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Department of renewable energies

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ACADEMIC MASTER

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Theme

Comparative study between fixed and tracking photovoltaic system in south Algeria

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appreciation

First, we thank Allah Almighty for granting us success in doing this thesis. We would like to thank the supervising professors, ***Ammari Chouaib*** *and* ***Abada Zhour****, for their staying up late and working hard, and for sharing their expertise and experiences with us in helping us to do this thesis. We thank our colleagues and everyone who helped us in doing this study, and we express our gratitude to everyone*

DIDECATION

This study is a dedication to God Almighty, my strong foundation, wisdom, knowledge and understanding. He has been my strength throughout this job, and I have only risen on his wings.

I dedicate this thesis to my dear parents and to all my family who have always been by my side and always supported me throughout these long years of study. Whose words of encouragement and motivation to persevere ring in my ears and who never left my side throughout the entire graduate program. As a token of appreciation, I hope they find here an expression of my profound gratitude for all the efforts and resources they have put in to see me succeed in my studies.

This work is also dedicated to all the people who know me and whom I know, whether from near or far, and to everyone who loves good deeds and is not ashamed of life's obstacles.

You have all been my biggest cheerleaders and my love for all of you can never be measured. God bless you.

SMAILI FOUAD

DIDECATION

After we have completed this study, I would like to thank Allah Almighty for granting me success in writing this memorandum. I could not do anything without him, and he was and still is my support. I wanted to dedicate this achievement to my mother and my deceased father and to my brothers, as they were the source of my strength and steadfastness. Encouraging me throughout, I also do not forget my friends and brothers who were like my second family, as well as my fellow students and the university staff, including professors and administrators.

OUSSAMA BOUZIDI

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Symbols	Meanings
T	Absolute temperature (in kelvin).
T_{ref}	Cell reference temperature.
R_s	The resistance series.
E	Gap energy of the semiconductor used in the cell
R_p	The parallel resistance
Ns	Number of modules in series.
N_p	Number of modules in parallel.
V_{pv}	voltage at the output of the PV generator
I_{pv}	Current at the output of the PV generator
P_{pv}	Power at the output of the PV generator
V_{dc}	DC voltage applied to the inverter
Iph	Photo-current
η	Energy conversion efficiency
I_{sc}	Short circuit current
V_{oc}	Open circuit voltage
I_d	Current passing through the dide
B	Boltzmann constant 1.381×10-23 J/K
I0	The saturation current of the diode reverses and it is a function of (T)
Q	the charge of the electron 1.069 × 10-19 C.
A	the ideality factor of the diode (1<a<2).
Eg	band gap energy of the material (1.12 eV for silicon).

T_{Cref}	the actual and reference temperature conditions (K°).
G_{ref}	the actual and reference lighting conditions (W/m2).
KI	the temperature coefficient of the short-circuit current (A/K°).
D	the converter duty cycle.
Ƒ	the switching frequency of the converter
V_m	average voltage
I_m	average courant
V_{eff}	Effective tension
I_{eff}	Effective courant

Abreviations list

CdTe	Cadmium tellurium
CIS	copper indium
CIGS	Gallium di selenide
MPPT	Maximum power point tracking
PV	Photovoltaic.
PVG	Photovoltaic Generator
MPP	Maximum Power Point
DC	Direct Current
AC	Alternative Current

General Introduction

General Introduction

The energy aspect is considered an important area in human life, as all of human activities are related to the use of energy in daily life. It provides the necessary facilities for all movements. In recent years, the energy demand has increased with demographic growth. The demand for fossil energy has been and remains large, increasing day by day. Simultaneously with the demand for energy, environmental pollution and carbon dioxide emissions are increasing. Renewable energies are considered a solution to help provide energy and reduce emissions and pollution. Renewable energies have several well-known sources of energy production, including photovoltaic energy and solar thermal energy, wind energy, along with some other sources.

In this memorandum, we seek to study the production of photovoltaic panels in an attempt to develop them, limit their negative aspects, and avoid damaging them through mishandling. In the first chapter, we studied the behavior of photovoltaic panels, their method of operation, their types, and the energy provided by each type of panel, examining the energy production stations in southern Algeria. We learned about the latest technologies used worldwide in sun-tracking devices to enhance and increase energy production from photovoltaic panels. We took an example from the Oued Nachou station to simulate and study it as a model throughout this memorandum.

In the second chapter, we discussed the latest modern literature on the use of techniques for developing sun-tracking devices and the method of operating the electrical devices necessary for operating a photovoltaic power station.

Then, in the last chapter, we presented the results and values for each component of the photovoltaic power station. We also compared the production of fixed-angle panels with panels using variable-angle sun trackers, aiming to better study the enhancement of energy production and development. The simulation was done using MATLAB/Simulink.

Chapter I : Photovoltaic energy and tracking systems

I.1 Introduction

One hundred years after Edouard Becquerel's discovery of the photovoltaic effect in 1839, the first cell capable of transforming solar energy into electric current was developed by a group of American researchers from Bell Labs. Remaining a laboratory curiosity for a very long time, the photovoltaic effect was first used in the space sector before being used as a source of energy in isolated sites. It eventually experienced the development we know today in applications connected to the grid.

In this chapter, we will discuss the photovoltaic field in general. To do this, we will first provide an overview of the global and Algerian photovoltaic situations. Then, we will briefly recall the principle of photovoltaic conversion and conclude by listing some advantages and disadvantages of this energy source.

I.2 Renewable energies

Renewable resources are energies with unlimited resources and continually replenished, include solar energy, wind, falling water, the heat of the earth (geothermal), plant materials (biomass), waves, ocean currents, temperature differences in the oceans and the energy of the tides. Renewable energy technologies produce power, heat or mechanical energy by converting those resources either to electricity or to motive power [1].

I.3 Solar radiation

Because of the earth's spin and orbit, the amount of solar radiation that reaches a particular location changes over time-both during the day and night. It also fluctuates in space at a given time due to variations in the solar rays' obliquity with longitude and latitude. It is determined by the earth's rotation about its polar axis, its unique astronomical position on its orbit around the sun, and the location of this point on the planet. Because of this, the amount of solar radiation that reaches the earth's surface depends significantly on both time and sun-earth geometry [2].

I.3.1 Solar radiation deposit in the world

There are numerous places in the world with abundant solar resources. (Figure I.1) depicts the solar resource map, which uses a color scale to indicate the regions of the world with the highest potential for solar energy gathering. There is significant potential for the development of solar energy projects, particularly in equatorial countries and regions. Specifically, The average daily and yearly radiation is displayed on this map. this map is published by the world bank group .funded by ESMAP. and prepared by solargis

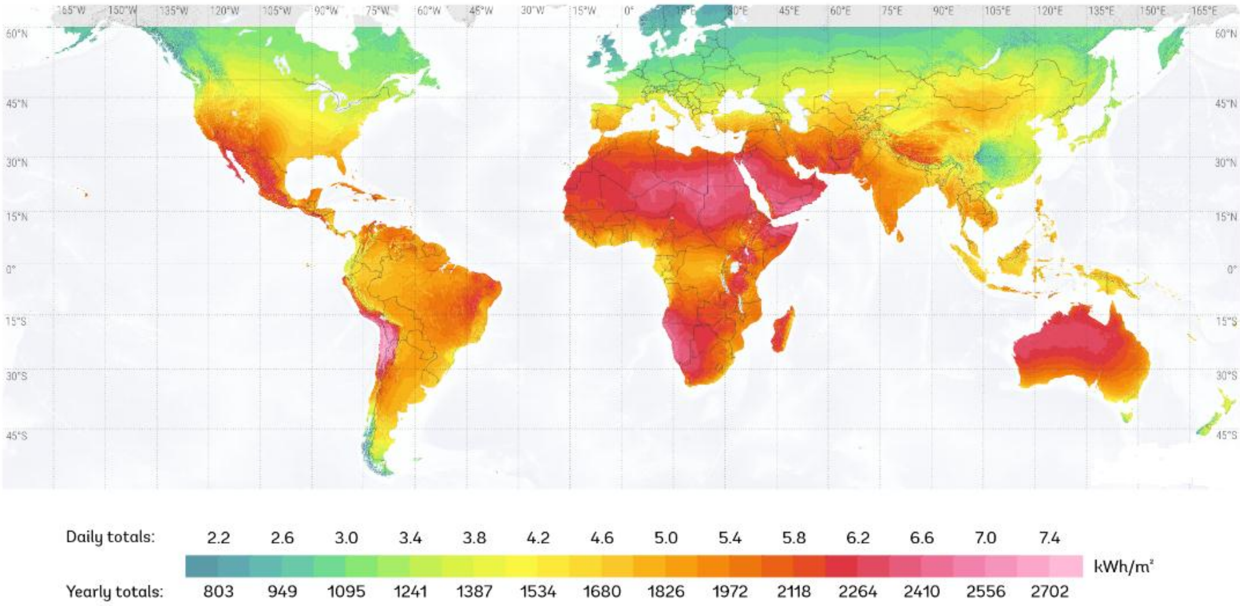


Figure I.1: average global harioznta l sun iradiation (2023) [3]

From the previous map, we note that the most suitable belt for solar energy development projects in the world is located between 35° degrees south and 35° degrees north latitude. This includes large parts of Africa, South America, Australia, India and China, regions that naturally have the best conditions for solar applications. Many of these areas are also semi-arid, receiving direct radiation due to limited cloud coverage and rainfall.

I.3.2 Solar radiation deposit in Algeria

Due to its geographical location, Algeria has one of the highest solar resources in the world as shown in (Figure I.1) (Figure I.2).

The duration of insolation over almost the entire national territory exceeds 2000 hours annually and can reach 3900 hours (highlands and Sahara). The energy received daily on a horizontal surface of 1 m2 is of the order of 5 KWh over most of the national territory, or nearly 1700 KWh/m2/year in the North and 2263 kwh/m2/year in the South of the country. [4]

(Table I.1) shows the distribution of solar potential by climatic area on Algerian territory based on the amount of sunshine received there each year.

Table I.1: Solar potential in Algeria (2010) [5]

Regions	Coastal regions	Highlands	Sahara
Area (%)	4	10	86
Average duration of sunshine (h/year)	2650	3000	3500
Average energy received (kWh/m2/year)	1700	1900	2650

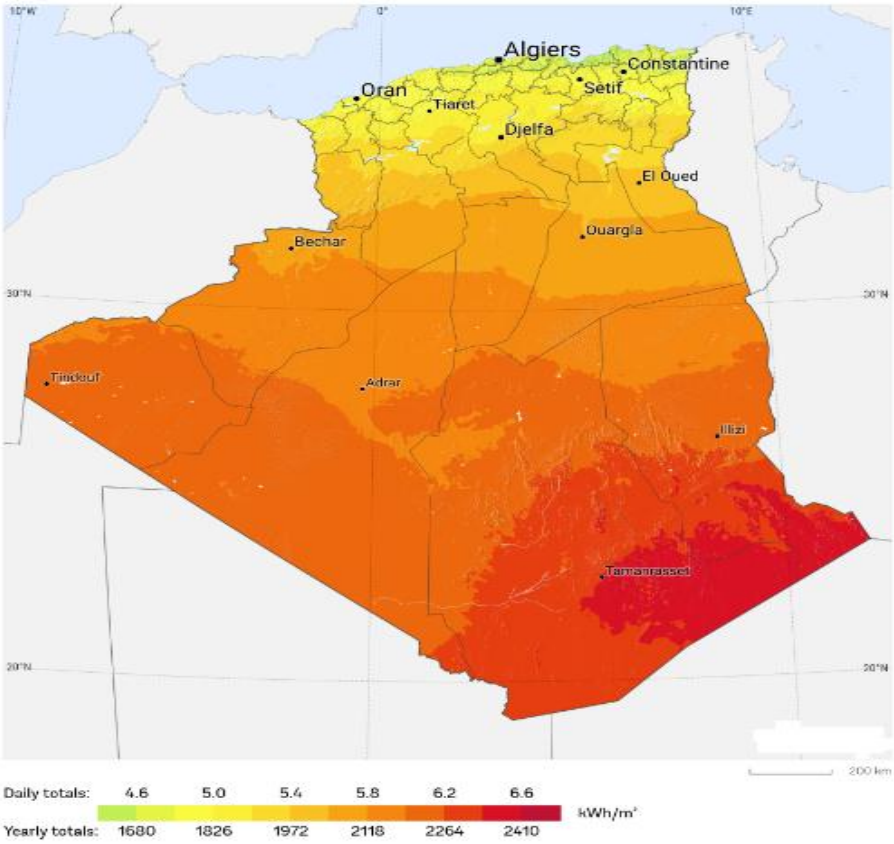


Figure I.2: average sun radiation in Algeria (2019)[3]

I.4 Photovoltaic working principle

When a photovoltaic cell is exposed to sunlight, a process known as the photovoltaic effect occurs that produces voltage or electric current. A p-n junction is formed by the joining of two distinct semiconductor types, a p-type and an n-type, in these solar cells. When these two kinds of semiconductors are combined, electrons flow to the positive p-side and holes to the negative n-side, creating an electric field in the vicinity of the junction. Positively charged particles go in one direction and negatively charged particles move in the opposite direction due to this field.[6] Photons are just tiny bundles of electromagnetic radiation or energy that make up light. When these cells are exposed to light at the right wavelength, energy from the photon is transferred to an electron of the semiconducting material, causing it to jump to a higher energy state known as the conduction band. In their excited state in the conduction band, these electrons are free to move through the material, and it is this motion of the electron that creates an electric current in the cell.

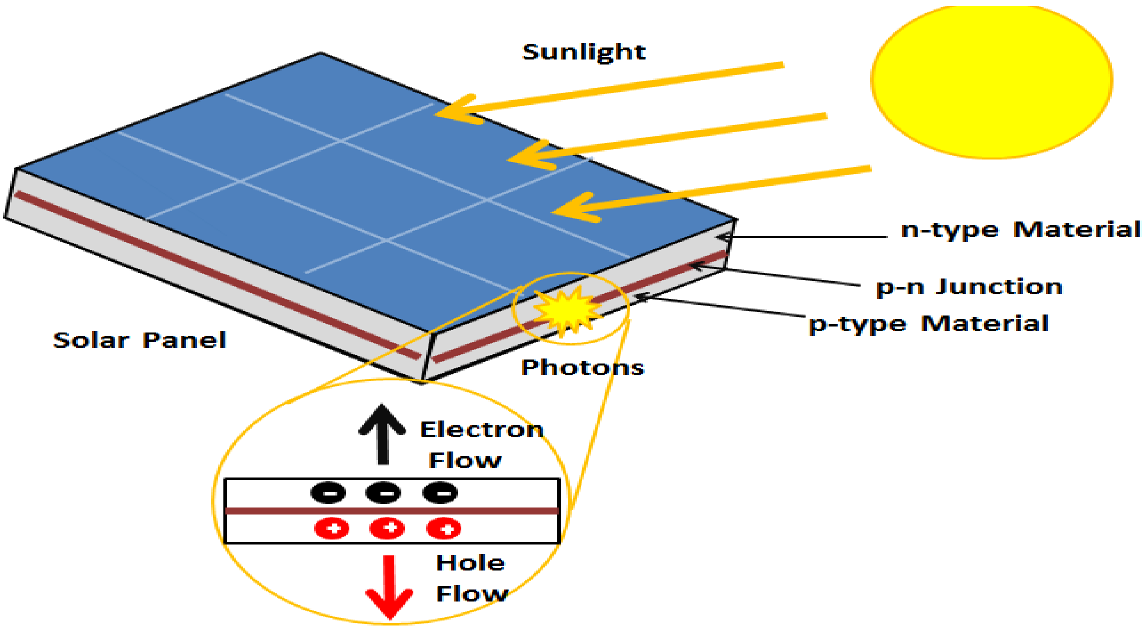


Figure I.3: A diagram showing photovoltaic cell fonctionnement.

I.5 Photovoltaic cell

PV cell is the fundamental component of PV systems. It is a semiconductor diode whose P–N junction is exposed to the light [7]. The photovoltaic cell is considered an electronic element in which a group of materials are assembled that convert sunlight into a continuous electric current. The electric current generated by the solar cell is proportional to the solar radiation.

The photovoltaic cell consists of the following layers from top to bottom: glass layer - non-reflective cover - conductive layer type (N) - conductive layer - conductive layer type (P) - bottom cover where it is shown (Figure I.5) Basic structure of a photovoltaic cell, and the equivalent circuit of a solar cell incorporating anti-parasitic components [8]

I.6 Associations of photovoltaic cells

Because the cell voltage and current are weak, a large number of cells are connected in series and in parallel to obtain the necessary voltage and current.

I.6.1 Association of photovoltaic in series:

Connecting photovoltaic cells in series, by connecting the ends with the beginnings, so that positive with negative and negative with positive in order to maintain the same current, but with the sum of the different voltage values for all the solar cells in order to raise the total voltage difference as shown in the picture Figure I.4 [9] .

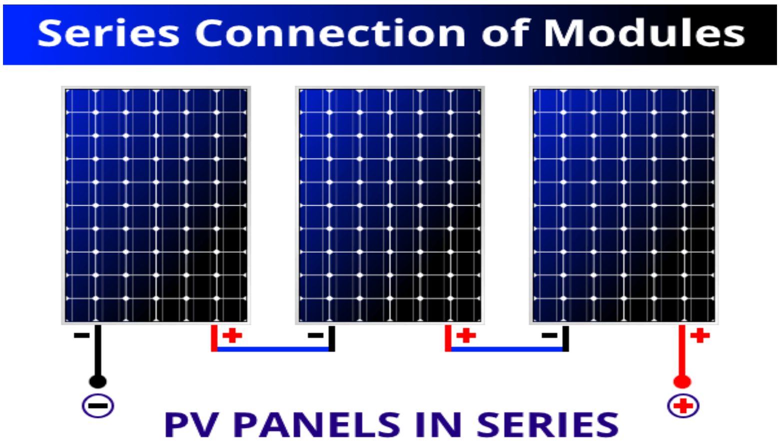


Figure I.4: Series connection of photovoltaic cells

Connecting a group of cells (NS) in series makes it possible to increase the voltage of the solar cell, so the total voltage is the number of one voltage cell that is multiplied many times, while the current is the in fixed value. as follows [10]:

$$V_T = N_S \times Vm$$

V_T: The total voltage of number of cells in series.

