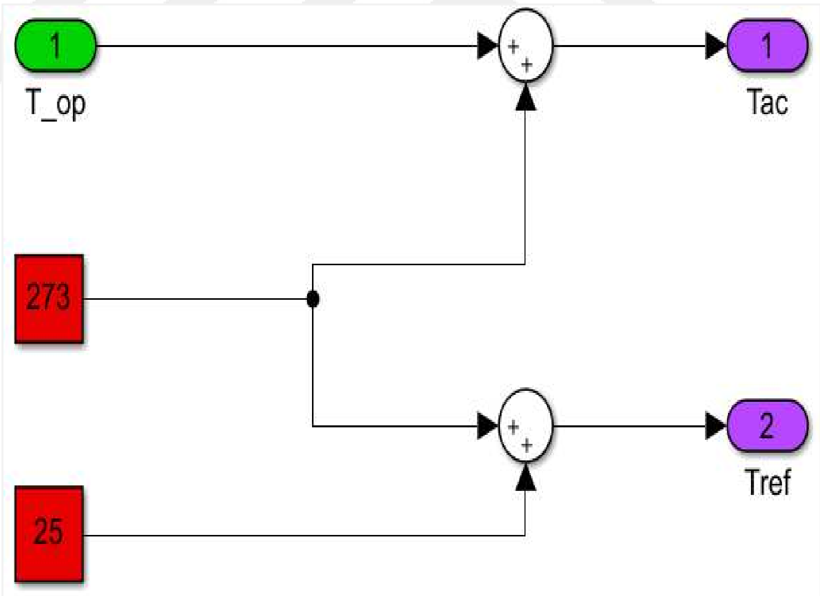


Figure 4.2 Temperature conversions from degrees Celsius to Kelvin

4.1.2 Step 2. The value of NskAT in equation (4.2)

NskAT value is calculated as shown in Figure 4.3. The temperature of the operating system from degrees Celsius to Kelvin.

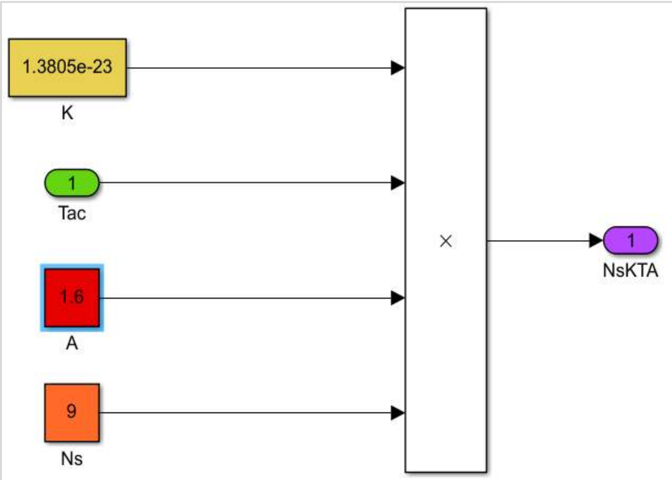


Figure 4.3 The value of NskAT

4.1.3 Step 3. Photocurrent, Iph, calculations

Based on Equation (4.1), the model which is given in Figure 4.4, calculates photocurrent.

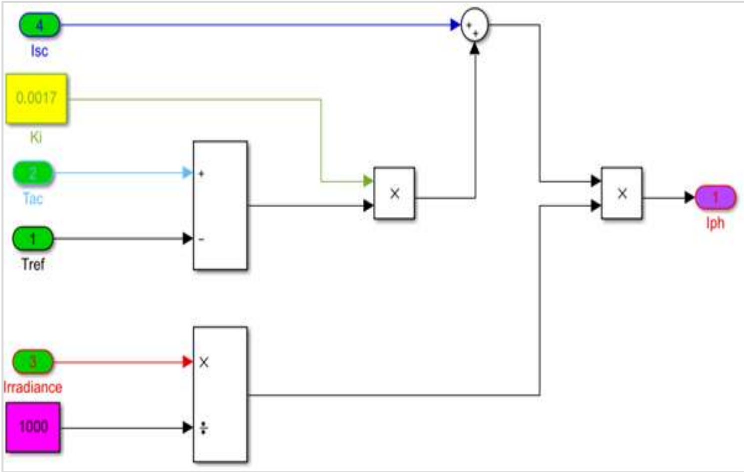


Figure 4.4 The model calculates photocurrent, Iph

4.1.4 Step 4. Shunt reverse current module

Based on Equation (4.2), the model which is given in Figure 4.5, calculates shunt reverse current.

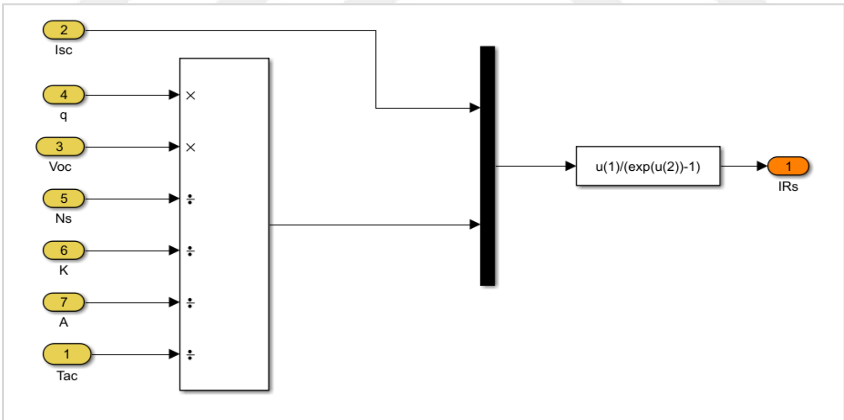


Figure 4.5 The calculates shunt reverse current module

4.1.5 Step 5. The PV saturation current measurement

Figure 4.6 shows PV saturation current model which is based on Equation (4.3).

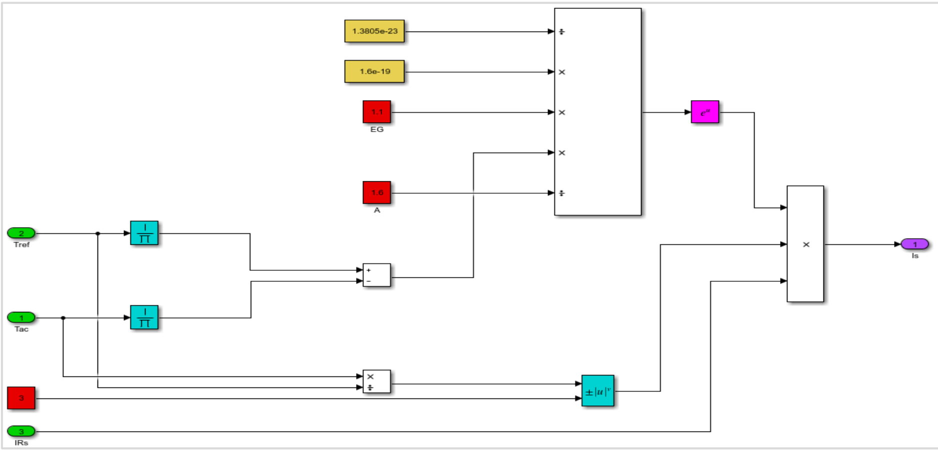


Figure 4.6 The PV saturation current

4.1.6 Step 6. The calculation of the PV output current

Based on Equation (4.4), calculating the PV output current is shown in Figure 4.7.

Figure 4.7 Calculating the PV output current

4.1.7 Step 7. PV module model by using Simulink.

With the subsystem creation, Figure 4.8 depicts the final PV model built using Simulink, which includes irradiation and temperature as inputs and results in voltage output, Vpv, and current output, Ipv.