N_S: The number of cells linked in the sequence.

Vm: maximum voltage.

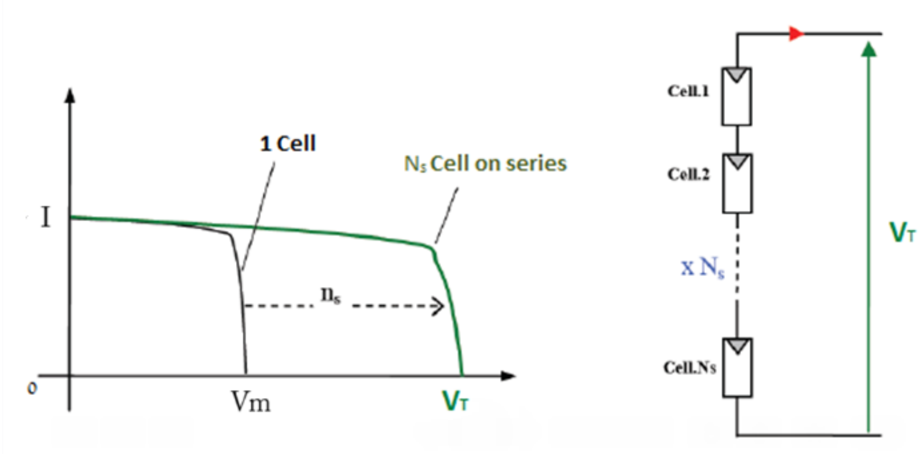


Figure I.5: Assembling in series

I .6.2 Association of photovoltaic in parallel:

Connecting photovoltaic cells in parallel by connecting the beginnings with the beginnings and the ends with The ends (positive with positive and negative with negative), in order to maintain the same voltage, but with the sum of the different current values for all the solar cells in order to increase the total current, as shown in the Figure I.6

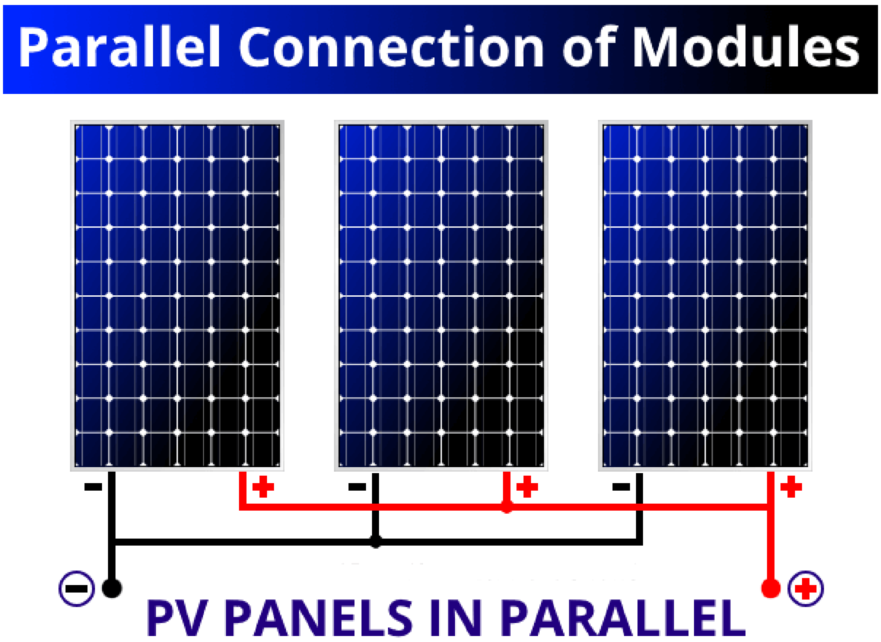


Figure I.6: Parallel connection of photovoltaic cells

Connecting a group of cells (NP) in parallel allows for an increase in the production of the solar cell, and thus the voltage is equal to the voltage of a single cell, while the current is multiplied by cells connected in parallel case, as follows[11]:

$$I_T = N_P \times I_m$$

I_{TOTAL}: the total current of connected cells in parallel case

Np: The number of cells linked in the parallel

Im : maximum current

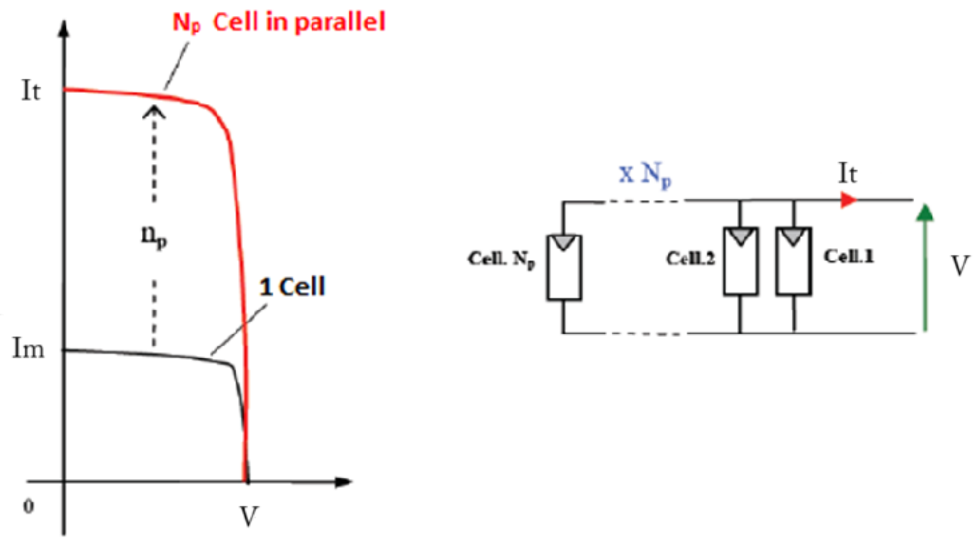


Figure I.7: parallel assembly

I .6.3 Association of photovoltaic cells in mix:

The cells are assembled in series and parallel at the same time to obtain greater capacity. Thus, we obtain a relatively high voltage and a relatively high current, and the connection is as in (Figure I.8) .

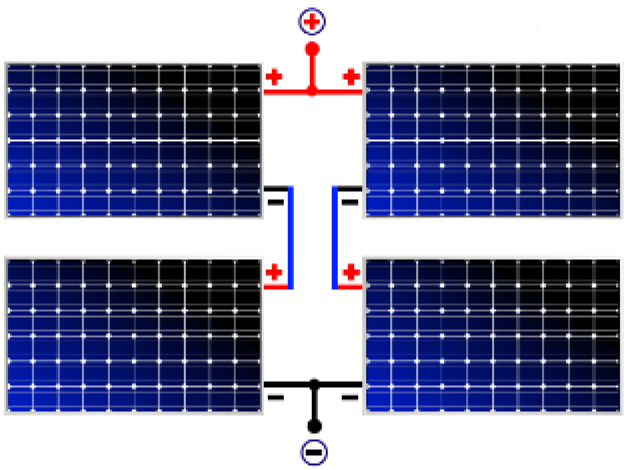


Figure I.8: PV Panels in series-parallel

I.5 Factors affecting the production of photovoltaic panel

In this part, we try to study the effect of climatic and environmental factors on solar panels and changes in solar radiation, temperature, and humidity

I.5.1 Effect of solar radiation

Buni, M.J., A.A. Al-Walie, and K.A. Al-Asadi .2018.Iraq they conducted an experiment where they found that the performance and effectiveness of photovoltaic panels do not change based on changes in the value of solar radiation. They detected changes in the current, voltage, and energy values, as well as the output received by the photovoltaic panel, under a temperature of 25 C and a maximum radiation of 1000 watts/m^2, according to some of the results obtained from their experiments. [12]

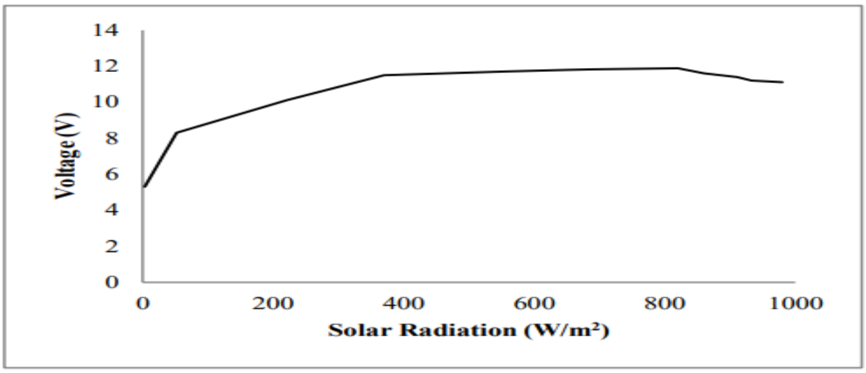


Figure I.9: Evolution of tension value under the influence of solar radiation[12]

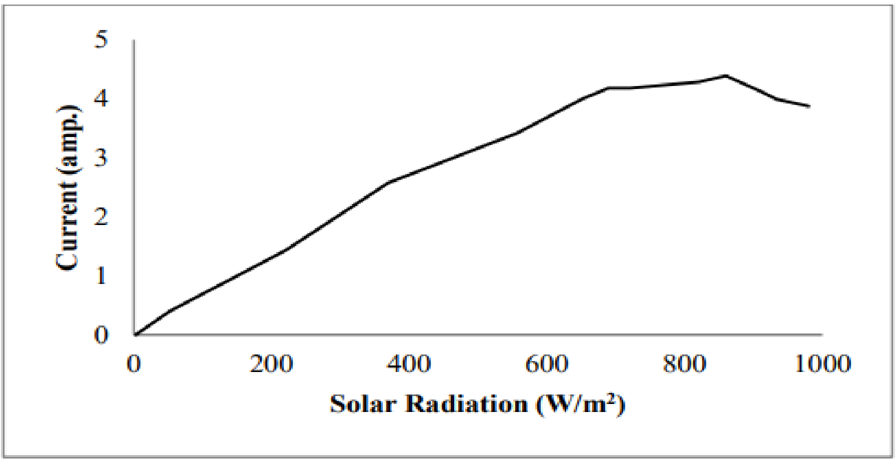


Figure I.10: Evolution of current value under the influence of solar radiation[12]

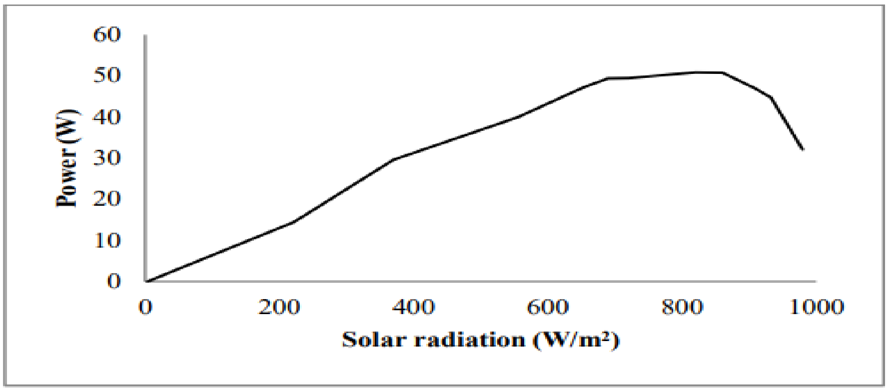


Figure I.11: Evolution of power value under the influence of solar radiation[12]

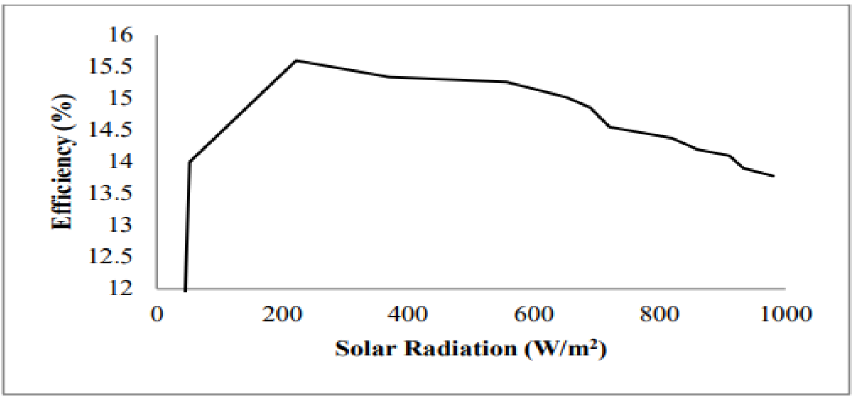


Figure I.12: Evolution of efficiency value under the influence of solar radiation[12]

I.5.2 temperature effect

Adeeb, J., A. Farhan, A. Al-Salaima, 2019.jordanThey conducted a study to confirm that temperature affects the productivity of photovoltaic panels. Temperature changes the properties of a photovoltaic cell under an irradiance of 1000 W/m^2 and an air mass of 1.5, as shown in the following figure.[13]

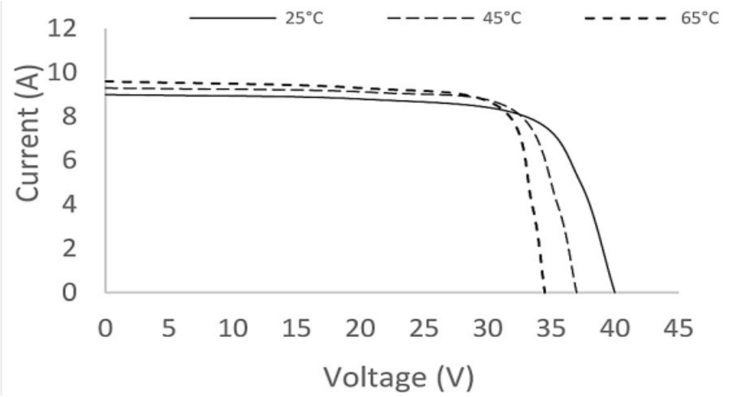


Figure I.13: Effect of Temperature on Solar photovoltaic I-V Curve[13]

Temperature has a strong effect on the properties and behavior of photovoltaic cells. When the temperature rises, the production of electrical current increases, and the production of electrical tension decreases. Likewise, when the temperature decreases, the production of electrical current decreases by a small amount with an increase in the production of electrical tension.

I.5.3 Humidity effect

Tripathi, A.K., et al.2021.India They found that the degree of humidity affects the effectiveness and productivity of the photovoltaic cell, just like temperature. In this part, we study the effect of humidity on the production of electric current and voltage according to some values taken from their experiments.[14]

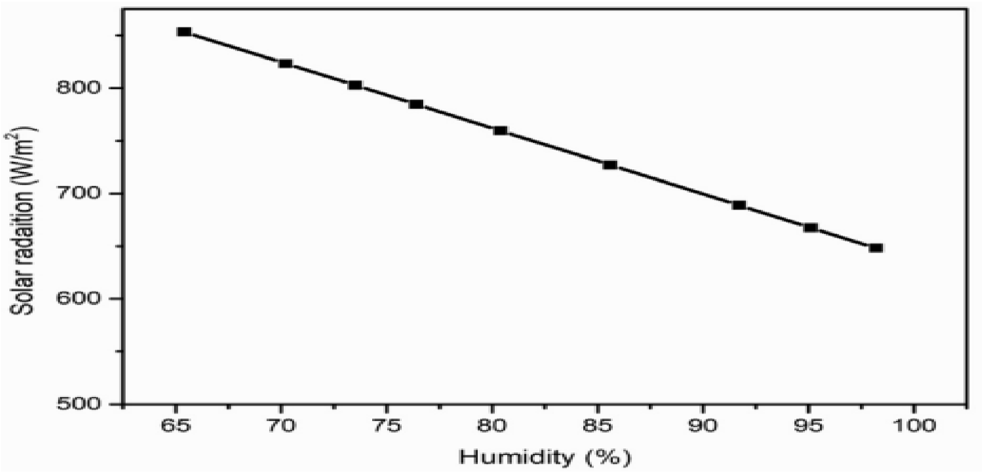


Figure I.14: Effect of Humidity on radiation in Solar photovoltaic[14]

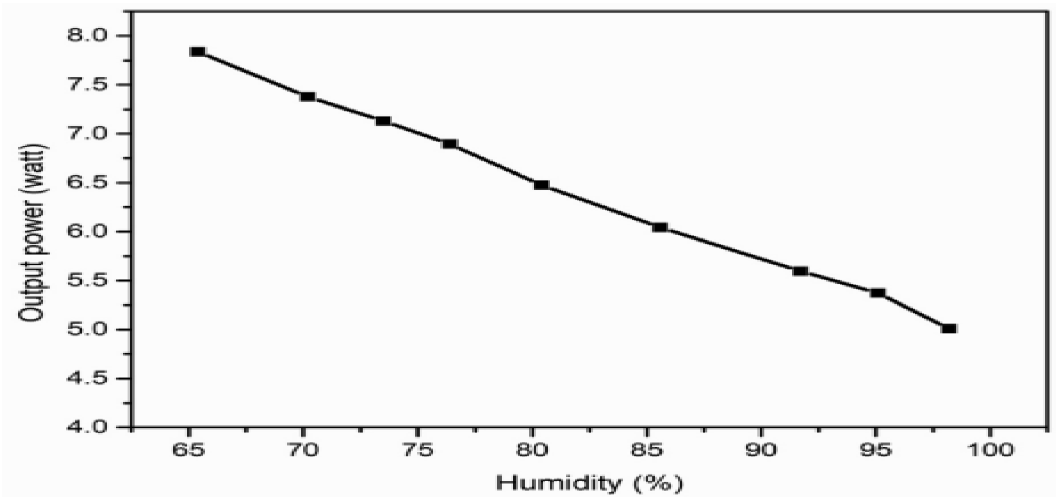


Figure I.15: Effect of Humidity on power in Solar photovoltaic[14]

High humidity affects the power production range of the photovoltaic cell, affecting the properties of the photovoltaic cell by decreasing the electrical current and voltage output, as well as the power obtained. We notice in the curves that an increase in the degree of humidity gradually decreases with the power produced by the solar panel. We also notice a decrease in solar radiation in the place due to humidity, as the radiation crosses the humid atmosphere in which there are water molecules, thus disrupting the full access of solar radiation to the photovoltaic panel.