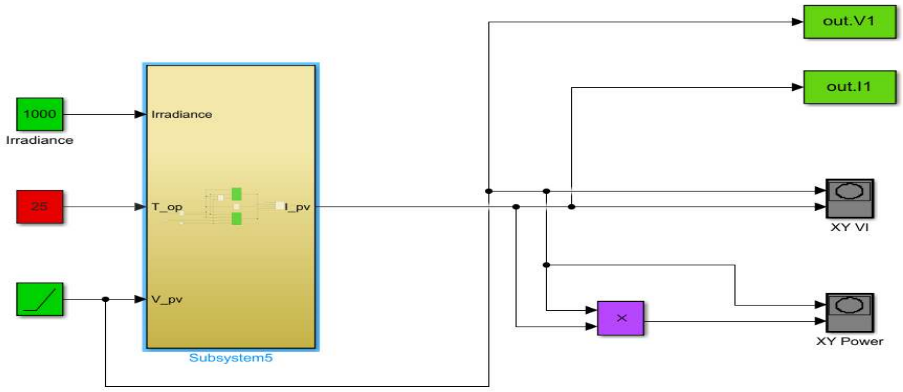
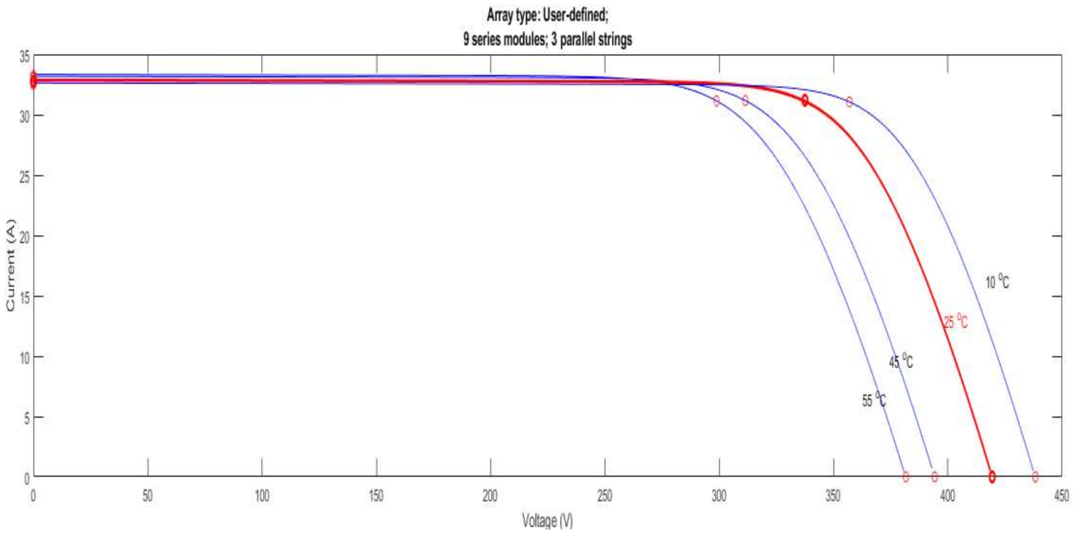


Figure 4.8 Final PV module

4.1.7.1 The Characteristics of V-I and V-P Change at Different Temperatures

As shown in Figure 4.9, when the temperature changes for four readings (10, 25, 45, 55) with the irradiance constant at (1000 W/m²), the results of the readings for both voltage and current as well as voltage and power will change with different degrees Heat, and this explains the effect of temperature change on the productivity of solar panels for electrical energy.



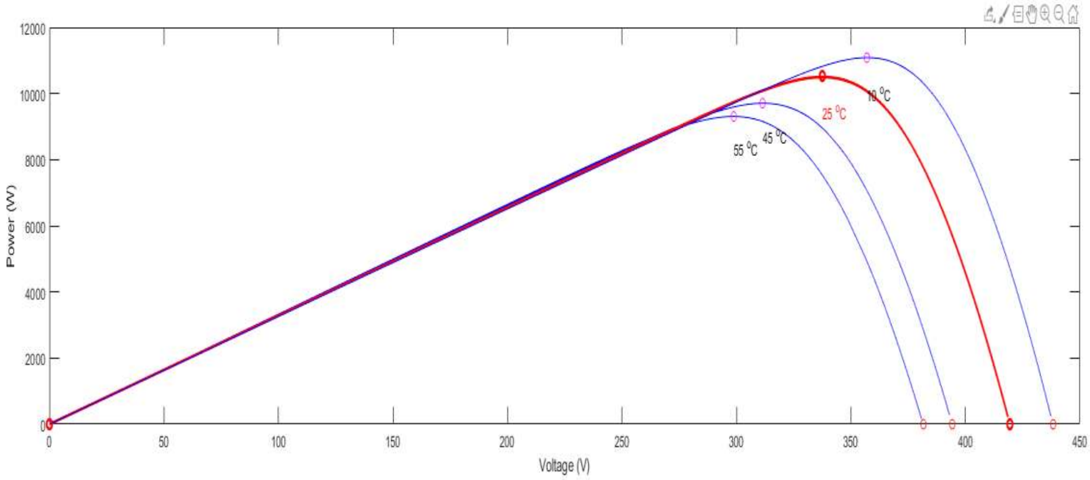


Figure 4.9 The values of V-I and V-P change at different temperatures

4.1.7.2 The Characteristics of V-I and V-P Change at Different Irradiance

Figure 4.10, shows when the temperature was fixed at (25°C) and the irradiance in values were changed to four readings (1000, 800, 600, 400) W/m² i.e., this figure is the opposite of Figure 4.9, for the comparison purposes.

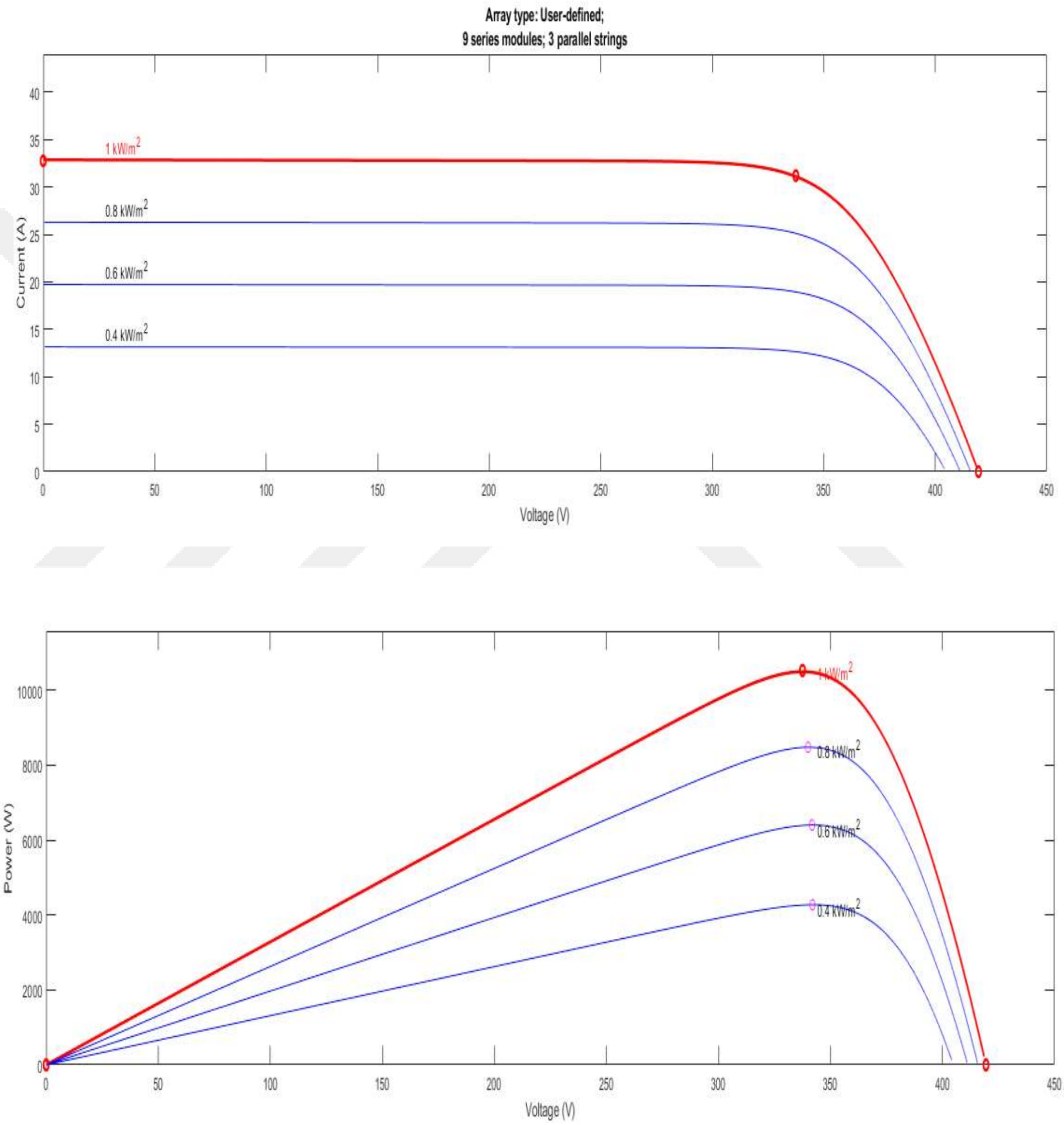


Figure 4.10 The values of V-I and V-P change at different irradiance

4.2 Control Circuit Related to the Flow of Water

Figure 4.11, illustrates a simplified idea of the three main parts of the control circuit related to water flow to agricultural crops with illustrative curves for their work in the later figures.

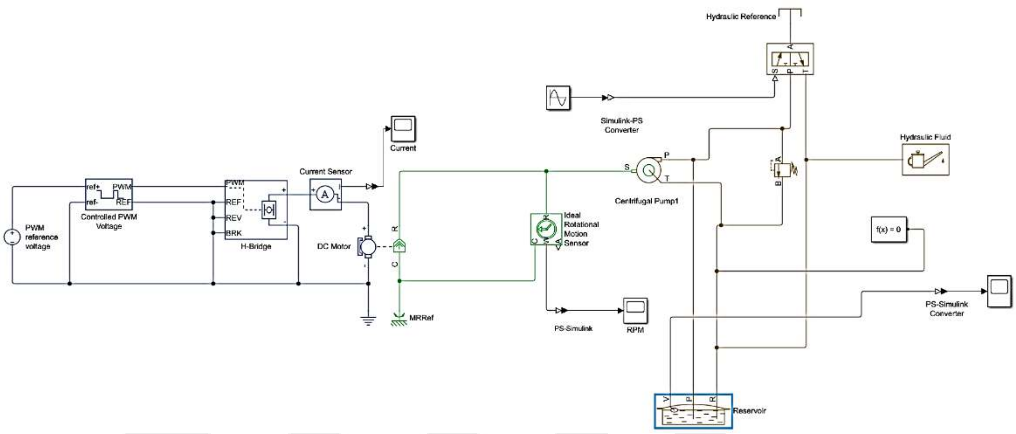


Figure 4.11 Control circuit related to the flow of water

4.2.1 Current sensor

The Figure 4.12, shows the voltage and current curves of the current sensor section.

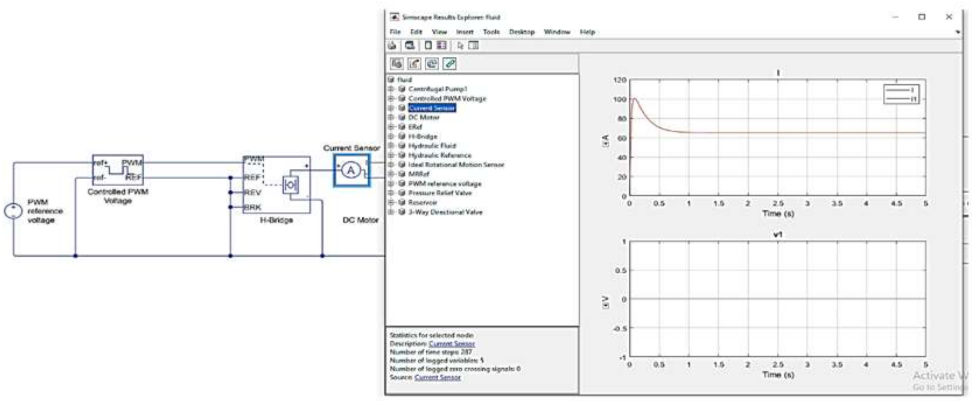


Figure 4.12 Current sensor circuit

4.2.2 Ideal rotational motion sensor

The Figure 4.13, shows the voltage and current curves of the Ideal rotational motion sensor section.

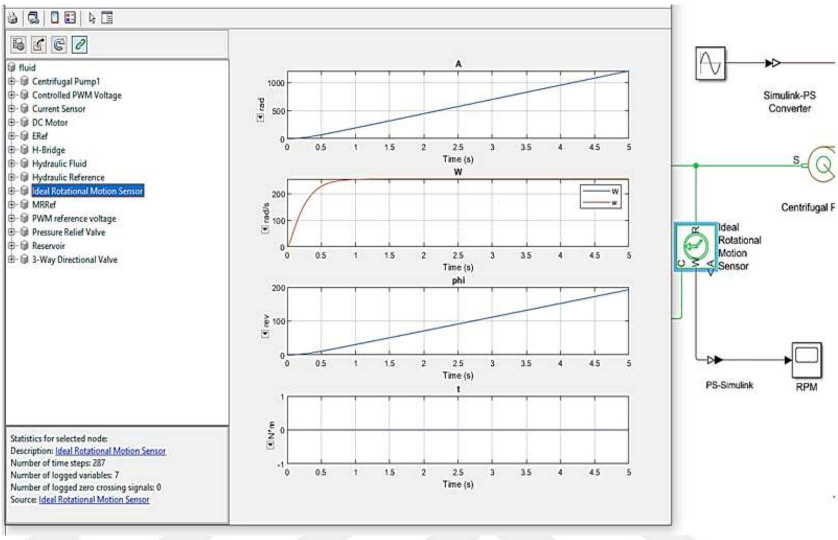


Figure 4.13 Ideal rotational motion sensor circuit

4.2.3 Reservoir

The Figure 4.14, shows the reservoir circuit section which has three water sensors (Volume (m^3), $flow$ (m^3/sec), and water pressure (pa). and illustrates these readings which had been observed responding with time. With the rising of water volume doesn't affect with the flow and pressure which they still fixed most of the time.