Table I.2: a table showing the percentage absorption values of solar radiation as a function of humidity[14]

SI.No	Humidity (%)	Percentage increase humidity (%)	Solar radiation (W/m^2)	Percentage decrease in solar radiation (%)
1	65.40	NIL	854	NIL
2	70.20	7.34	823	3.52
3	73.50	12.39	802	5.93
4	76.40	16.82	784	8.06
5	80.40	22.94	759	10.99
6	85.60	30.89	726	14.81
7	91.70	40.21	688	19.28
8	95.10	45.41	667	21.78
9	98.20	50.15	648	24.05

1.5.4 dust effect

Saidan, M., et al.2016.Iraq They found that dust significantly impacts the productivity of photovoltaic panels and how they work. In this section, we will study the effect of dust on voltage, current, and power. All results are taken from tables and curves obtained from their experiment[15].

Table I.3**:** daily value measurement of dust effect[15]

Module (1) for daily measurements		
Module (1): Daily measurements		
Parameter	**Module without dust**	**Module with dust**
Mean dust density (mg/m^3)		0.412
I_{SC} (A)	2.22	2.14
V_{oc} (V)	17.81	17.68
I_m (A)	2.02	1.88
V_m (v)	13.21	13.37
Efficiency (%)	10.22	9.62

Table I.4: weekly value measurement of dust effect[15]

Module (1) for weekly measurements		
Module (1): weekly measurements		
Parameter	**Module without dust**	**Module with dust**
Mean dust density (mg/m^3)		0.072
I_{SC} (A)	2.20	2.0
V_{oc} (V)	17.70	17.65
I_m (A)	2.02	1.76
V_m (v)	13.21	13.56
Efficiency (%)	10.22	9.14

Table I.5: monthly value measurement of dust effect[15]

Module (1) for monthly measurements		
Module (1): monthly measurements		
Parameter	**Module with dust**	**Module without dust**
Mean dust density (mg/m^3)		0.030
I_{SC} (A)	2.20	1.89
V_{oc} (V)	17.81	17.70
I_m (A)	1.95	1.63
V_m (v)	13.64	14.04
Efficiency (%)	10.39	8.75

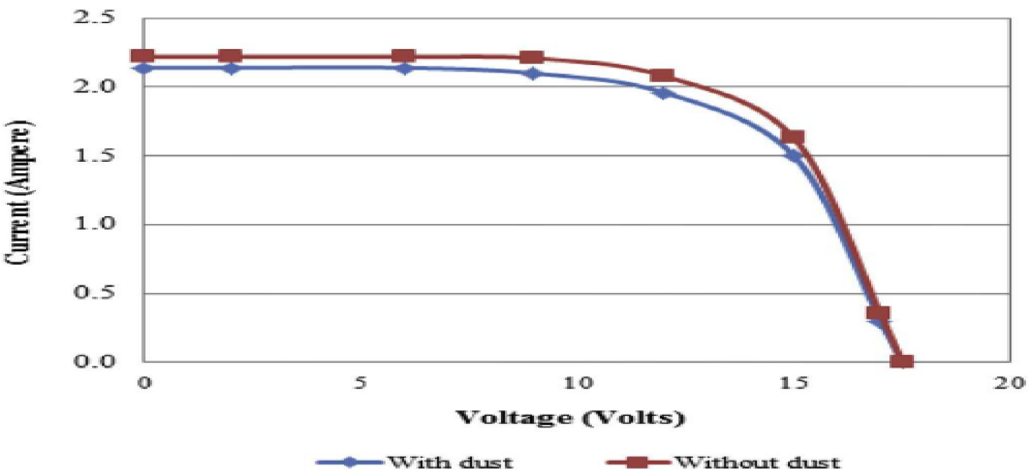


Figure I.16: I-V curve under effect of dust within one day[15]

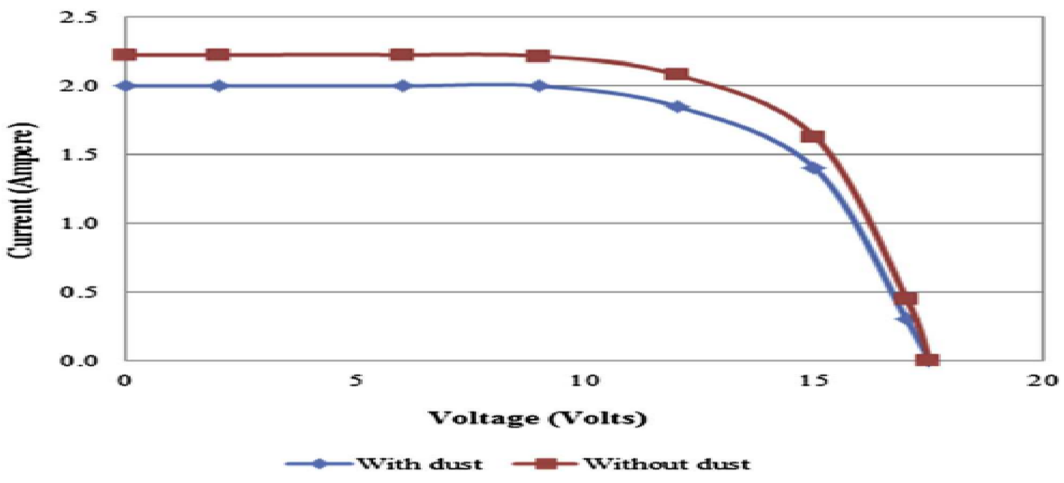


Figure I.17: I-V curve under effect of dust within one week[15]

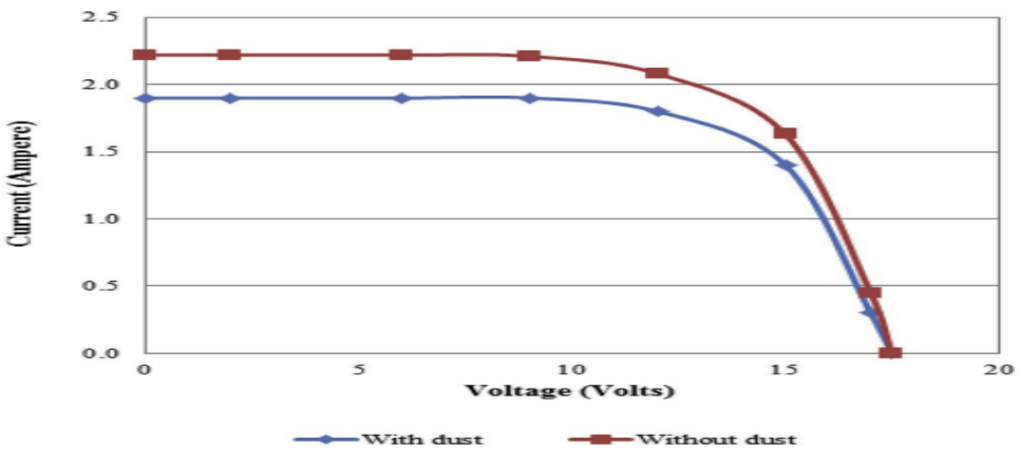


Figure I.18: I-V curve under effect of dust within one month[15]

The results of the experiment show us the effect of dust on the photovoltaic panel for a day, a week, and a month We notice in the tables that electric current and electrical tension are affected by dust, and we notice a decrease in the value of the short-circuit current, as well as the maximum current, significantly compared to the effect of open-circuit voltage and the maximum voltage, which is affected little.

We also notice in the curves a significant decrease in the value of the current output in the presence of dust, as well as a decrease in the value of the resulting power, even though the unit of dust is mg/m2 (a small unit). We conclude that dust has a significant impact on the productivity of the photovoltaic panel

I.5.5 effect of electrical parameters

Hysa, A.2019.Albinia said that electrical settings have a significant impact on the performance of the photovoltaic cell in terms of energy production. These settings include series and parallel resistance. We will study some of the results obtained from her simulations[16]

- Resistance effect in series condition

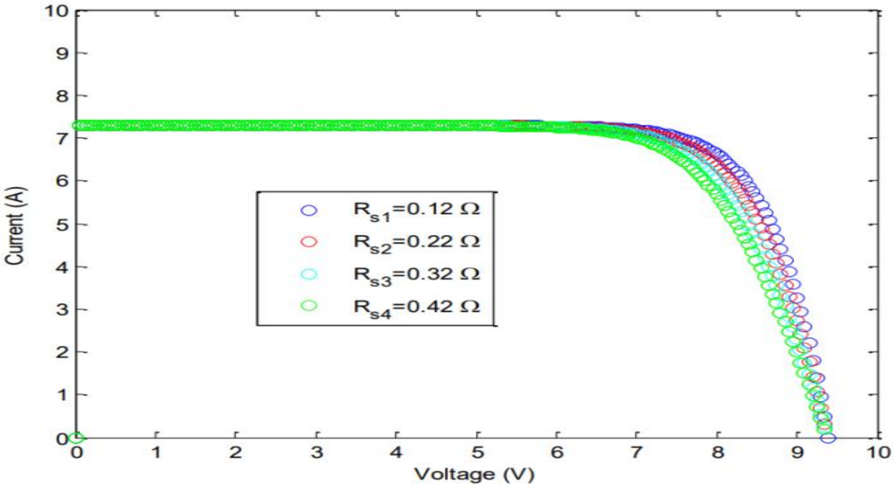


Figure I.19: series resistance effect in I-V curve[16]

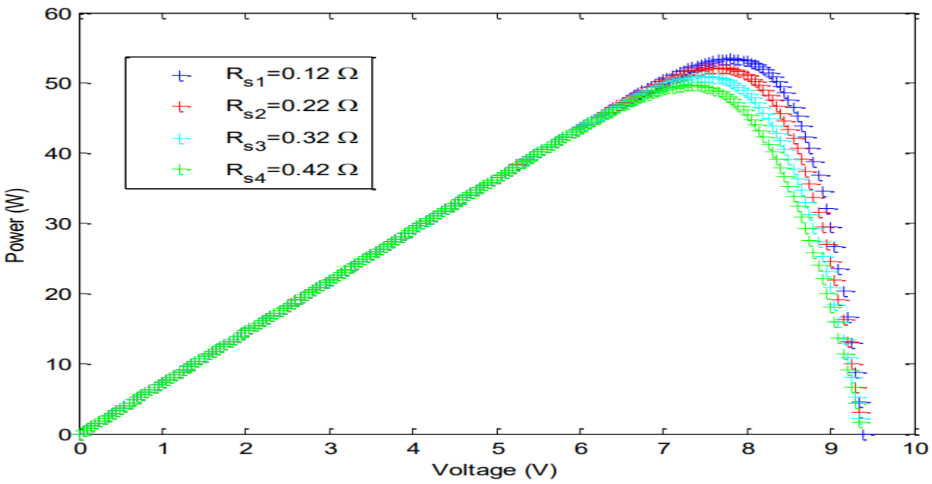


Figure I.20: series resistance effect in power-voltage curve[16]

Increasing the series resistance value affects the power production by the photovoltaic cell and greatly reduces the maximum power value. We notice that the power value decreases as the series resistance value increases.

- Resistance effect in parallel condition

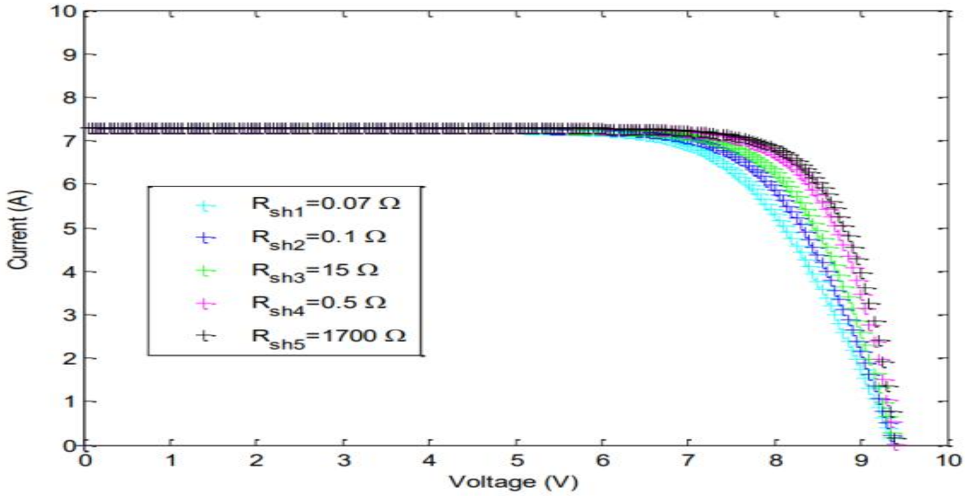


Figure I.21: parallel resistance effect in I-V curve[16]

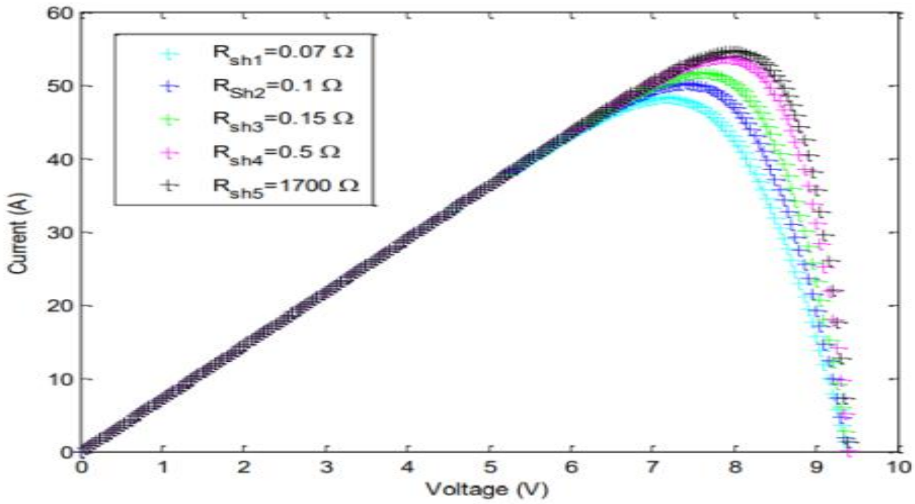


Figure I.22: parallel resistance effect in power-voltage curve[16]

the shunt resistance is very high. A meager shunt resistance affects the open circuit voltage of a photovoltaic cell. In addition, the solar cell has low switching resistance and will not produce power in weak conditions.

I.6 photovoltaic production stations

In this section, we study some energy production stations using photovoltaic panels and we will learn about the advantages that distinguish them from others.

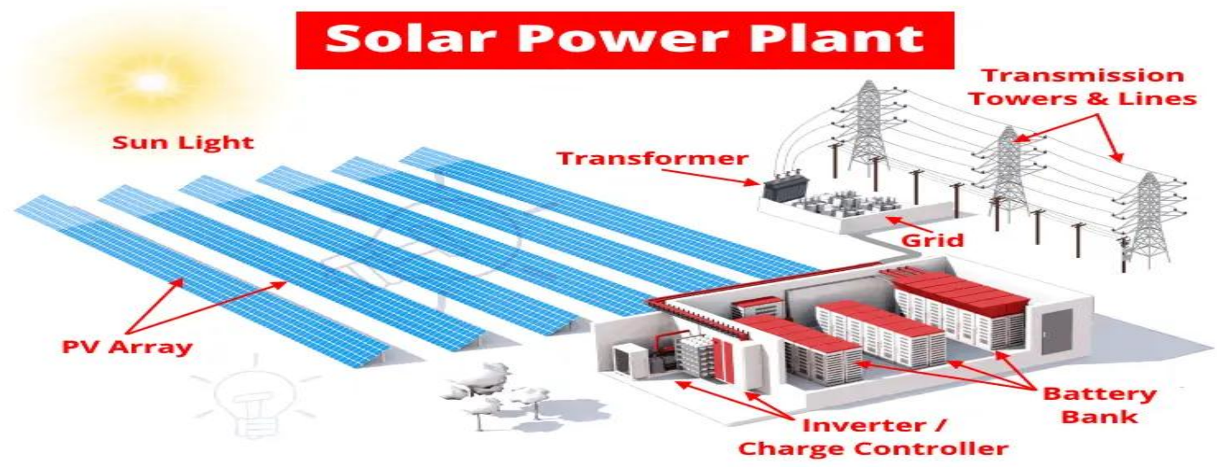


Figure I.23: structure of solar power plant

Photovoltaic power stations are establishments that harness solar radiation and light to produce electricity. These solar power stations are made up of several solar panels with solar cells that transform solar radiation into electrical energy. They also typically have storage devices to hold energy for usage during periods of low solar radiation.

1.6.1 photovoltaic tracking systems

In this part, we will learn about some of the methods on which solar panel tracking systems depend, and we will learn about the advantages of each of them, in addition to the pros and cons of each of them.

- **Methods of Drive**
- **Passive solar Trackers**

Passive solar trackers also track the sun but without any added energy source. At a high level, they move by using the heat from the sun to warm a liquid. When that liquid expands, it causes a mechanical movement of the solar modules. As the sun moves and the liquid cools, it compresses again, and the panels return. Given their lower accuracy, you can use passive trackers for simple PV systems – but not for much else. Passive solar trackers are also not as efficient in cold temperatures because the liquid inside the tracker usually takes time to heat up[25].