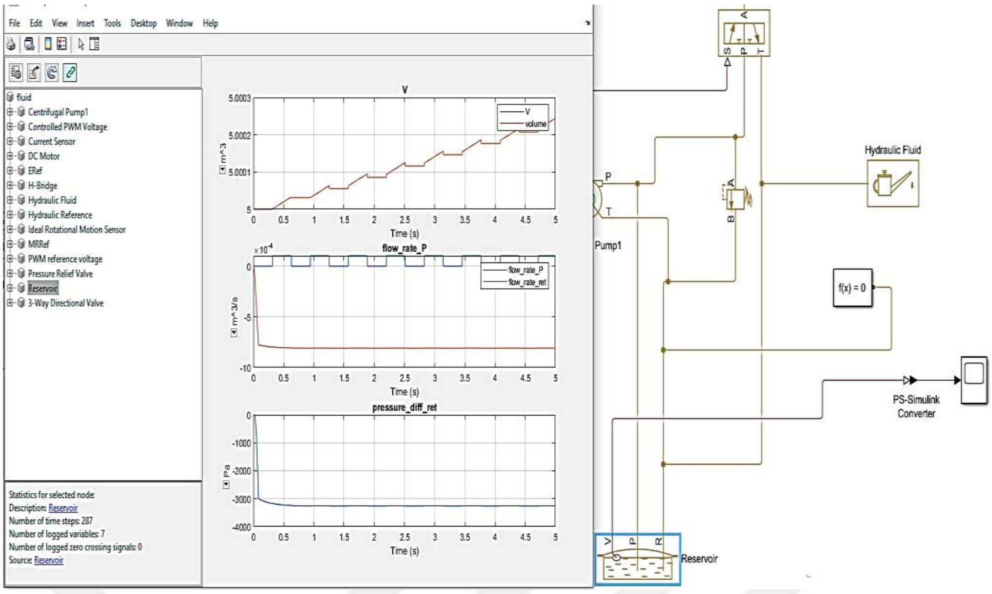


Figure 4.14 The reservoir circuit section and readings of water sensors

4.2.4 The water sensor

We need to control the water level of the tank so it does not overflow nor gets empty so we will put a water level sensor in the tank with an Arduino controller that opens or closes the pump according to the readings, show in Figure 4.15.

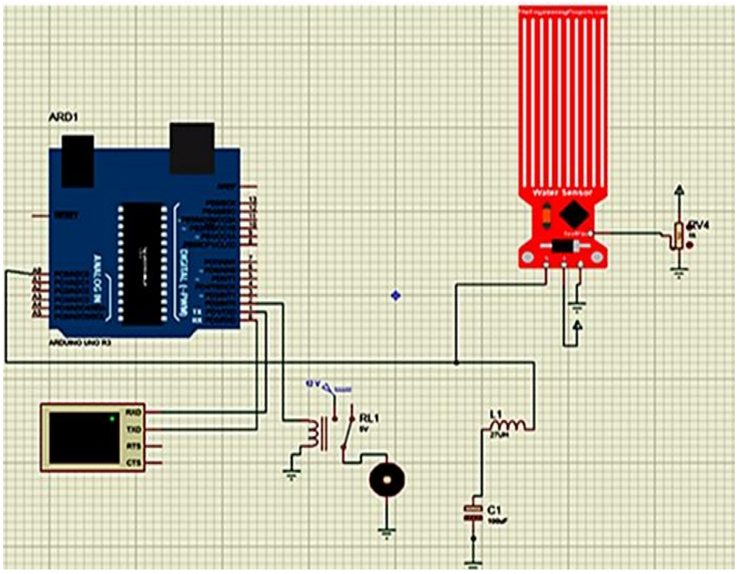


Figure 4.15 The Arduino circuit for tank water sensor

4.2.5 The soil moisture sensor

We also need to control the water that reaches the plants, so we will divide the land into three areas in each area and put some soil moisture sensors, so we measure the soil moisture and if it is above a certain threshold, a valve will be opened and the plants will be watered according to their need for water throughout the day, show in Figure 4.16.

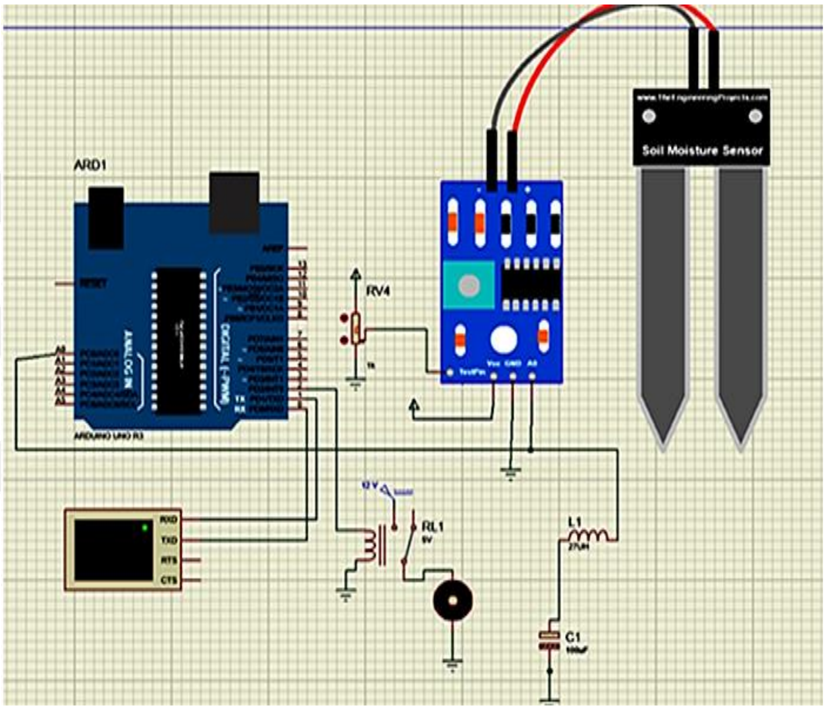


Figure 4.16 The Arduino circuit for soil moisture sensor

4.3 An Integrated Simulation System to Supply the Agricultural Crop Irrigation System with Electric Power

Figure 4.17, represents the main circuit for irrigation of desert land with an area of 12500 m^2 and consists of a 10.53 kW photovoltaic array connected to an RLC load to simulate the load of the tank pump via a DC-DC boost converter connected to six batteries that supply it with electricity at night and on dusty days, as well as the inverter to supply the AC well pump.

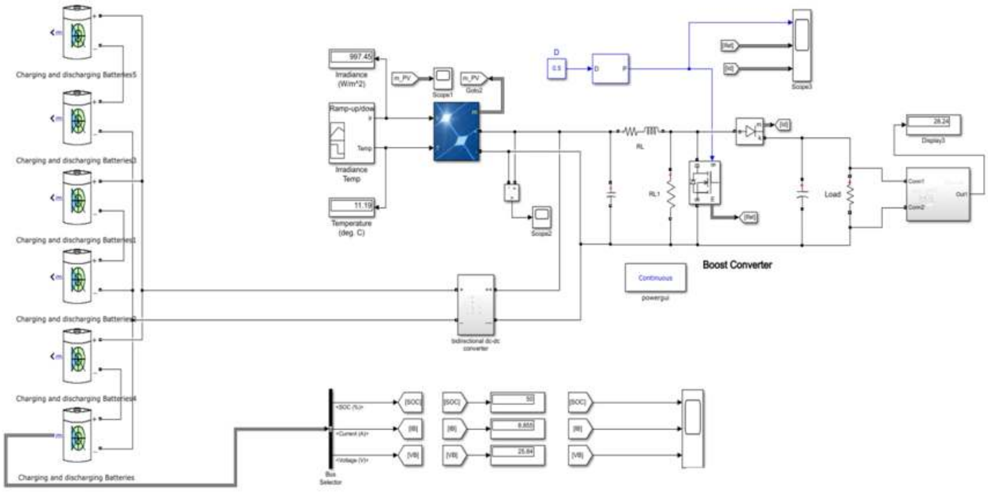


Figure 4.17 The main system that supplies electric power to the irrigation system

The 10.53 kW PV array uses 27 Sun Power modules (NN-390W). The array consists of 9 strings of 3 series connected modules in parallel. The manufacturer specifications for one module are:

- Number of series connected cells: 72
- Open circuit voltage: V_{oc}= 46.6 V
- Short circuit current: I_{sc} = 10.40 A
- Maximum power voltage: V_{mp} = 37.5 V
- Maximum power current: I_{mp} = 5.58 A

The PV array block menu allows you to plot the I-V and P-V characteristics for one module and for the whole array, as will be explained later.

4.3.1 Entrances of PV array

There are two inputs in the PV array block that allow varying sun irradiance (input 1 in W/m²) and temperature (input 2 in deg. C). The Signal Builder Block that is connected to the PV array inputs determines the irradiance and temperature profiles; The model is shown in Figure 4.18.

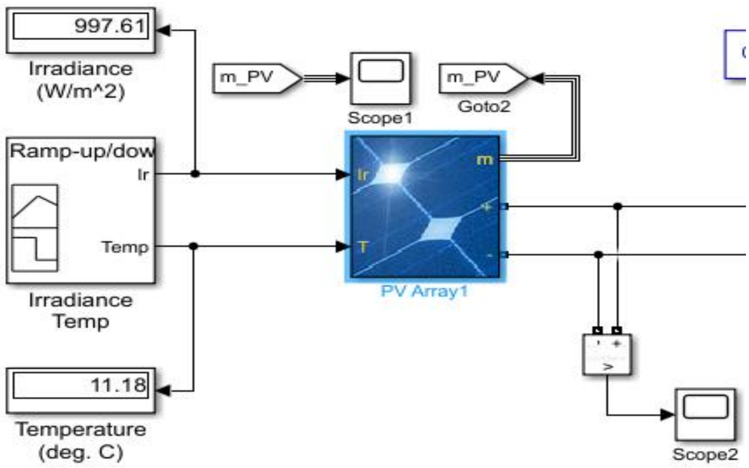


Figure 4.18 Entrances associated with the PV array

Figure 4.19, the graph explains the measurements of the PV block as [current, voltage, current of diode, temp, irradiance.

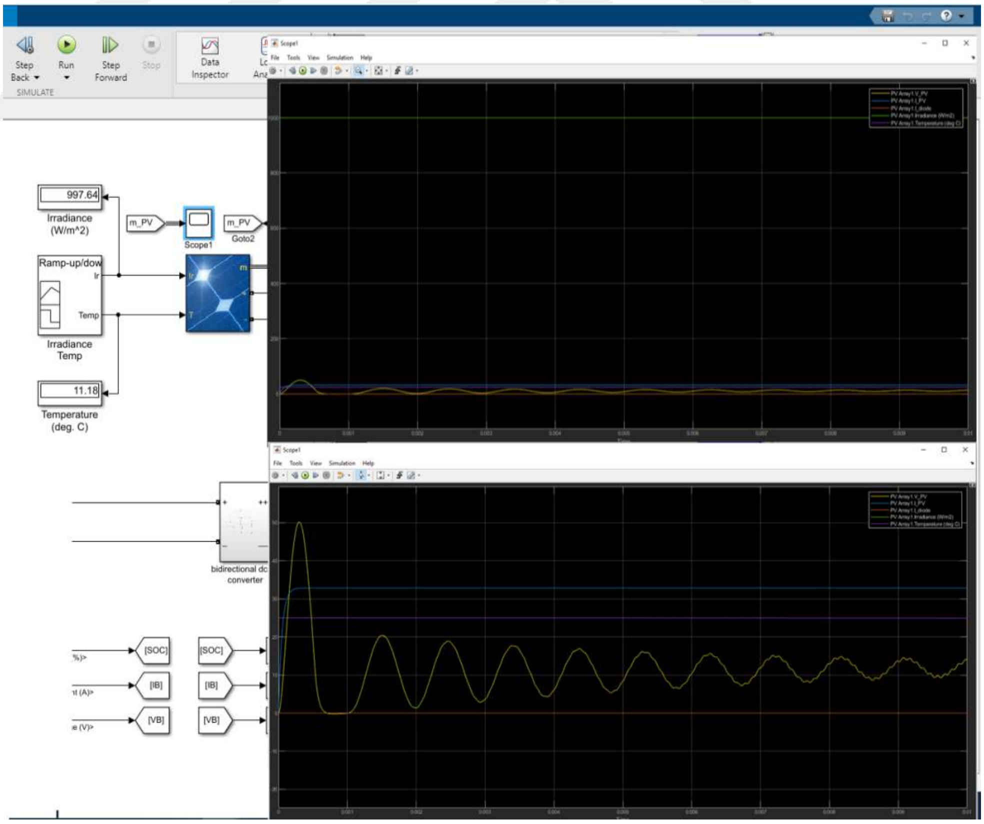


Figure 4.19 The graph shows each (current, voltage, current of diode, temp, irradiance)

Figure 4.20, shows the diagram, the design shows the voltage signal from the PV array just before entering into the Boost converter, the graph shows the shape of the signal, at first the signal takes a large calculation of the voltage and then the signal takes the normal value of the voltage and continue with it.

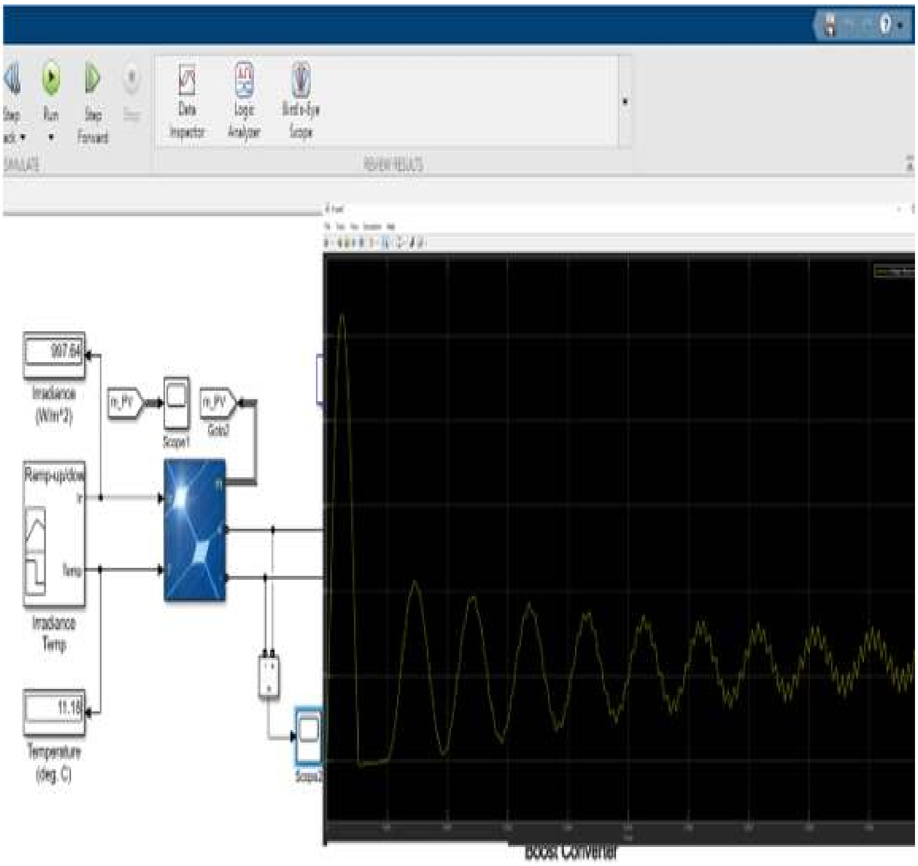


Figure 4.20 Voltage signal before entering the boost converter

4.3.2 Boost converter

In Figure 4.21, the graph explains the signal from the boost converter output which working on amplify the signal from the PV array.