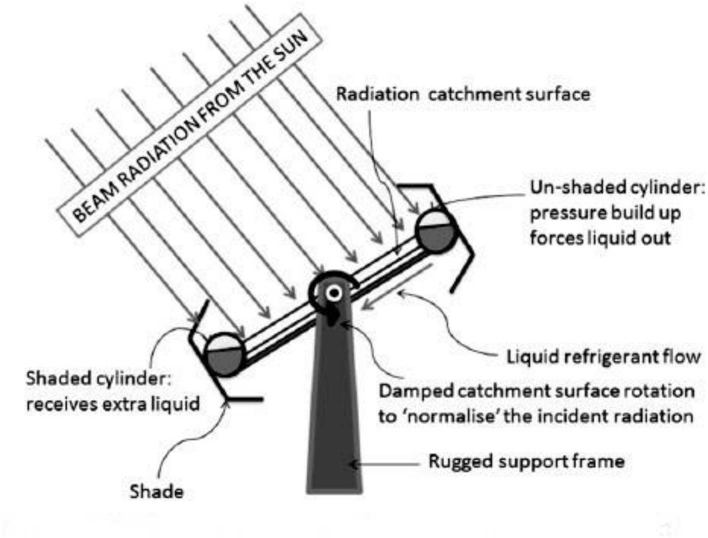


Figure I.24: passive solar tracker system[25]

- **Active solar Trackers**

Most tracking systems are active, meaning they use energy to run a motor or other mechanical stuff that tilts the attached solar panels the right way. Active solar trackers are generally more well-suited for large and complex installations[25].

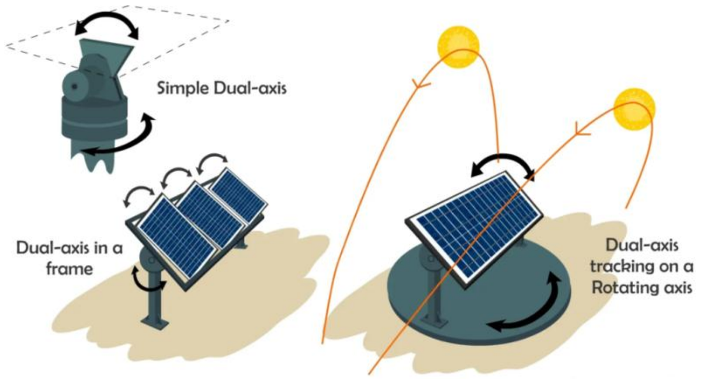


Figure I.25: Active solar tracker system[25]

- **The chronological solar tracking**

Time tracking is based on time and location It moved at a steady rate all day. It moves against the Earth's rotation The way this is done is that the sun moves across the sky at a constant rate. Thus the thrust motors are programmed to rotate continuously "Average rate of one cycle per day (15 degrees per hour)." This method of tracking the sun is very accurate[25].

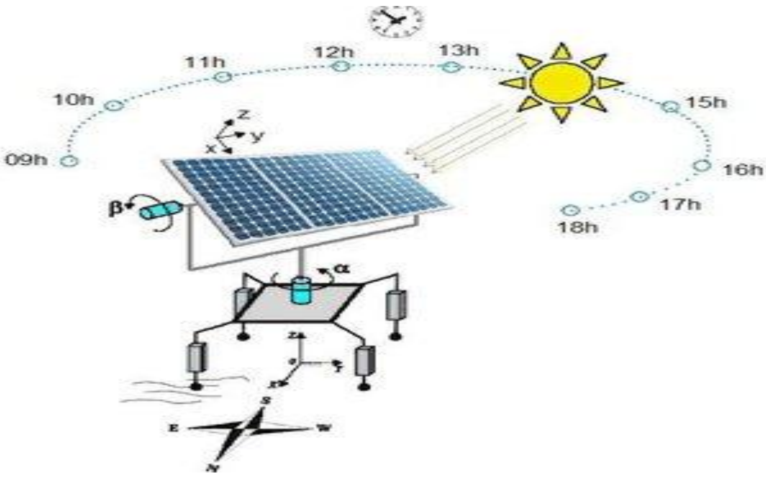


Figure I.26: chronological solar tracking system[25]

Table I.3: advantage and drawbacks of each technology

Photovoltaic tracking technology	Advantage	Drawbacks
• Passive solar Trackers	• It relies on heat to work, not on energy • Not as expensive as active trackers	• Less accurate • Less efficient • Do not work at low temperature
• Active solar trackers	• More accurate • More efficient	• Needs energy to operate mechanics • More expensive than passive trackers • Likely requires more maintenance
• The chronological solar tracking	• More accurate • More efficient	• More expensive than • passive trackers Follow the sun even in cloudy weather • Efficiency is affected by different seasons

1.6.2 photovoltaic production stations in the world

Solar trackers are an important part of the production of electrical energy from photovoltaic panels to ensure maximum benefit from solar radiation. Here we study some stations that rely on solar tracking devices.

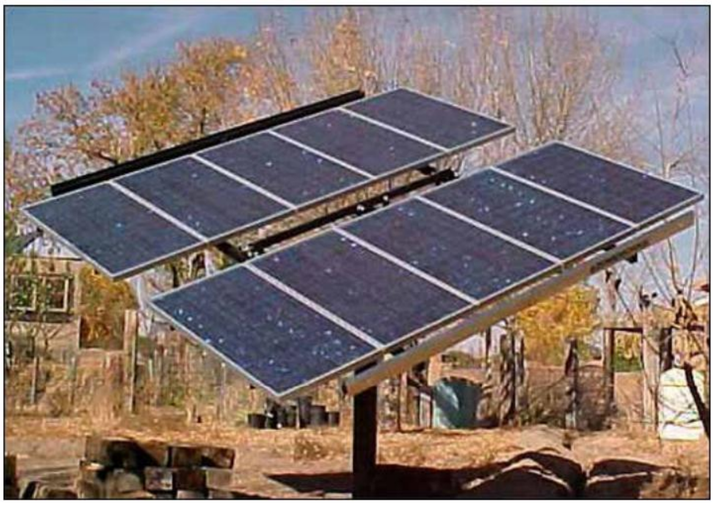


Figure I.27: passive solar tracking model

The tracking device is powered by the photoelectric module precisely towards the sun, Changes the angle of the panels to track the sun During the day. Solar trackers are classified as active and

Negative trackers and Chronological Trackers of leadership in the following sections, the technology for tracking solar radiation will be studied through 3 sections

- **Las Vegas, Nevada, North America**

Figure I.28: North America power station

The largest solar PV plant covers an area of 140 acres (588,116.2 m2) in the desert outside. It provides more than 14 megawatts of electricity provided by the solar array. 100 percent power in the winter Using GPS technology and solar panels, the movement of the sun tracks the amount of energy coming from the sun. The electricity is sent directly to the power grid that helps power the base. [17]

- **CPV project in Golmud, China**

Figure I.29: CPV project in Golmud, China

In Haixi County, Qinghai Province, China, the 138 MW (about 110 MW) Golmud concentrated solar power plant near Golmud. Installed in two phases starting in 2012 by Suncore Photovoltaics, it is the largest operational concentrated solar power installation in the world. It is located next to several other conventional photovoltaic power plants on the Tibetan Plateau, near the Gobi Desert, at about 2,800 meters (9,200 feet).

The 270-acre, 57.96 MW Golmud 1 Unit, located 7 km south of the airport, and the 370-acre, 79.83 MW Golmud 2 Unit, located about 27 km east, are part of the park. Divided into 100 sections, Golmud 1 consists of 2,300 dual-axis Suncore CPV-Gen3.5 solar trackers. Golmud 2 consists of 120 parts containing 3,168 systems. In both units, 23 systems are connected in parallel with a central 500 kW Growatt inverter which is connected to the grid for the majority of the departments. Forty systems in the second unit are connected to a 1-megawatt Chint central transformer, representing one-sixth of the departments[18].

1.6.3 photovoltaic production stations in Algeria

In this title, we review some photovoltaic power stations in Algeria and study the most important characteristics of each of them[19][20][21].

Table I.4: photovoltaic production stations in Algeria

Geographical location	Work start date	Total area	Produced energy	most panel used
Tamanrasset	**2015**	**26 hectares.**	**total production capacity of 13,1085 MW**	**YL245P-29b (POLY-SI)**
el Bayadh , El Abiodh Sidi Cheikh	**August 2015 and was completed in November of the same year**	**39 hectares**	**maximum production capacity of 23.92 MW**	**polycrystalline type CS6P 255-P**
Adrar	**2016**	**40 hectares**	**total production capacity of 20 MW**	**polycrystalline YL245P-29b**

I.6.4 photovoltaic production station in Ghardaia "Oued Nechou"

A photovoltaic power plant was established in the state of Ghardaia-Oued Nechou, Algeria, with a capacity of 1.1 megawatts. This experimental complex was established with the aim of testing and evaluating photovoltaic panel technology, in addition to the equipment that was added to the complex to study the best efficiencies of photovoltaic panels and to better evaluate and study their tolerance to weather conditions. Comprehensive method. This compound was manufactured by the Algerian company Sonalgas on April 7, 2013, All data taken from [22]

Figure I.30: photovoltaic power plant -Ghardaïa- Oued Nechou [23].

➢ Geographical location

La station est située à 15 km au nord de Ghardaïa, à proximité du village d'Oued Nechou.[22].

- the border
  - To the North: National Road No. 01;
  - To the South: Vacant land;
  - To the East: Vacant land;
  - To the West: National Road No. 01.

➢ Geographic coordinates

- Latitude : 32°34’43,79’’ N .
- Longitude : 3°41’55, 36’’ E.

➢ Climatic data

Ghardaia Province is one of the regions of southern Algeria. It is characterized by high solar radiation, which makes it a suitable area for the use of photovoltaic panels in producing electricity. Solar radiation is about 6000 watts/m2 on average annually[22].

➢ temperature

The state of Ghardaia is characterized by high temperatures in summer, where the temperature starts from 36 degrees Celsius at the beginning of summer in July until a maximum of 47 degrees Celsius, and in winter, where the temperature starts from 9 degrees in the middle of winter in January, and at night it is -1 degrees Celsius[22].

✓ **Technical description of the plant**

Identification of the installer: CPE Algerian Production Company

Electricity [11]:

- Type of installation: Photovoltaic panel plant;
- Rated power (peak): 1,100 kW;
- Total power of the inverters (AC side): 1054 kW;
- Inverter voltage: 95.5%;
- Number of photovoltaic panels: Around 6000;
- Output voltage: 30 kV;
- Primary energy used: Photovoltaic energy (sunlight);
- Backup power if applicable: 160 kVA maximum for auxiliary systems during the night or in the absence of sunlight;
- Location: About 15 km north of the town of Ghardaïa, near the village from Oued Nechou (next to the RN1 road);

- **Presentation of the plant**

It will have a nominal power of approximately 1100 kWp (kW peak), distributed as follows:

- 452 kWp: monocrystalline silicon panels, 1880 panels
- 452 kWp: polycrystalline silicon panels, 1960 panels
- 100 kWp: amorphous silicon (a-Si) panels, 988 panels
- 100 kWp: thin film panels (cadmium telluride CdTe), 1261 panels
- The total number of panels is 6089 [23]

Table I.5: electrical characteristics of photovoltaic panels[23].

	type	Structure	Power of arrays	Nbr of modules /panels	Number of strings in parallel	Modules connected in series in strings	Module energy Wc	Module efficiency
1	mono	Tracking	105000	420	21	20	250	15.35٪
2	Poly	Tracking	98700	420	21	20	235	14.43٪
3	Cd-Te	Fixed	108000	1260	105	12	80	11.10٪
4	a-Si	Fixed	100116	972	54	18	103	7.10٪
5	Mono	Fixed	100105	420	21	20	250	15.35٪
6	Poly	Fixed	98700	420	21	20	235	14.43٪
7	Mono	Fixed	22500	1020	51	20	250	15.35 ٪
8	Poly	Fixed	258000	1100	55	20	235	14.43٪
	TOTAL		1174016	6.032	349	150		

I.7 Conclusion

In this chapter, we discussed and learned about the concepts and principles of operating photovoltaic cells, the factors affecting them, and their productivity. We explored modern technologies for tracking the sun and examined some global stations that use these technologies. Additionally, we gathered information about the private photovoltaic generating station in the Nashou Valley in Ghardaia, southern Algeria. This foundation allows us to model the station in the second chapter and present the simulation results in the third chapter.

Chapter II

Technologies of photovoltaic systems

II.1. Introduction

The world today has become more interested in renewable energies than before to limit the phenomenon of global warming resulting from the unregulated exploitation of traditional resources. Therefore, knowing the potential amount of solar radiation for a particular location is essential to converting sunlight into another form of energy. In Algeria, central photovoltaics are one of the most popular sources for high-level solar energy production.

In this study, the state of Ghardaia in southern Algeria was chosen to model and simulate this central photovoltaic network linked to the “Oued Nacho” network site.

Literature reviews

Suneetha Racharla & K. Rajan (2017) in india .In this study, the researchers conducted a study by providing all the necessary devices and algorithms to study the difference between fixed and sun-tracking photovoltaic panels, and they found a significant improvement in the energy produced by sun-tracking panels. [24].

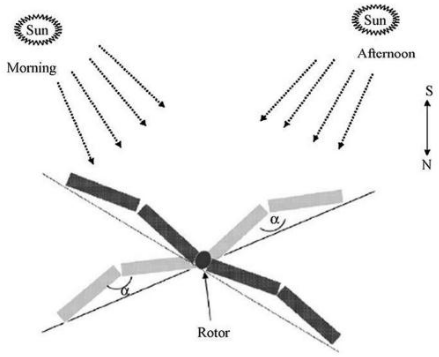


Figure II.1: Position of PV modules[24]

A.R. Amelia et al 2020 Malaysia. This literature presented different performance components, and references and research revealed that active trackers are more popular compared to passive trackers. Some previous literature has indicated that the dual-axis active tracker is more effective and efficient than last methods [25].

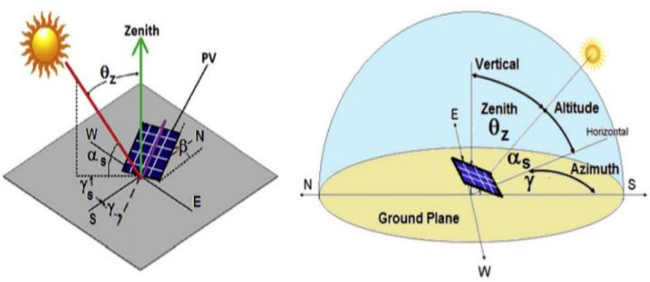


Figure II.2: Solar angles in tracking sun position[25]

A Mohamad et al 2021 malysia. The performance and efficiency of solar tracking systems compared to fixed photovoltaic panels were compared and analyzed. The experiment was conducted under different weather conditions to conduct an optimal test for comparison, and the results showed that the single- and two-phase tracking systems are relatively better and more flexible under the influence of weather conditions. [26].

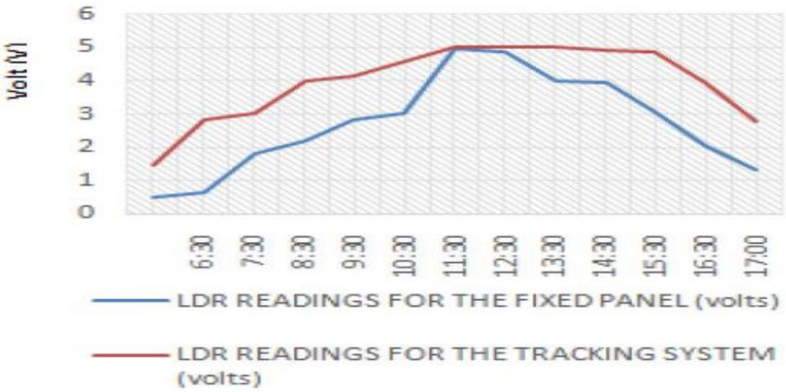


Figure II.3: The plot of output voltage against time[26]

Singh, R., et al 2018. india The focus was on using a PLC controller and a microcontroller using FPGA technology. This technology focuses on monitoring the electrical current, voltage, and characteristics of photovoltaic cells during production. It is noted that the efficiency of the photovoltaic system can be increased by 12-25% (single axis), 30-45% (two axis). and 30-45% sun tracking systems (multi-axis) using this technology, [27].

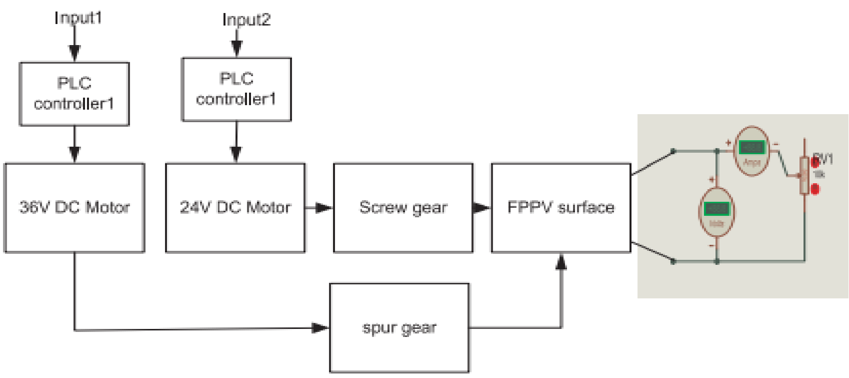


Figure II.4: PLC controller based two axis sun tracking system[27].

Rubio, F., et al. 2007. Spain Researchers use two methods to reduce errors in solar tracking devices. The system relies on reducing errors in the presence of high radiation, and the second method works to reduce production in the presence of weak solar radiation. Both methods showed a significant improvement in production through Discovering errors and reducing production at times we do not need [28].

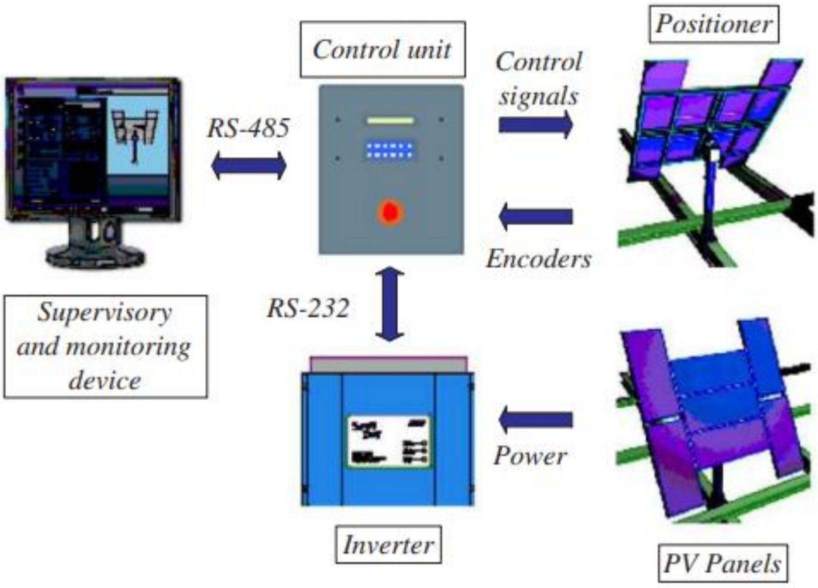


Figure II.5: Block diagram of a control system[28]

Rosma, I.H., et al.2018.Batam, Indonesia.A system or technology for single axis sun tracking with an SPV panel and a panel without a tracker has been studied in this literature, where an LDR sensor and some other equipment are used to input the signal to the control system. In the sun tracking control system, single axis sun tracking using an SPV panel is 22% higher. % of the board without the tracker [29].

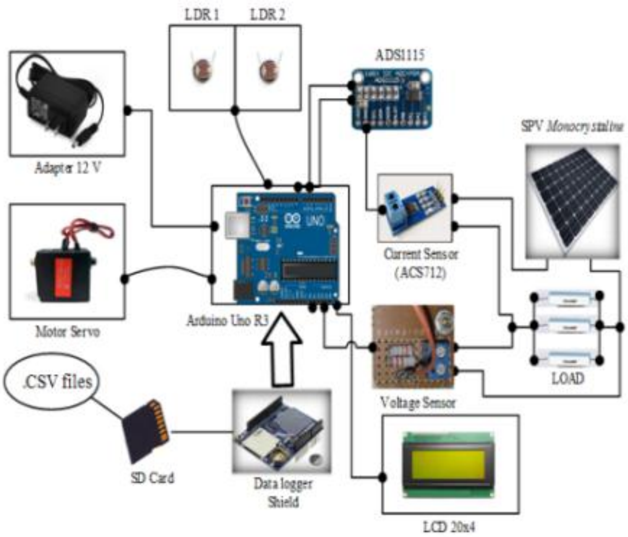


Figure II.6: Block diagram of single axis sun tracker[29].

Akbar, H.S et.al 2017.iraq. This effective and cost-effective literature was dealt with by the single axis sun tracking system, where the system was taken advantage of in terms of its low cost and all products available in the market, and production was improved by 18-25% compared to the fixed panel and we noticed that the energy was produced more with rear side panel and reflector about (65%) and (70-80%) [30].

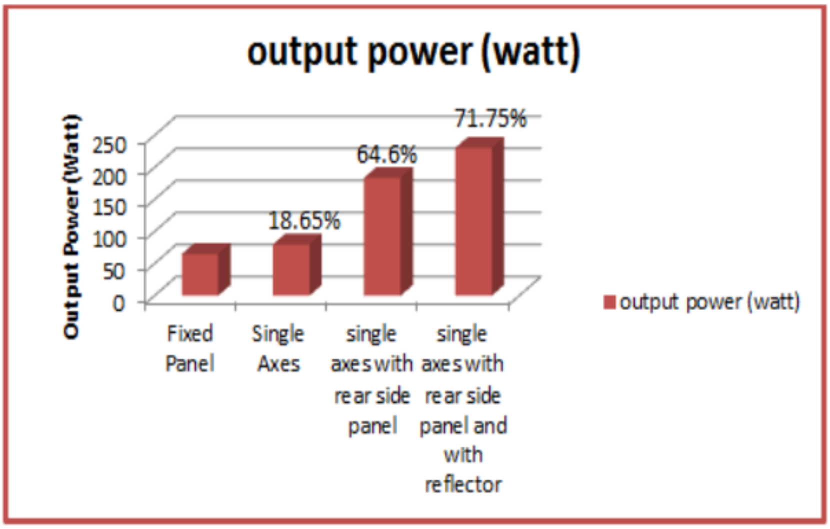


Figure II.7: The Percentage of the Output Power for the Single Axis Tracker, Fixed Panel and addition rear side Panel with Reflector in November 2016[30].

Elibrahimi, M., et al.2018.morroco This literature dealt with the evaluation and performance of the dual-axis tracking system, and it was concluded from the results that an increase of 31% was obtained from the theoretical study (simulation) and 28% in a real experiment, where it was concluded that when the tracking system is installed for 3 days we will gain the energy produced within 4 days of fixed plate, [31].

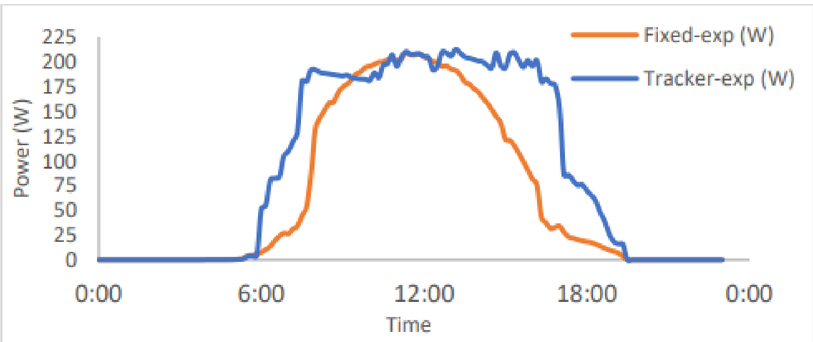


Figure II.8: Experimental results for fixed and tracked systems[31]

Lee, K.-Y., et al 2017. Taiwan. This literature discusses a new algorithm for tracking the sun, called the direct search method, where the solar panel rotates once an hour to avoid the effect of cloud shadow and the shadow of neighboring buildings. The results show that the direct search algorithm is 3.4% higher than the 1A-3P algorithm [32].

Alayi, R., et al., 2022. Russia This literature dealt with ways to save energy through tracking devices, and which tracking method is more energy-saving, and the results were that a panel without a tracking device has the same production as vertical tracking of the sun, while two-way tracking technology has a greater production rate, using sun-tracking technology. It produces more energy and helps free up batteries during the day to cover high-consumption [33].

Reeve, A. 2011. Tunisia In this literature work, a comprehensive review of the DAST algorithm for sun tracking has been carried out, in which different modules are introduced and included in the simulation. The sun is tracked by changing the orientation of the solar panel in the horizontal and vertical directions by two motors. These motors are controlled by a microcontroller. The proposed system has the ability to track using sun position data. [34].

Shankar, G. and R.S. Singh, 2014. India The review focused on the types of sun-tracking devices and models on which sun-tracking technology depends were presented. They were classified into two types, horizontal and vertical, and each type has several categories with which it operates, such as linear and non-linear intelligence technology and artificial intelligence [35].

II.2. Modeling of photovoltaic system:

The mathematical modeling of solar cells is essential for any operation to optimize the efficiency or diagnose the photovoltaic generator. The photovoltaic module is generally represented by an equivalent circuit whose parameters are calculated experimentally using the current-voltage characteristic. These parameters are not generally measurable quantities or included in manufacturing data. Consequently, they must be determined from the systems of equations V-I at various operating points given by the manufacturer or from direct measurement on the module.

The current voltage characteristics of the PV generator are represented by I=f(V). Temperature and illumination data obtained from the generator characteristics are the two inputs used in this simulation, which are often used to approximate the generator output (voltage, current). The photovoltaic module's generated current at a specific voltage is solely dependent on the cell's temperature and level of illumination. The circuit load determines a solar cell's efficiency under constant lighting and temperature conditions. [36]

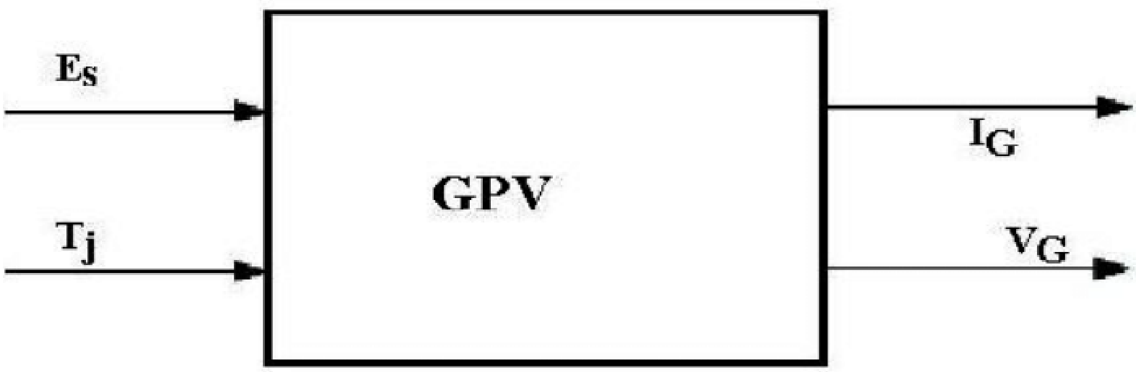


Figure II.9: Photovoltaic generator block diagram.

- Modeling of a Photovoltaic cell

An equivalent electrical diagram for a photovoltaic module consists of a power source that simulates the conversion of light into electrical energy, a series of resistance Rs that simulates resistance losses within the solar cell and consequently the metallizations (differing contact and connection resistances), and a parallel-connected diode that simulates the PN junction. As a result, the photovoltaic module is distinguished by its electrical diagram

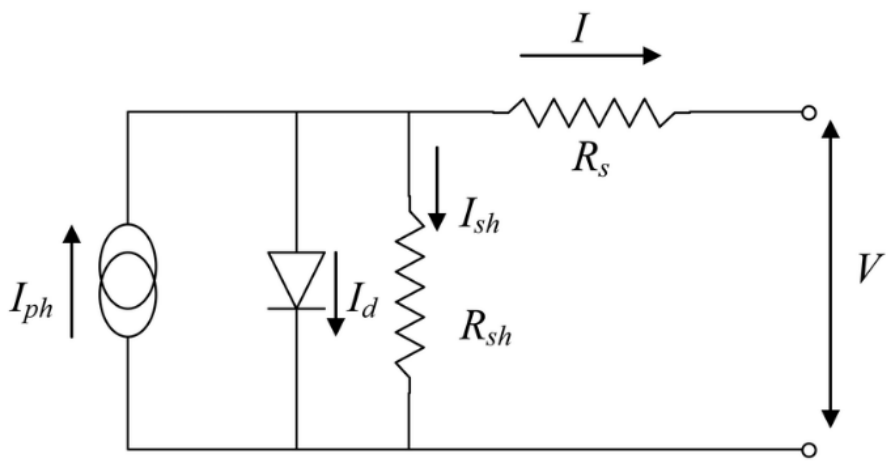


Figure II.10: Equivalent diagram of a one-diode model PV cell

Using the analogous circuit shown in the picture, the following analysis can be performed using Kirchhoff's law and ignoring the shunt resistance:

$$\mathbf{I = I_{ph} - I_d} \qquad (II.1)$$

Where:

$I_{ph:}$ is light or photo current, and it depends on irradiance and temperature, it can be measured at certain reference conditions as written in (II.2):

$$I_{PH} = \left(\frac{G}{Gref}\right) Iccref[1 + K0(Tc - Tr)] \qquad (II.2)$$

G, $G_{ref:}$ the actual and reference lighting conditions (W/m^2).

le coefficient de température du courant de court-circuit (A/K°).

T_C, T_{Cref}: the actual and reference temperature conditions (K°).

I_D: is the diode current, and it can be expressed as follows:

$$I_D = I0\left[\left(\exp\left(q\frac{V + RsI}{nKT}\right)\right) - 1\right] \qquad (II.3)$$

$$I_0 = I0(Tr)\left(\frac{T}{Tr}\right)^3 \exp\frac{-qVg}{nK}\left(\frac{1}{T} - \frac{1}{Tr}\right) \qquad (II.4)$$

Where:

E_g: band gab energy of the material (1.12 eV for silicon).

From equation (II.2) and (II.3), equation (II.1) can be written in more detail as follows:

$$I = Ip\square - I0\left[exp\, q\left(\frac{V + RsI}{nKT}\right) - 1\right] \qquad (II.6)$$

II.2.3 modeling of inverter

The inverter is an important device in the field of electrical engineering and is one of the most widely used converters, as it converts direct current (DC) into alternating current (AC), as most devices use alternating current. The inverter relies on connected electrical elements to convert current, some of which can be controlled and others which are not. The closing and opening of the static transformer switches of the circuit breakers (GTO, transistors, MOSFET, IGB, etc.) that the inverter relies on to transform current is controlled by codes 0 and 1, meaning 1 means the breaker is closed and 0 means open. Commands are issued via automatic control devices.

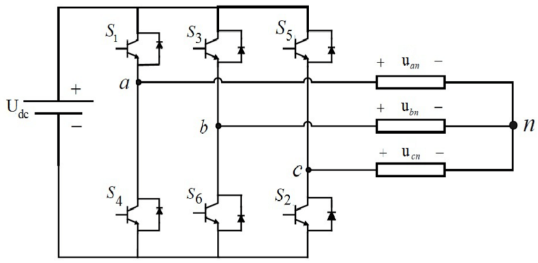


Figure II.11: Three phase inverter structure

- **PWM command**

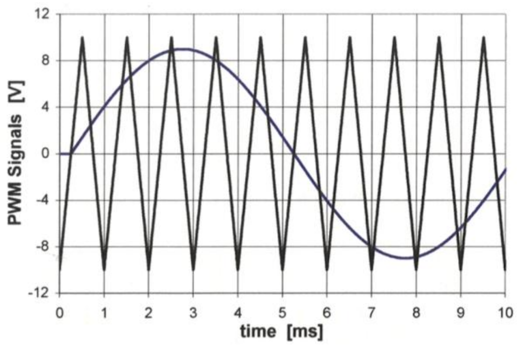


Figure II.12: PWM command[37].

The PWM control method is based on two curves: the first is sinusoidal and the second is highly frequency. When the sinusoidal curve is above the high-frequency curve, the method gives an order to open, and when the sinusoidal curve is below the high-frequency curve, the method gives an order to close. This is how the method works in Converting direct current to alternating current [37].

The modulation index:

$m = \frac{fd}{f0}$ with m >> 0

f_d: The carrier frequency.

f_0: The frequency of the modulator.

$R = \frac{Vsin\ max}{Vtri\ max}$

R :The ratio of the amplitudes of the modulator and the carrier. Generally, R is between 0 and 1 (the amplitude of the reference remains lower than that of the carrier).

II .2.2 Modeling a Chopper

Choppers are used in solar energy systems to find the maximum power point by performing an impedance adaptation between the GPV and the load.

DC-DC converters are power electronic circuits that convert a DC voltage to a different voltage level. Choppers are used in PV systems to regulate the voltage and current output, ensuring efficient energy transfer from the PV panels to the load or battery storage. Here, we'll outline the basic principles and mathematical equations involved in modeling such a system. [38].

The mathematical equations for the chopper circuit depend on the specific configuration (buck, boost, or buck-boost) and control strategy (voltage mode control, current mode control, etc.)[39].

For a basic buck-boost converter operating in continuous conduction mode, the relationship between input and output voltages, duty cycle, and the switch is described by the following equations:

$$V_0 = \frac{D}{1-D} V_S$$

Where:

V_0 = Output voltage

V_S = Input voltage

D = Duty cycle of the switch (ratio of ON time to total period)

The duty cycle D can be controlled based on the desired output voltage or current to regulate the power delivered from the PV module.

The overall system model combines the PV module model and the chopper circuit model to predict the behavior of the PV system under different operating conditions.

This model can be used for simulation and design optimization of PV systems.

When designing a PV system with a chopper circuit, it's essential to consider factors such as efficiency, control strategy, component selection, and environmental conditions to ensure optimal performance[40].

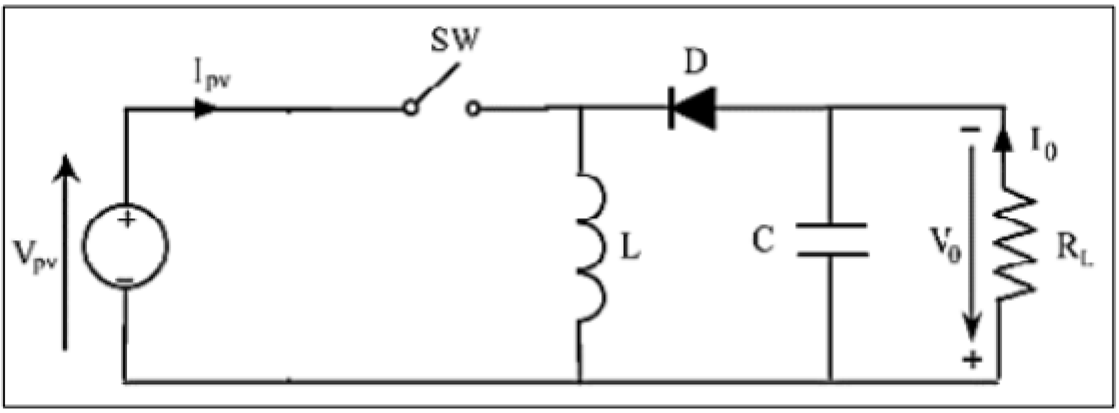


Figure II.13: Circuit diagram of a Buck-Boost converter[40].

➢ **MPPT control algorithm**

A typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. Maximum power point tracking (MPPT) technique is used to improve the efficiency of the solar panel [41].

By definition, an MPPT control makes it possible to operate a PV generator to continuously produce the maximum of its power. Thus, whatever the weather conditions (temperature and irradiation), and whatever the battery voltage or the load, the converter control places the system at the maximum operating point [42].

Consequently, for the same illumination, the power delivered will be different depending on the load. An MPPT controller therefore makes it possible to control the static converter connecting the load and the photovoltaic panel so as to constantly provide maximum power to the load at all times.