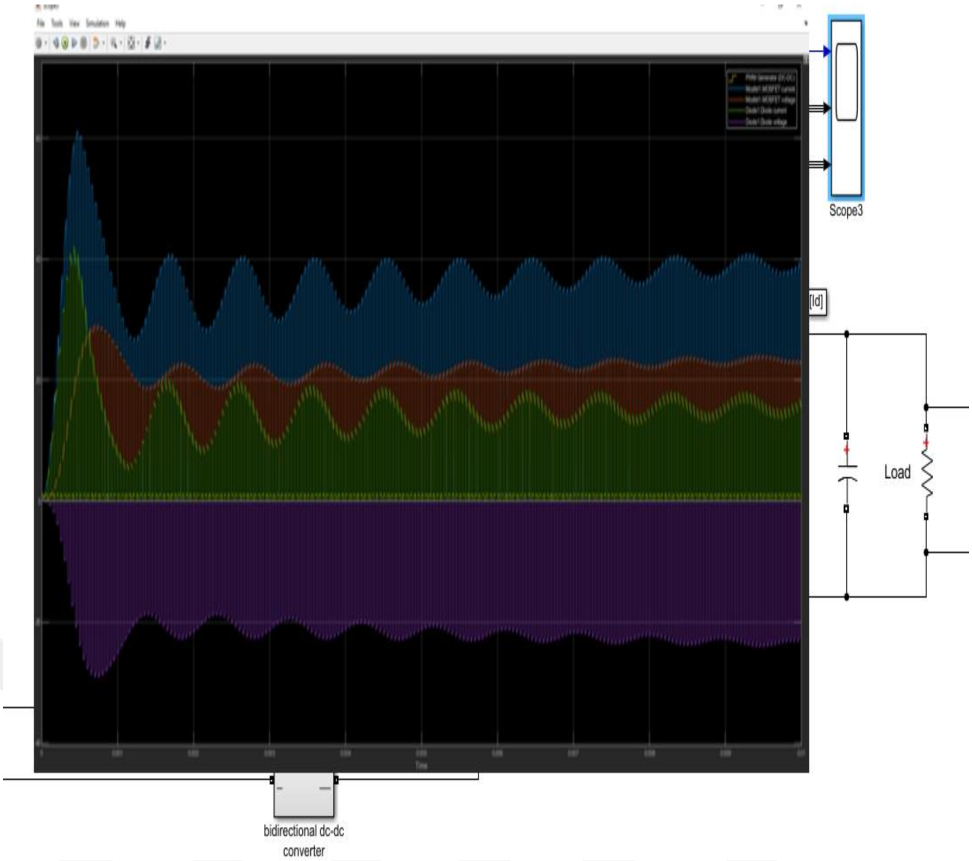


Figure 4.21 The graph explains the signal from the boost converter

4.3.3 Tank pump batteries

We rely on batteries to supply the DC voltages of the tank pump on dusty and cloudy days, as well as for irrigation after sunset, Figure 4.22, shows three graphs of batteries, where the first curve represents the battery discharge rate DOD, which is no more than 49.99991, in order to extend the life of the batteries, represents the second curve represents the charging current of the batteries, and the third curve represents the output voltage of the batteries constant at 25.8 V.

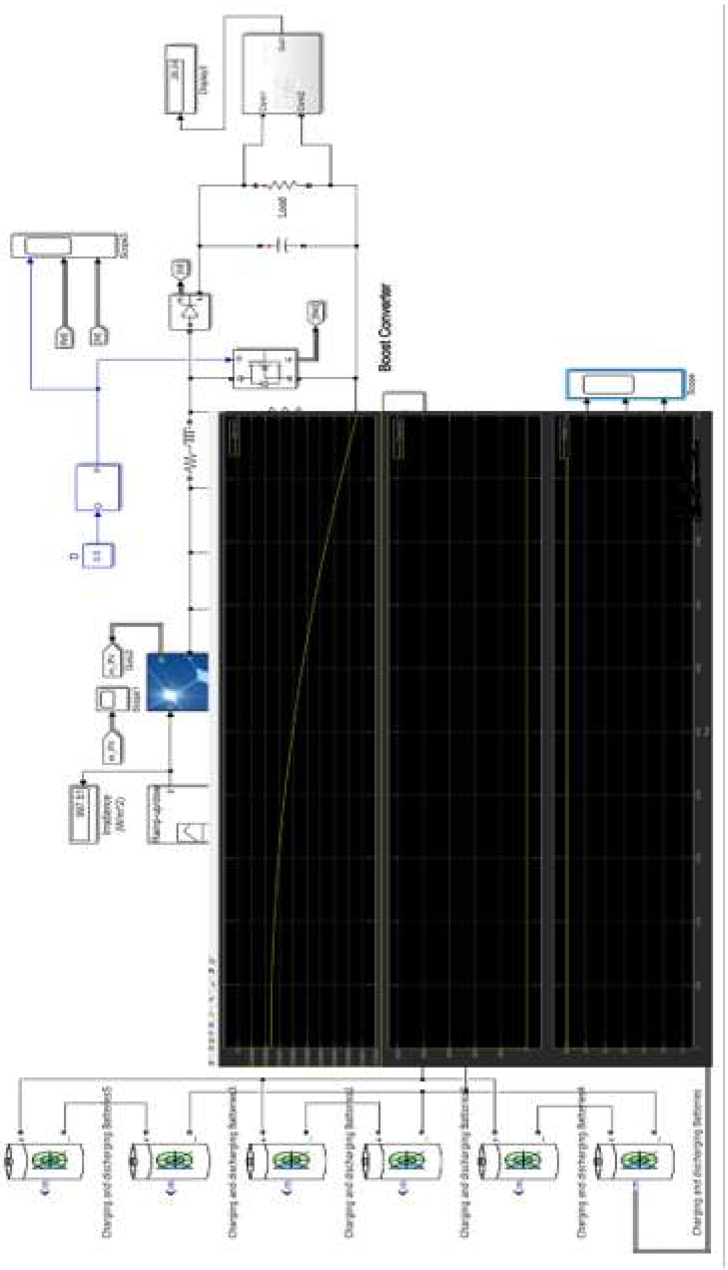


Figure 4.22 The battery graph

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The deserts (i.e., western plateau) occupy the largest part of Iraq's area. The estimated area of the land that can be recovered for agricultural purposes is more than 198,000 km^2 of this desert. The city of Najaf occupies 31% of that area. Diesel generators are considered the traditional source of electric energy for agricultural pumps and other demands in those areas. This research presents a novel design that employs a sustainable source of energy, i.e., solar panels, which are appropriate to the climatic conditions for agriculture in desert. In this study, a solar panel simulation is designed to control and operate efficiently the pumps during irrigation periods. Numerous Finite Element analyses, utilizing MATLAB /Simulink software, were conducted, investigated and compared to the diesel pumps outputs and following outcomes are concluded:

1- In the new design presented in the research, generating electricity for 25 years using solar energy is more economical, i.e., 600% less expensive, compared to conventional energy. In numbers, the solar system of 10.53 KW generation costs $1.95/day while for the same power generated by a conventional (gasoline) powered generator the cost is $11.73/day not counting the standby generator price cost. In addition, the above gasoline generators costs do not calculate the transportation costs of casino, oil, and periodic maintenance. Hence, it is possible to deliver water and electricity to remote areas at much lower costs than delivering it to those areas with electric power normal, please refer to calculations included in the Appendixes at the end of this thesis.

2- A smart monitoring and controlling for solar agricultural pumps are presented. This new system uses a soil and water sensor to control the watering system by connecting them to the Arduino. Among the other features, this system has the potential to:

- Stop the operation of the pumps except when the crops need to be fed with water, meaning not to over-run, and this provides us with an increase in the life span of these panels.
- Obtain abundant and good production of these crops, due to the irrigation system.
- Stop the over-watering of the crops, which saves water that will benefit us for the future.