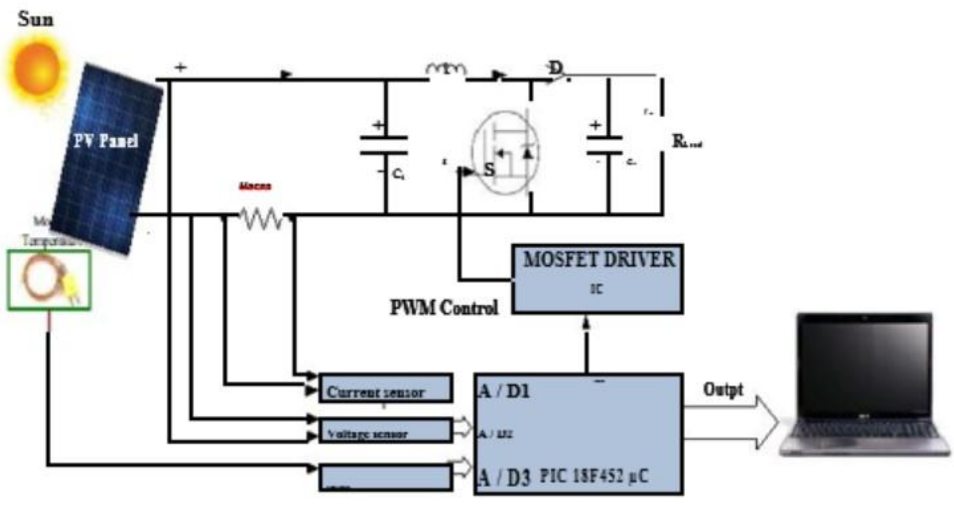


Figure II.14: MPPT Controller, Solar PV block diagram[42]

II.2.5 modeling of grid

The electrical network is a means of transmitting electrical energy over large distances, to deliver energy from production to consumption, as well as connecting cities and factories to each other to ensure energy parity. The network bears high-voltage energy to reduce electrical losses and to transmit it properly to the consumer. It is divided into three The main departments are production, transportation and distribution

Figure II.15: A diagram of the electrical network

The three-phase network three sinusoidal quantities of the same frequency, phase shifted from each other of $2\pi/3$, and having the same effective value, form a balanced three-phase system[43]

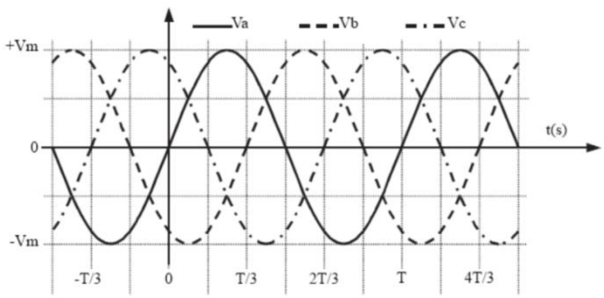


Figure II.16: Three-phase diagram

Electricity distribution network. It is based on a three-phase voltage system. We can generally look at the voltage equations for each phase and notice that there is a displacement between each phase and another at an angle $2\pi/3$.

- $V_a = V_m \sin(\omega t)$ $U_{ab} = U_a - U_b$ $V_m = \sqrt{2}\, Veff$
- $V_b = V_m \sin(\omega t - \frac{2\pi}{3})$ $U_{bc} = U_b - U_c$ $U_m = \sqrt{3}\ Vm$
- $V_c = V_m \sin(\omega t - \frac{4\pi}{3})$ $U_{ca} = U_c - U_a$ $U_{eff} = \sqrt{3}\, Veff$

II.2.4 modeling of transformer

Electrical transformers are transformers that raise or lower the voltage or electric current from a sinusoidal alternating current to a sinusoidal alternating current. They are usually part of the electrical network in any part of it, whether in the production, transmission, or distribution phase. Transformers consist of a number of turns of copper wires such that There are a number of turns of a primary copper wire on one side and a number of turns of a secondary copper wire on the other side, without touching each other. They are wrapped around an iron structure that is usually square in shape. The electrical values between the copper windings are doubled or decreased through their transmission through magnetic induction.

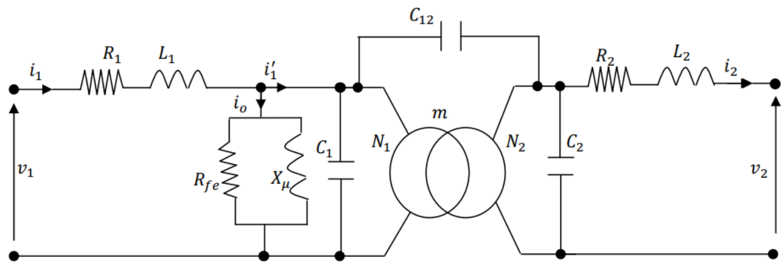


Figure II.17: Actual transformer diagram[44].

The transformer has three columns, each column has its own electromagnetic field. Each column contains a primary coil and a secondary coil. The total electromagnetic fields are balanced between them, and the following relationship connects them: ($\phi 1 + \phi 2 + \phi 3 = 0$)

A three-phase transformer uses the effects of magnetic induction, with each phase having a primary winding and a secondary winding built into it, connected to a structure that is usually iron. With the passage of an electric current, the primary coil begins to produce an electromagnetic field, and the secondary coil receives it to produce a flow of F.e.m. In turn, it will produce an alternating electric current. The equations of the secondary and primary coil[44]:

$e_1 = n_1 (d\phi /dt)$

$e_2 = -n_2 (d\phi /dt)$

- **General operating equation**

$V_a = V_1\sqrt{2}\,\sin(\omega t) = N_1 \frac{d\phi a}{dt}$

$V_b = V_1\sqrt{2}\,\sin(\omega t - \frac{2\pi}{3}) = N_1 \frac{d\phi b}{dt}$

$V_c = V_1\sqrt{2}\,\sin(\omega t - \frac{4\pi}{3}) = N_1 \frac{d\phi c}{dt}$

Electromagnetic loss equations[46]

$\phi_c = L_1 i_1 + M_{12} i_2$

$\phi_c = L_2 i_2 + M_{21} i_1$

Transformation ratio per column mc: $mc = \frac{N2}{N1} = \frac{e2}{e1} = \frac{i1}{i2}$

It is defined as the ratio of the number of secondary turns to the primary

Transformation report by phase mph : $mph = \frac{Uab}{UAB}$

It is the ratio of the secondary no-load voltage to the primary voltage.

II.3 Characteristics of the PV model (for each type):

The different existing PV cell technologies are:

1st technology based on crystalline silicon:

The first generation cells are based on a single P-N junction which uses generally silicon in crystalline form as a semiconductor material. The method of production based on silicon wafers is very energy-intensive and therefore very expensive. It also requires a high level of pure silicon. This technology uses monocrystalline and poly crystalline silicon base cells [46]

2nd generation thin-film technology:

This model of a photovoltaic cell is made of silicon or other materials. Thin-film cells are what some call second-generation cells because they historically follow on from relatively thick crystalline silicon cells. There are several types of thin film cells, namely [47]:

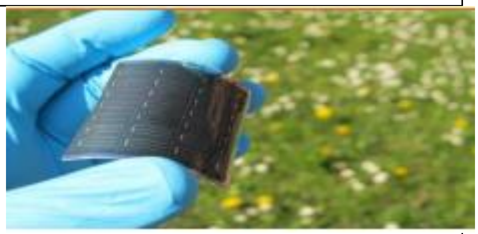
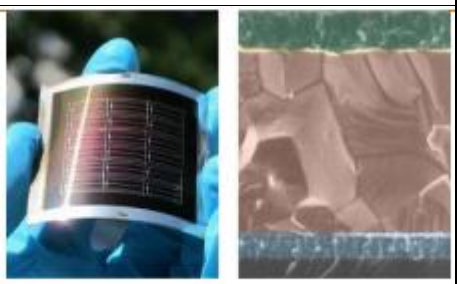
- Amorphous silicon (a-si).
- Cadmium tellurium (CdTe).
- Copper / Indium / Selenium or Copper / Indium / Gallium / Selenium (CIS or CIGS)

3rd generation technology:

They are made up of organic molecules combining flexibility and lightness. These technologies are still in the research and development stage. There are three types of cells [46]:

- Multilayer cell
- Organic cell
- Concentration cell

Table II.1: types and Characteristics of photovoltaic

Cell type	**yield**	**Advantages**	**disadvantages**	**Drawing**
Silicon polycrystalline	11-15%	Good yield for module	High manufacturing cost, loss of material during manufacturing	
Silicon monocrystalline	13-17%	Good yield for a cell	High manufacturing cost, loss of material during manufacturing	
Amorphous silicon	5-6%	Easy to make	Poor performance	
CdTe	7-11%	Absorbs 90% of incident photons	Cadmium Very polluting	
CIGS	20%	Adjustable gap energy 99% of absorbed photons	Lack of raw material	
Organic cells	5%	Low cost of flexible manufacturing	Yield still too low	

II.4 Conclusion

In this chapter, some literature has been referred to identify the modern technologies that science has reached at present in tracking systems for photovoltaic panels and how to exploit them to benefit from maximum efficiency. The direct current transformer is considered an essential part to ensure good conversion in raising the value of the energy produced, then the transformer Sinusoidal transforms direct current into alternating current so that its type is suitable for the local network. Then we send the alternating current to the central transformer to raise the energy to send it to the network. The types of photovoltaic panels were also reviewed and studied to choose the most suitable according to their need, and the “Ghardaia-Oued Nechou” production station was also taken into consideration. A model for studying the structure of a production station

CHAPTER III

Results of simulation and comparison between fixed and tracking systems

III.1. Introduction

In this chapter, we will analyze and monitor the voltage, current, and energy resulting from a photovoltaic power station in an area in southern Algeria, Ghardaia Province, in the village of Oued Nashou. In this study, we attempt to analyze the curves resulting from the simulation of the station, stabilize it, and increase efficiency, in environmental conditions. The study aims to simulate between a variable-angle photovoltaic panel and a fixed-angle photovoltaic panel, and conclude the best possible yield in terms of the necessary energy production, discover some defects, and try to propose realistic solutions to improve the system for higher production.

III.2 Definition of Matlab Simulink

A programming language and software environment used in scientific and engineering computers is called MATLAB. It was created by MathWorks and is now a widely used tool in the natural sciences, engineering, and mathematics domains. Numerical analysis, model building, numerical experimentation, equation solving, signal processing, and other sophisticated mathematical and engineering tasks can all be carried out with MATLAB.

The primary benefit of MATLAB is its efficient handling of arrays and numerical data. Because of its versatile language, users may easily understand and implement mathematical principles and design programming scenarios. A vast array of tools and libraries are also included with MATLAB, supporting a wide range of scientific and engineering applications. [43].

III.3 Climatic condition

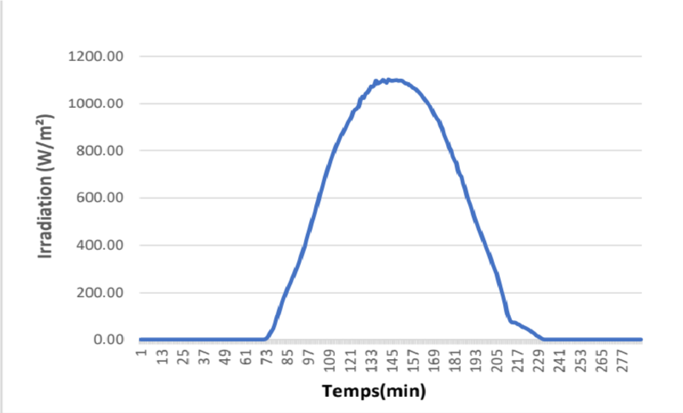


Figure III.1: a real evaluation curve of solar radiation from the Oued-Nechou power plant for the day of 02/05/2016 [22].

This curve shows the change in solar radiation as a function of time during 4.6 hours during a specific day, where the radiation starts from zero and increases to the maximum value in the middle of the day and then decreases until it reaches zero.

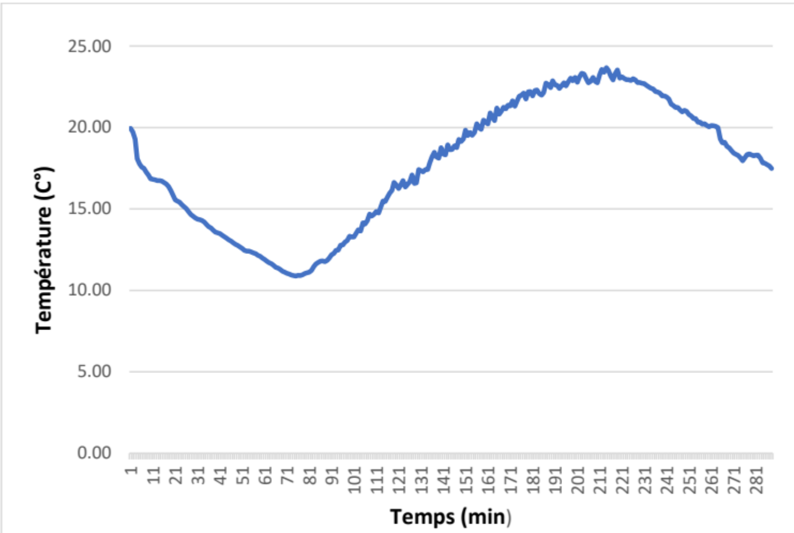


Figure III.2: The real evaluation curve of the temperature in the Oued Nshou power station for 05/02/2016 [22].

The curve shows a change in temperature over a period of 4.68 hours, as the temperature begins to rise gradually from the beginning of the day, reaching a maximum value of 24 degrees Celsius, and then begins to gradually decrease coinciding with sunset.

III.4 simulation of photovoltaic systems with grid

We will review and analyze the systems used in the photovoltaic generating station on the role of each system

III.4.1 simulation of tracking and fixed panel systems

Table III.1: the parameters of each PV array for simulation [22].

PV arrays	Parallel Chains	Modules connected in series by chain	P max (W)	number of PV cells	Voc (V)	Vmp (V)	Isc (A)	Imp (A)	T Isc (%/C°)	T Voc (%/C°)
Pv Array 1	21	20	250.084	60	37.62	30.35	8.79	8.24	+0.03	-0.34
PvArray 2	21	20	235.224	60	36.94	29.04	8.64	8.10	+0.04	-0.32
PvArray 3	105	12	80.025	154	60.8	48.5	1.88	1.65	+0.04	-0.20
PvArray 4	54	18	103.056	72	41.1	30.4	4	3.39	+0.08	-0.33
PvArray 5	21	20	250.084	60	37.62	30.35	8.79	8.24	+0.03	-0.34
PvArray 6	21	20	235.224	60	36.94	29.24	8.64	8.10	+0 .04	-0.32
PvArray 7	21	20	250.084	60	37.62	30.35	8.79	8.24	+0.03	-0.34
PvArray 8	21	20	235.224	60	36.94	29.04	8.64	8.10	+0.04	-0.32

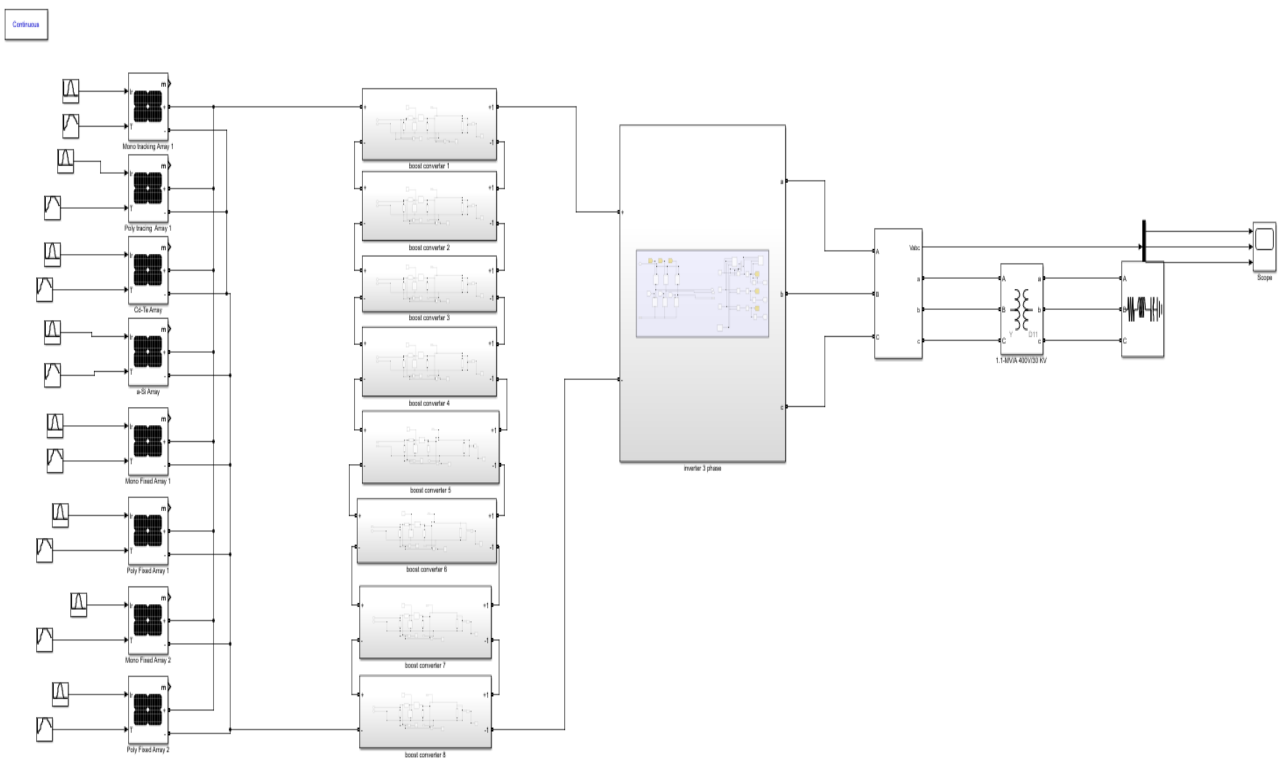


Figure III.3: plan of ouad-Nachou photovoltaic power plant

The plan showing the parts diagram of the photovoltaic power generation station in Ouad Nachou Where 8 photovoltaic arrays were connected, 2 under the sun tracking system and 6 with a fixed angle, the energy produced from them is collected in a power boost converter (chopper), then the energy is transferred from the direct current converter to the alternating current converter, then to the voltage step-up transformer to be sent to the local network.

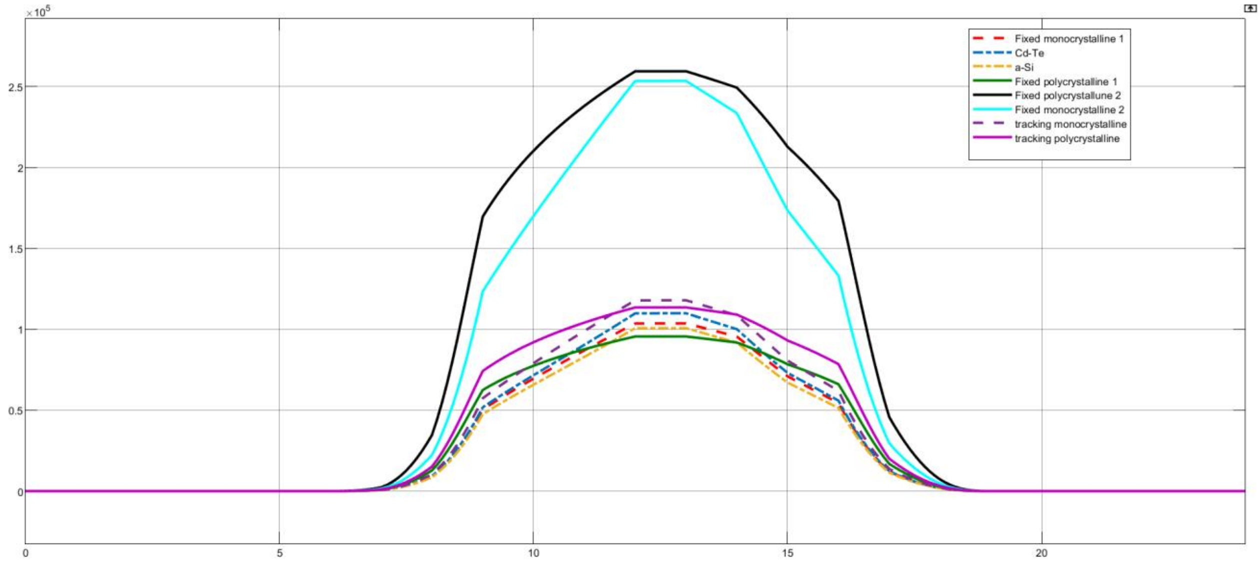


Figure III.4: photovoltaic arrays results

The (III.4 Figure) shows the power production curves during 24 hours, where we notice that there are 6 curves, 2 with variable angle and 4 with a fixed angle. The power produced among them ranges from 100 KW. We also noticed 2 curves with a higher power production, about 250 KW, with a fixed angle.

III.4.2 simulation of boost converter (DC-DC)

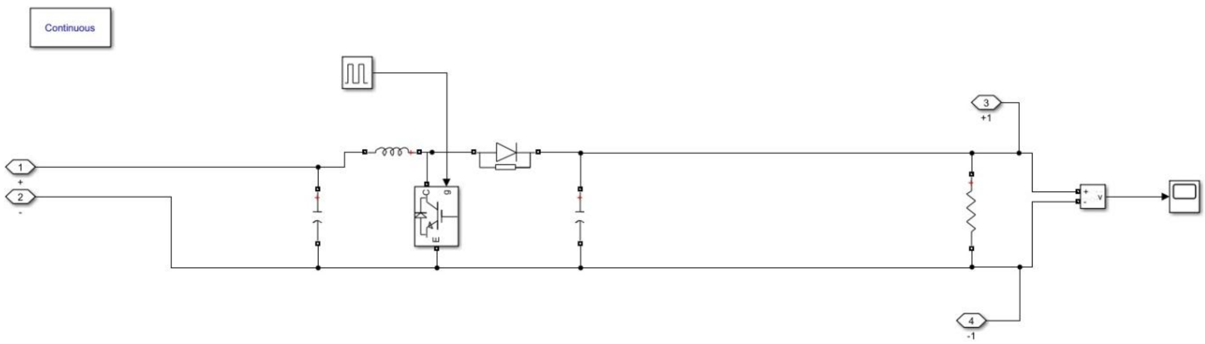


Figure III.5: boost converter block diagram

We use a DC/DC converter to raise or lower the value of direct current , and it is usually connected to a PV panel to raise the produced voltage. The diagram represents a schematic of it.

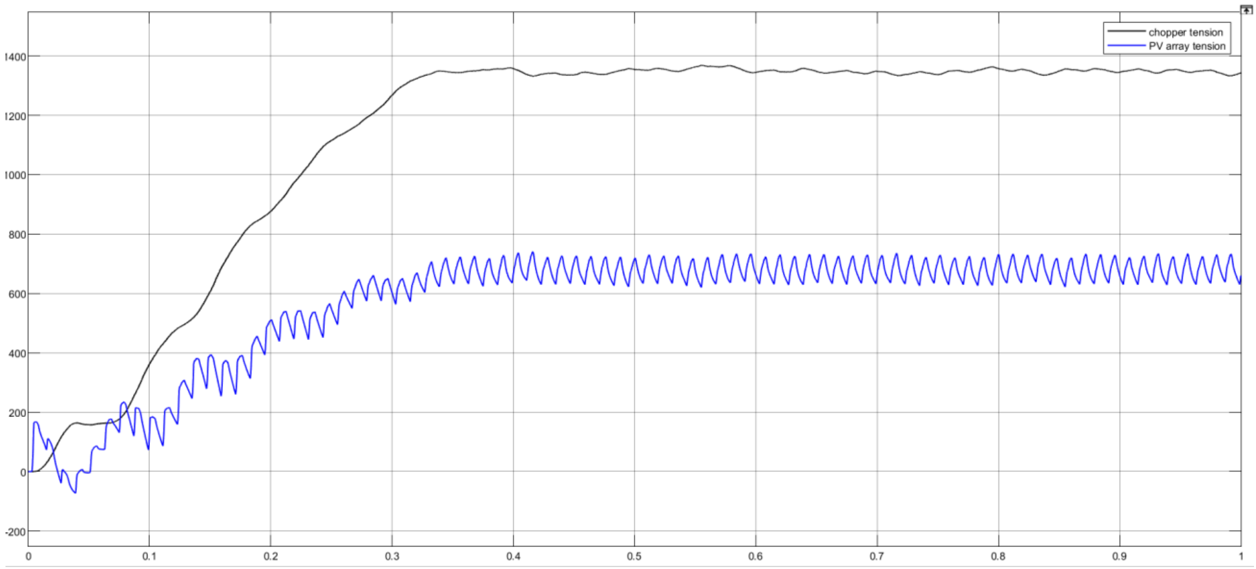


Figure III.6: Tension curve before and after connecting to boost converter

We notice that the boost converter increases the voltage of the photovoltaic panels after it is connected with a filter

III.4.3 simulation of three phase inverter (DC-AC)

The function of the three-phase inverter is to change the DC voltage to the AC voltage to the transformer output so that the three-phase grid can be supplied.When using pulse width modulation, the inverter modifies the pulse width. It consists of 6 switches in the form of a bridge that is quickly controlled for good conversion and to ensure the maximum power value, a voltage is usually obtained that is usually not sinusoidal enough, then it is preferable to use a filter to obtain a sinusoidal current properly.

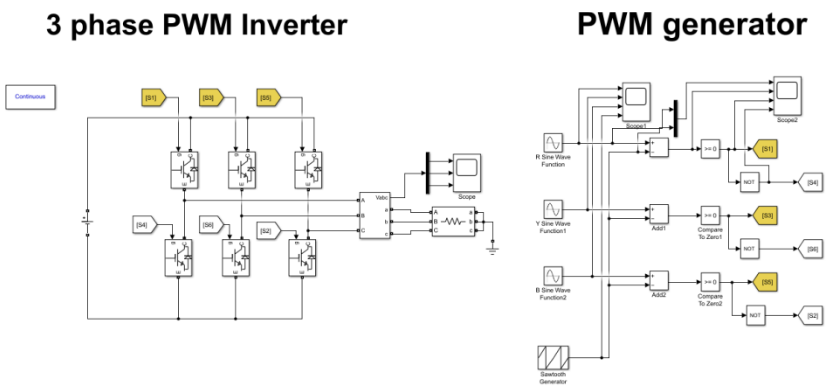


Figure III.7: Three-phase inverter block diagram.

We examine the three-phase voltage coming out of the inverter

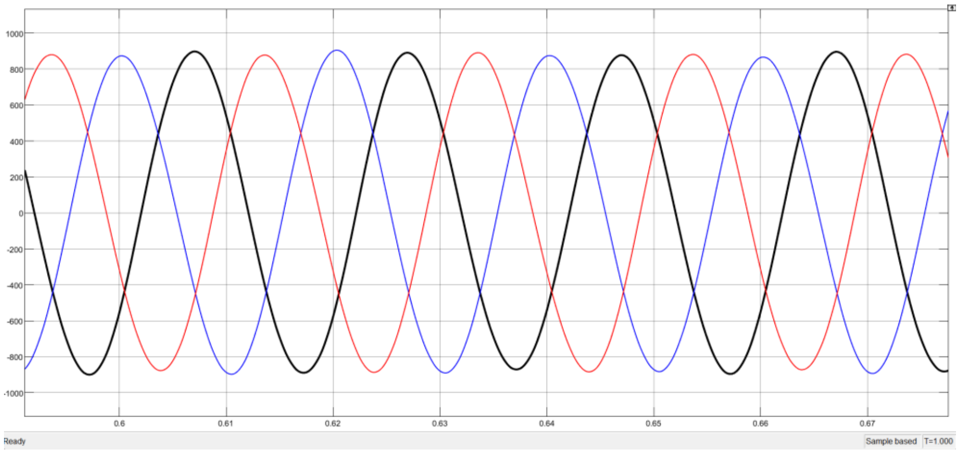


Figure III.8: filtered output three phase voltage.

III.4.4 simulation of transformer and the grid

We use a BT/MT step-up transformer with a power of 750 Kva to represent our model of the Oued-Nechou photovoltaic power plant, which is connected to the public electricity distribution network. This converter is located on the power supply (AC) side and offers the possibility of raising the output voltage of the inverter from 1000 V to the grid voltage of 30 Kv. Our model therefore presents an electrical network with a voltage of 30 Kv and a frequency of 50 Hz.

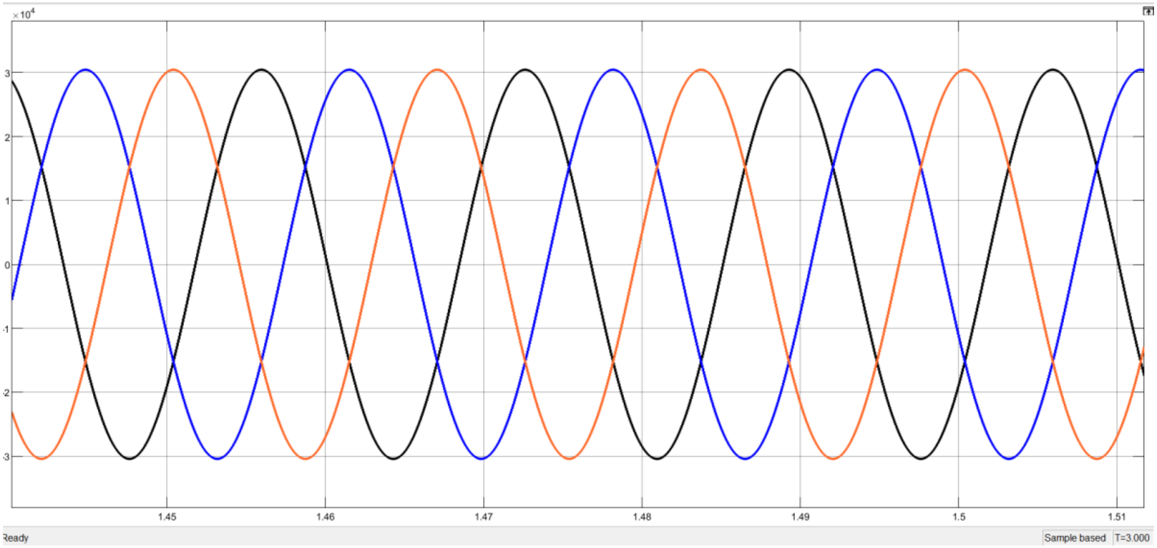


Figure III.9: tension of transformer and the grid.

III.5 result of power generated from tracked and fixed panels

- **result of power generated from tracked and fixed arrays**

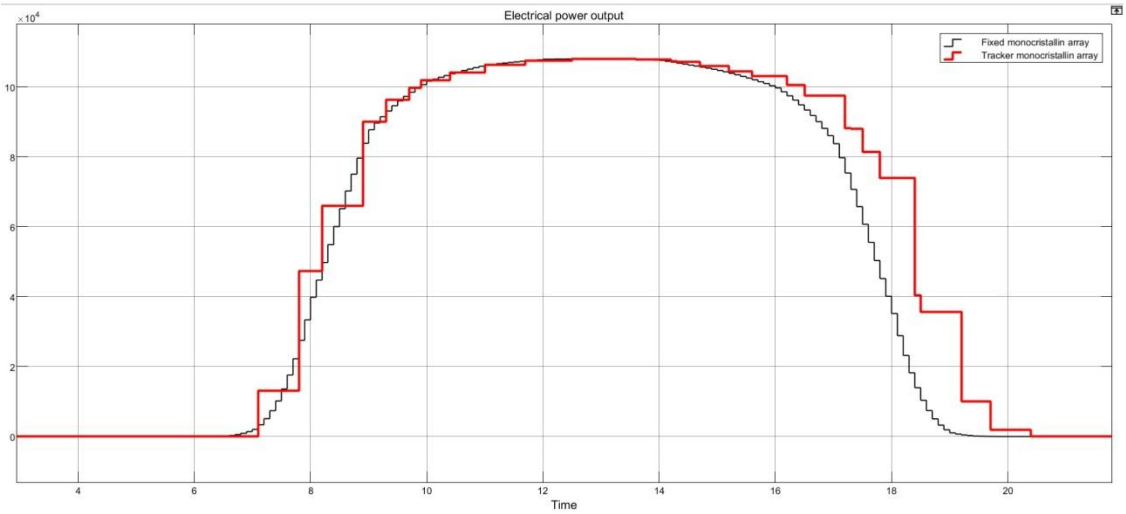


Figure III.10: power generated curves from tracked and fixed monocrystalline arrays

Table III.2 : Table of power generated form monocrystalline arrays during one day

Hours	Power of fixed case (W)	Power of tracked case(W)	power difference(W)
7	3356.166	13056.28	9700.11383143102
8	39859.32	47376.97	7517.6484756381
9	87757.16	90039.46	2282.2926352981
10	101668.5	101878.5	209.999302380995
11	106326.2	106397.4	71.2163481019961
12	107957.6	107593.6	-364.066904512991
13	108098.5	108071.6	-26.8466536979977
14	107623.8	107952.1	328.355951042002
15	104740.3	105955.7	1215.410729116
16	99728.61	103168.1	3439.4476510088
17	83764.57	97595.75	13831.1784698729
18	35175.68	73932.29	38756.6164301891

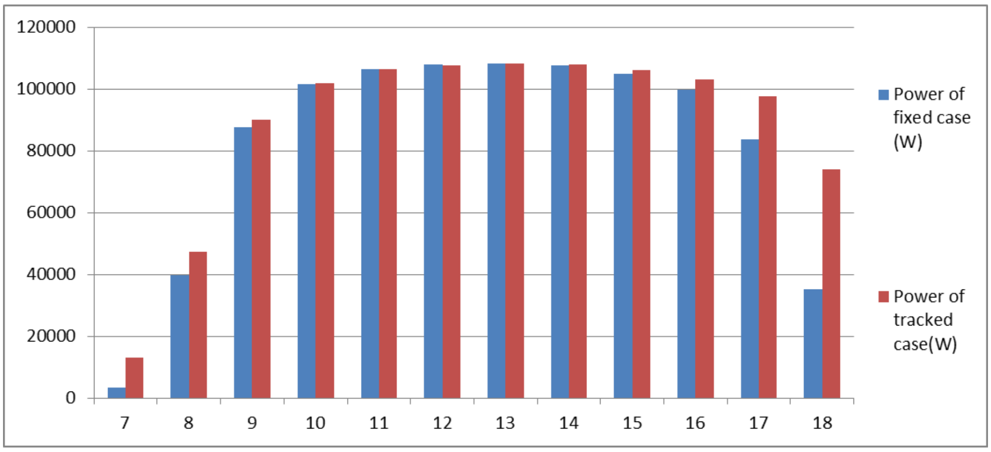


Figure III.11 : Bar charts to compare power generated between monocrystalline tracked and fixed arrays

We notice an increase in production for the sun-tracking array from the beginning of the day from 7 a.m. until 10 a.m., where we notice equal production between the monocrystalline sun-tracking array and monocrystalline fixed array, with a maximum value of about 108 kilowatts, and stability continues until 14 noon, then power increases. By sun-tracking panels from 14 noon until 18

There is an error in the beginning curve because the optimization and the control method are not suitable enough for our study this is why the curve is not smooth but with calculation, we could reach the necessary result