3- Solar energy can be used for sites that 1200 meters or more from the national electric power transmission lines.

4- The cost of solar energy systems is high at the time of construction, compared to the electric power generation system (powered by fossil fuels), which is low in cost at the time of construction; But it has high costs in terms of long-term use. But it will be economically feasible from the perspective of the distant future.

5- The solar panel system has been compared with the diesel system. We note that if all those desert lands are fed with power from diesel, the percentage of gases emitted from those engines and noise will be very high, which greatly affects the environment of those areas, so when we use the solar panel system it is the best with everything in terms of cost, cleanliness and tranquility, thus obtaining a green and beautiful environment at the lowest cost.

5.2 Recommendations for Future Work

Through my studies, I recommend researchers who work in the field of solar energy use as a major source in reclamation of the following agricultural land.

Implementing the study in a practical way as a result of not applying it due to the Covid-19 disease pandemics. The use of double-sided solar panels in design calculations, and one of the most important advantages of these panels are to increase the production of electrical energy over single-sided panels by no less than 15% of the total production, and these increases the benefits that accrue to us by recalculating our design because the number of panels used It will be less, in addition to providing less space to install these panels which reduces the final system cost.

Encouraging and supporting the farmer in using the soil moisture sensor in the reclamation of agricultural land by governments and investment companies. The work of a radioactive tracking system instead of the stationary in large agricultural lands (this method It helps us collect the largest amount of radiation and thus save more energy which is useful for us in design calculations). Encouraging investment in desert and rural areas for long periods of more than 25 years by using solar energy to generate electric power due to the long life of the solar system.

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APPENDICES

APPENDIX 1. Specifications of the Well Pump

APPENDIX 2. Specifications of the Tank Pump Specifications

APPENDIX 3. Lithium Batteries

APPENDIX 4. Offers of Solar Panel System and Diesel Generator System

APPENDIX 1. Specifications of the Well Pump

Specifications

Product name SP 17-9

Product No 12A01009

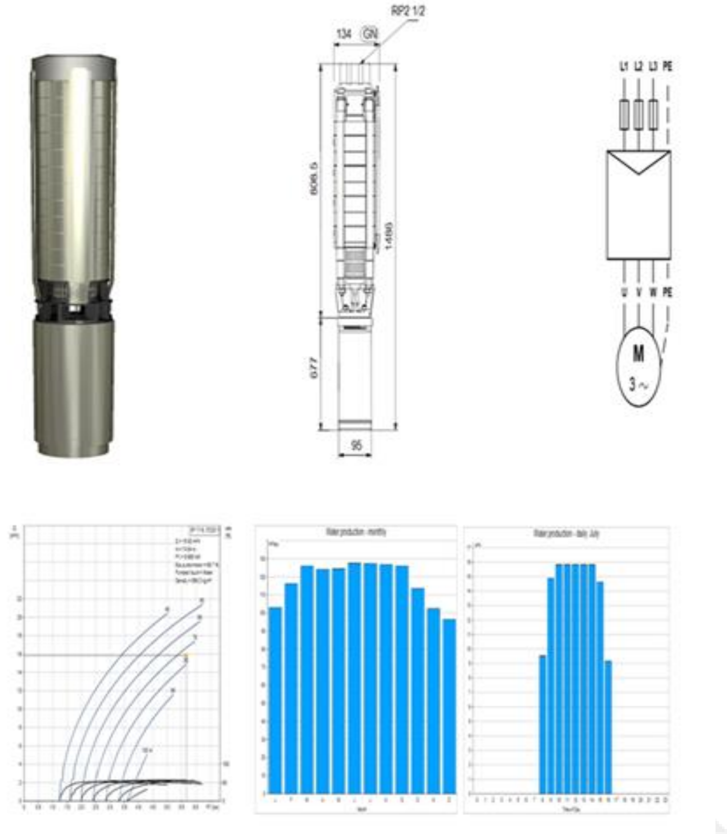
EAN number 570039113066

Specification of the well pump

ELECTRICAL DATA		OTHERS		TECHNICAL	
Motor type	MS4000	Minimum efficiency index, MEI â‰¥	0.70	Pump speed on which pump data are based	2900 rpm
Applic. Motor	GRUNDFOS	ErP status	EuP Standa	Rated flow	17 m³/h
Rated power - P2	5.5 kW	Net weight	43.2 kg	Rated head	73 m
Power (P2) required by pump	5.5 kW	Gross weight	68.4 kg	Stages	9
Mains frequency	50 Hz	Shipping volume	0.2 m³	Impeller reduc.	NONE
Rated voltage	3 x 220-230			Shaft seal for motor	HM/CER
Rated current	23.6-24.2 A			Approvals on nameplate	CE,EAC
Starting current	520-550 %			Curve tolerance	ISO9906:2012 3
Cos phi - power factor	0.81-0.76			Model	B
Rated speed	2865-2870 rp			Valve	YES
Start. Method	direct-on-line			Motor version	T40
Enclosure class (IEC 34-5)	IP68				
Insulation class (IEC 85)	F				
Motor protect	NONE				
Thermal protect	External				
Built-in temp. transmitter	Yes				
Motor No	79105511				

LIQUID		MATERIALS	
Pumped liquid	Water	Pump	Stainless steel EN 1.4301 AISI AISI 304
Maximum liquid temperature	40 °C	Impeller	Stainless steel EN 1.4301 AISI AISI 304
Max liquid t at 0.15 m/sec	40 °C	Motor	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Drawings and Curves of the well pump



Drawings and Curves of the well pump

APPENDIX 2. Specifications of the Tank Pump Specifications

Product name CRNF 10-01 A-CA G-E-HQQE

Product No 98415326

EAN number 5711494633944

Specifications of the tank pump

TECHNICAL	
Pump speed on which pump data are based	3400 rpm
Rated flow	12.1 m^3/h
Rated head	10 m
Stages	2
Impellers	01
Primary shaft seal	HQQE
Approvals on nameplate	CE,TR
Pump version	A
Model	A

ELECTRICAL DATA	
Motor type	80A
Power input - P1	0.88 kW
Rated power - P2	0.75 kW
Rated voltage	1 x 90-240 V ac
Rated voltage	30 - 300 V dc
Cos phi - power factor	0.99
Rated speed	500-3600 rpm
Enclosure class (IEC 34-5)	IP55
Insulation class (IEC 85)	F
Motor protec	ELEC
Motor No	98367492

INSTALLATION	
Maximum ambient temperature	50 °C
Max pressure at stated temp	25 bar / 120 °C
	25 bar / -20 °C
Flange standard	CLAMP
Pipe connection	FlexiClamp
Flange size for motor	FT100
Connect code	CA

MATERIALS	
Pump housing	Stainless steel
	DIN W.-Nr. 1.4408
	AISI 316
Impeller	Stainless steel
	DIN W.-Nr. 1.4401
	AISI 316
Material code	G
Code for rubber	E

CONTROLS	
Control panel	HMI200 – Standard
Function Module	FM300 – Advanced

LIQUID	
Pumped liquid	Water
Liquid temperature range	-20 .. 120 °C

APPENDIX 3. Lithium Batteries

In this thesis, and to compensate for the dark hours when crops need water, lithium-type batteries were used to supply the tank pump with DC voltage, as this type of battery has high specifications as shown below:

Lithium Power Bank

12V 24V and 48V lithium battery module

SAKO

TECHNICAL PARAMETER

Model	12V100AH	12V200AH	24V100AH	24V200AH	48V100AH
Battery Type	LiFePO4				
Normal Battery Voltage(Vdc)	12.8V	12.8V	25.6V	25.6V	51.2V
Normal Capacity(25℃, 0.2C) (WH)	1280WH	2560WH	2560WH	5120WH	5120WH
Voltage window (Vdc)	11.2~14.6V	11.2~14.6V	22.4~29.2V	22.4~29.2V	44.8~58.4V
Folat Charge Voltage(Vdc)	13.8V	13.8V	27.6V	27.6V	55.2V
Max continue discharge current(A)	100	150	100	150	100
Max pulse discharge current(A)	200A 30Sec.	200A 30Sec.	200A 30Sec.	200A 30Sec.	200A 30Sec.
Max.continue charge current(A)	100	100	100	100	100
Cycle life(+25℃ 0.2C 100%DOD)	>3000 Cycles				
Cell Equalizer Current(A)	1~5A Max.				
Terminal	M6				
Storage temperature	0℃~30℃				
Storage duration	6 months at 25℃				
Safety standard	UN38.3,IEC62619,MSDS,CE				
IP degree	IP20				
PROTECTION					
Protection	Overcharge protection, Overdischarge protection, Overcurrent protection, Shortcircuit protection, Overtemperature protection				
AMBIENT					
Noise(dB)	<40dB (1 meter)				
Working Temperature	-10℃~+50℃				
Humidity	0~95% (no condensation)				
Sea Level(m)	≤1500				
DIMENSION					
L*W*H (products size) mm	L350*W185*H189	L429*W261*H189	L429*W261*H189	L521*W488*H218	L521*W488*H218
L*W*H (package size) mm	L410*W255*H230	L490*W331*H229	L490*W331*H229	L581*W558*H258	L581*W558*H258
Weight(NW Kg)	17.0Kg	33.0Kg	33.0Kg	58.0Kg	58.0Kg
Weight(GW Kg)	17.5Kg	33.5Kg	33.5Kg	58.5Kg	58.5Kg
20FT QTY(UNIT)	1100 set	600 set	600 set	330 set	330 set

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SUNFUTURE 24V 200Ah 12V 300Ah Lifepo4 Battery Pack Lifepo4 Battery 12V 200Ah 300Ah Lifepo4 Battery

2 - 15 Pieces	16 - 79 Pieces	>=80 Pieces
$445.00	$432.00	$419.00

$100.00 OFF Order more than $5,000.00 Get Coupon

Battery Type: pack

Nominal Capaci... 200Ah

Nominal Voltage: 25.6V $445.00 − 6 +

Samples: pack , 200Ah , 25.6V
$500.00/Piece | 1 Piece (Min. Order) | Buy Samples

Customization: Customized logo(Min. Order: 20 Pieces)
Customized packaging(Min. Order: 20 Pieces)
More

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Advantages

- All in one mould design and production,easy to install.
- With longer span life LiFePO4 battery,over 12 years lifespan,ensure the whole set product's life span.
- Dustproof structure design,DC output,safe and reliable.
- Integrated packaging,safe and convenient to transport

Specification

Model	SF24-150	SF24-200
Standard capcity	25.6V 150Ah	25.6V 200Ah
Storage capacity	3840Wh	5120Wh
Charge voltage	29.2~30V	
Continuouse working input current	100A	
Continuouse working output current	100A	
Cut - off	2.5V single cell	
Self-discharge (25°C)	<3% / month	
Depth of discharge	>80%	
Cycle life	>5000 times (<0.5C)	
Charge method (CC/CV)	Operation: -20°C ~ 70°C	Recommendation: 10°C ~ 45°C
Product size	635±2*373±2*315±2mm	
Warranty	5 years	

APPENDIX 4. Offers of Solar Panel System and Diesel Generator System

In this appendix, the special prices of the power generation system for solar panels as well as the power generation system for diesel generators have been known through correspondence with the competent companies, as shown in the attached pictures.

البريد الوارد × 回复： The cost of an integrated irrigation system

<sale@sunfuturetech.com> **SUNFUTURE**
أنا

الإنجليزية > العربية عرض الرسالة المترجمة

,Hi Ahmed

!How are you

.Yes, the last offer 9508usd includes submersible solar water pump, and off grid solar power system for booster pump by using Li-battery

.And attached you each pump performance curve

.If you have any question, you can contact me on whatsApp more easier

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Electrical Characteristics(STC)				
Encapsulation	Class/Eva/Cell/Eva/Backsheet			
Module Type	SW410M-72 ~ SW410M-72			
Maximum Power (Pmax)	380	390	400	410
Maximum Power Voltage (Vmp)	39.9	40.3	40.6	40.9
Maximum Power Current (Imp)	9.52	9.68	9.85	10.01
Open-circuit Voltage (Voc)	48.7	49.2	49.7	50.2
Short-circuit Current (Isc)	9.97	10.14	10.21	10.28
Cell Efficiency(%)	21.48	22.05	22.61	23.18
Module Efficiency (%)	19.68	20.2	20.72	21.13
Power Tolerance	0~+5W			
Temperature Coeffcient of Isc	+0.05%/°C			
Temperature Coeffcient of Voc	-0.29%/°C			
Temperature Coeffcient of Pmax	-0.37%/°C			

Generator price and specifications

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Home > All Industries > Electrical Equipment & Supplies > Generators > Diesel Generators | Subscribe to Trade Alert

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P13.5-6 50Hz @ 10kw 60Hz@ 15kva 403D-15G UK Original FG Wilson Genset Diesel Generator

1 - 4 Sets	>=5 Sets
IQD 6,240,521	IQD 6,169,060

Rated Power: 15kva

Output Type: AC Three Phase

Lead Time:

Quantity(Sets)	1 - 5	>5
Est. Time(days)	30	To be negotiated

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Overview

Quick Details

Place of Origin:	China	Brand Name:	FGWILSON
Model Number:	P13.5-6	Rated Voltage:	400V@50HZ, 480V@60HZ
Rated Current:	10-2500A	Speed:	1500/1800RPM
Frequency:	50/60HZ	Engine:	403D-15G
Power factor:	0.8	Warranty time:	1000 Working Hours/1 Year
Certificate:	EPA CE	Alternator:	Leroy Somer / Stamford
Cooling method:	Water Cooled Method	Fuel tank capacity:	8-12 Hours
Fuel comsumption:	3.7L/Hr at 100% Load		

Supply Ability

Supply Ability: 500 Set/Sets per Month

Packaging & Delivery

Packaging Details: PLYWOOD CASE

Port: Fuzhou

Picture Example:

Lead Time:

Quantity(Sets)	1 - 5	>5
Est. Time(days)	30	To be negotiated

FG Wilson Generators

- **13.5kVA to 50kVA** P9.5-4 P11-6S P13.5-6
- **55kVA to 150kVA** P50-3 P65-5 P150-5
- **165kVA to 275kVA** P165-5 P200-3 P220-3 P250H-3
- **400kVA to 605kVA** P400-1 P450-1 P500-1 P550-1 P605-1
- **660kVA to 1000kVA** P730P1/P800E1 P800P1/P900E1 P910P1/P1000E1
- **1100kVA to 1650kVA** P1250P3 P1250P3/P1375E3 P1350P1/P1500E1 P1500P1
- **1875kVA to 2500kVA** P1700P1/P1875E1 P1750P1/P1925E P1825/P2000E P2000/P2250E P2250-1/E P2500-1/E

CURRICULUM VITAE

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Education

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Undergraduate	Baghdad Technology University Faculty of Engineering Department of Electromechanical Engineering	1999-2004

Work Experience

Year	**Institution**	**Position**
2009-Present	Kufa University, Department of Ages and Projects	Iraq-Najaf

Academic Activities

1. Ghazi, A.J., Korkmaz, F., and Ahmed, A. (2021). Design and Evaluation of Solar Energy Powered Groundwater Pumping System for Irrigation Farm in Desert. Kufa J. Eng. 12, 69–83.