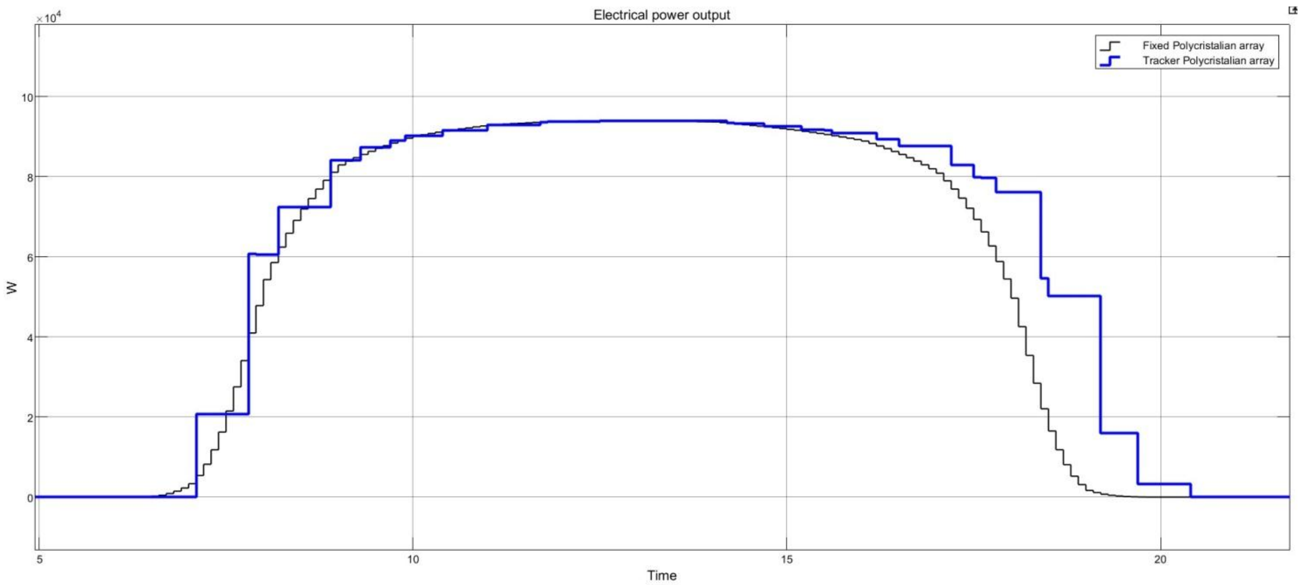


Figure III.12: power generated curves from tracked and fixed polycrystalline arrays

Table III.3 : Table of power generated form polycrystalline arrays during one day

Hours	Power of fixed case (W)	Power of tracked case(W)	power difference
7	5408.863995	20697.22547	15288.3614732083
8	54318.97992	60647.81181	6328.8318888463
9	82964.06015	84068.11594	1104.0557919733
10	90172.20827	90290.90583	118.697556486601
11	92949.59707	92992.81148	43.2144121548918
12	93965.87915	93728.52061	-237.358543628594
13	94028.50957	94009.94446	-18.5651089972962
14	93691.26355	93903.01799	211.754438008502
15	91854.69972	92602.72855	748.0288330068
16	88918.89331	90884.9557	1966.0623924588
17	80895.54905	87733.20112	6837.65207274309
18	49665.26793	76229.14748	26563.8795486469

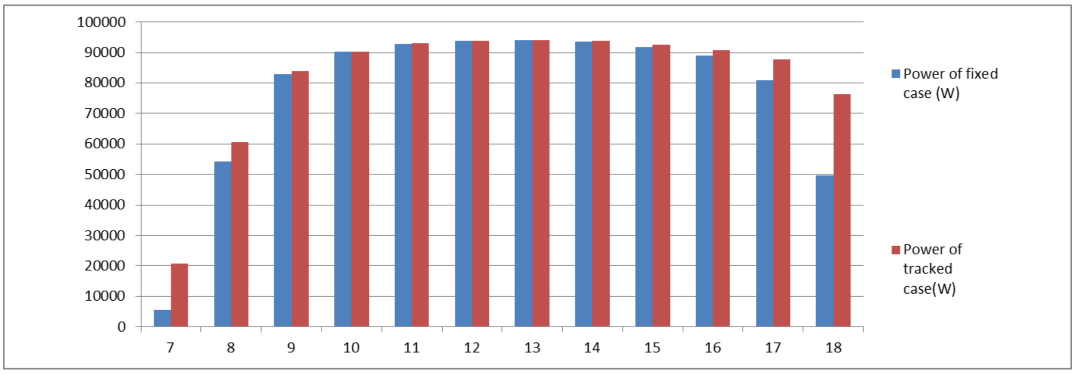


Figure III.13 : Bar charts to compare power generated between polycrystalline tracked and fixed arrays

We notice an increase in production for the sun-tracking array from the beginning of the day from 7 a.m. until 10 a.m., where we notice equal production between the polycrystalline sun-tracking array and polycrystalline fixed array, with a maximum value of about 94 kilowatts, and stability continues until 14 noon, then power increases. By sun-tracking panels from 14 noon until 18

There is an error in the beginning curve because the optimization and the control method are not suitable enough for our study this is why the curve is not smooth but with calculation, we could reach the necessary result

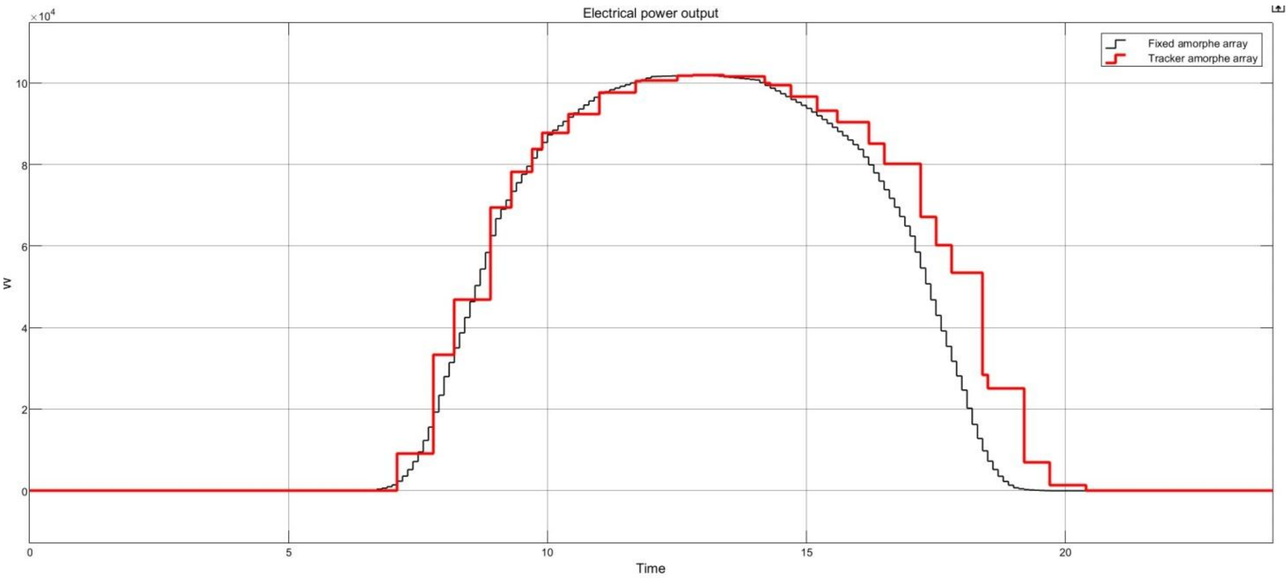


Figure III.14 : power generated curves from tracked and fixed Amorphe arrays

Table III.4 : Table of power generated form amorphe arrays during one day

Hours	Power of fixed case (W)	Power of tracked case(W)	power difference
7	1448.416622	9160.430412	7712.01378931566
8	27983.39158	33309.35785	5325.9662663079
9	66758.92219	69451.8735	2692.9513120216
10	87294.94269	87705.48947	410.546777947195
11	97436.52325	97609.95011	173.426862993001
12	101591.8546	100636.4278	-955.426812320991
13	101982.7404	101909.6573	-73.0830398429971
14	100748.3679	101609.1941	860.826272221006
15	93772.17625	96595.37056	2823.19431287861
16	83730.25184	90367.31249	6637.0606490432
17	62468.48992	80103.6713	17635.1813748854
18	24684.76863	53390.70759	28705.9389641171

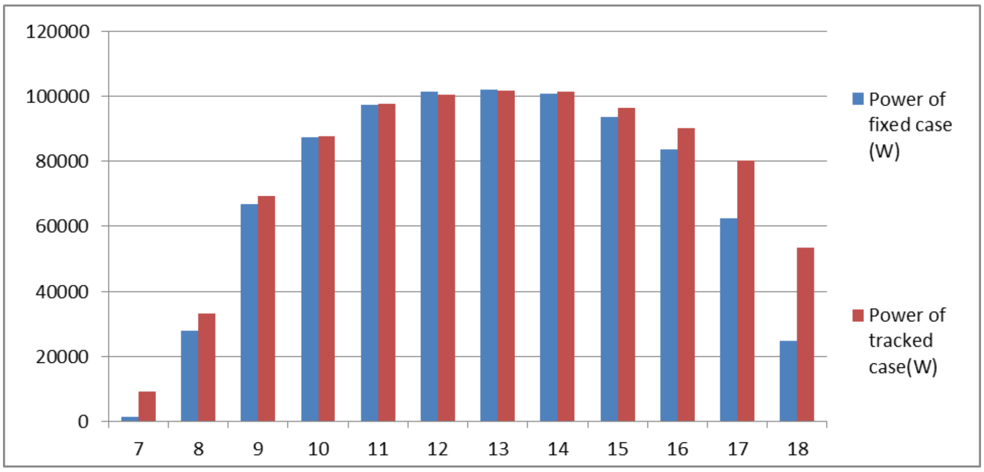


Figure III.15 : Bar charts to compare power generated between Amorphe tracked and fixed arrays

We notice an increase in production for the sun-tracking array from the beginning of the day from 7 a.m. until 10 a.m., where we notice equal production between the Amorphe sun-tracking array and Amorphe fixed array, with a maximum value of about 101kilowatts, and stability continues until 14 noon, then power increases. By sun-tracking panels from 14 noon until 18

There is an error in the beginning curve because the optimization and the control method are not suitable enough for our study this is why the curve is not smooth but with calculation, we could reach the necessary result

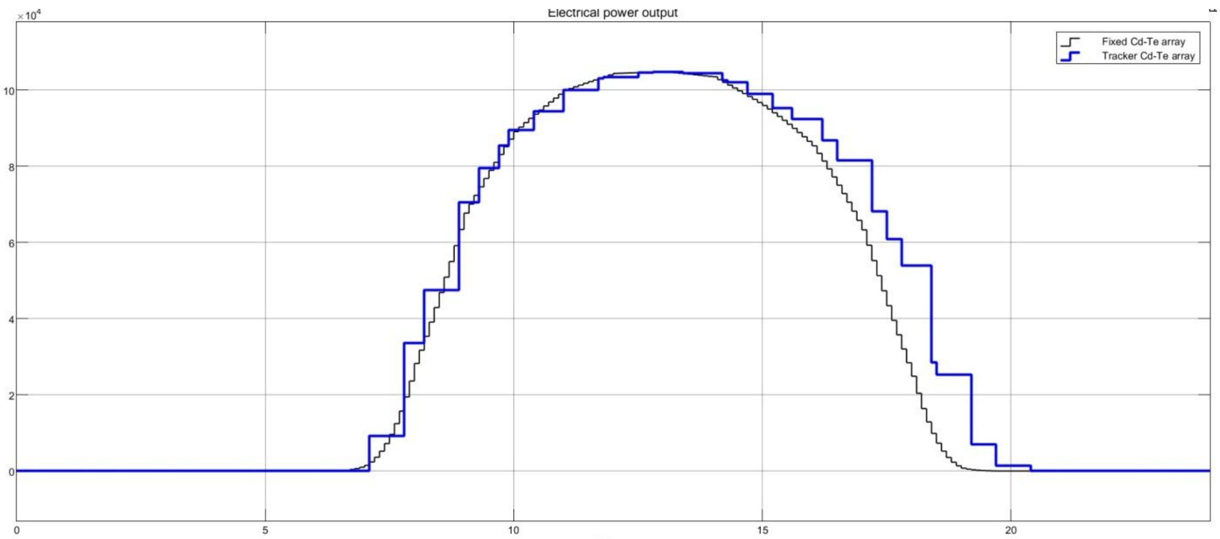


Figure III.16 : power generated curves from tracked and fixed Cd-Te arrays

Table III.5 : Table of power generated form Cd-Te arrays during one day

Hours	Power of fixed case (W)	Power of tracked case(W)	power difference
7	2372.693821	9230.907037	6858.21321553583
8	28230.74987	33619.34642	5388.5965505527
9	67735.49211	70514.80681	2779.3146997617
10	89140.53116	89574.41004	433.878882725898
11	99947.07652	100133.6981	186.621617485696
12	104435.1117	103399.1211	-1035.990644064
13	104857.1897	104777.7978	-79.3919078499894
14	103515.7803	104449.1789	933.398596084997
15	96011.76305	99034.91965	3023.1565963005
16	85377.3987	92385.07448	7007.67577873349
17	63316.9354	81575.8875	18258.9521011588
18	24896.24626	54023.19227	29126.9460129332

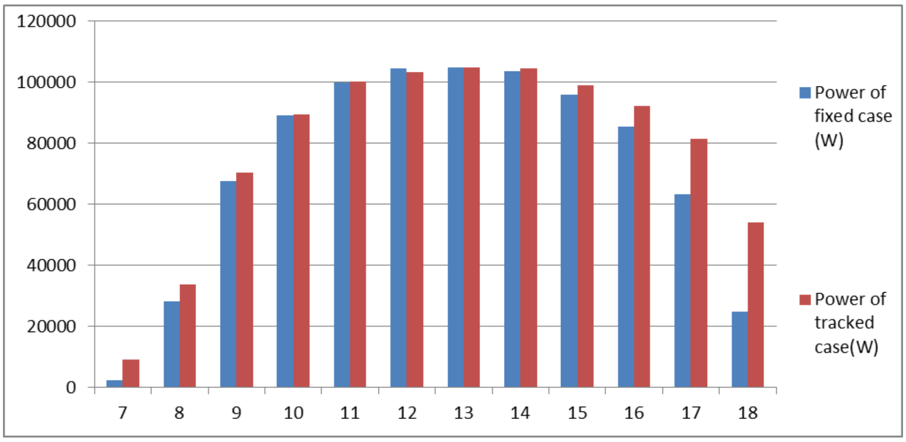


Figure III.17 : Bar charts to compare power generated between Cd-Te tracked and fixed arrays

We notice an increase in production for the sun-tracking array from the beginning of the day from 7 a.m. until 10 a.m., where we notice equal production between the Cd-Te sun-tracking array and Cd-Te fixed array, with a maximum value of about 104kilowatts, and stability continues until 14 noon, then power increases. By sun-tracking panels from 14 noon until 18

There is an error in the beginning curve because the optimization and the control method are not suitable enough for our study this is why the curve is not smooth but with calculation, we could reach the necessary result

III.6 problems and solutions of using photovoltaic panels tracking system

III.6.1 problems of tracking systems

By monitoring the sun's movement throughout the day, sun trackers for photovoltaic panels seek to improve energy production efficiency. But these systems could run into a number of issues, such as:

- Mechanical failures : Tracking systems need moving components like axles and motors. Over time, these components may wear out and break, which could result in a system failure.
- Periodic Maintenance : To maintain tracking systems' effective operation, frequent maintenance is required. Cleaning the panels, inspecting the mechanical components, and making sure no obstructions are obstructing the system's motion are all included in maintenance.
- Energy consumption : The energy provided by photovoltaic panels is diminished by the consumption of tracking systems, which takes up some of their energy.
- Installation and Maintenance Costs : Installing a sun tracking system adds additional cost to the photovoltaic system, and ongoing maintenance costs may be high.
- Sensitivity to weather conditions : Tracking systems' accuracy and stability may be impacted by strong winds.
- Control and Technology : Software-based systems that use sun monitoring may have software bugs or need to be updated on a regular basis.
- Integration with the electrical system : This can be a challenging process that calls for sophisticated technology and careful management. It can involve tracking systems, energy storage systems, or electricity grids.

III.6.2 solutions of tracking systems

Many fixes and precautions can be done to avoid the issues that solar trackers for PV systems encounter. Here are a few ideas for potential fixes:

- Periodic maintenance and monitoring : Create a routine maintenance plan that includes cleaning panels and inspecting mechanical components.
- Using high-quality materials : When manufacturing mechanical parts, go for strong, weather-resistant materials.

  -Reducing breakdown rates by using high-quality motors and electrical components.
- Improved system design : Including supports and fortifying structures to make systems more resilient to winds and storms.

  -Improving tracking accuracy with the use of contemporary sensor technology.
- Reducing energy consumption : The tracking system's energy consumption can be decreased by using more energy-efficient motors and controllers.

  -Better control software that minimizes needless panel movement.
- Software system update: To increase performance, use sophisticated control software that receives regular upgrades.

  -Including artificial intelligence methods to decrease errors and improve sun movement predictions.

By implementing these fixes, solar tracking systems' functionality can be enhanced and possible issues can be decreased, increasing energy production efficiency and lengthening the system's lifespan.

III.7 Conclusion

In conclusion, important details regarding the overall performance of the grid-connected PV power plant were obtained by examining the power, voltage, and current curves. This analysis helped enhance its balance, raise its efficiency, and improve its cost-effectiveness in energy production. Thanks to this analysis, the study conducted a simulation comparing a variable-angle photovoltaic panel with a fixed-angle photovoltaic panel, aiming to achieve the best possible productivity and efficiency in energy production. It identified some defects and proposed realistic solutions to improve the high-production system. We concluded that tracking devices can increase energy production during the morning and evening periods, which guarantees the consumer more energy when needed during these times. The percentage of energy increase depends on the type of photovoltaic panel.

General conclusion

During this study, we conducted a comparative analysis between fixed and tracking photovoltaic systems in southern Algeria, examining the operational dynamics of the photovoltaic station and the contributions of each component. Our investigation culminated in simulating the station connected to a network consisting of 8 arrays utilizing 4 types of photovoltaic panels, some fixed-angle and others variable-angle. These arrays are connected to DC transformers to adjust power according to demand and control, followed by an AC converter to convert energy for delivery to a transformer and onward distribution through the local network.

We evaluated four types of photovoltaic panels—monocrystalline, polycrystalline, Amorphous, and Cadmium Tellurium—in both fixed and variable configurations, comparing their performance and developmental potential. Our analysis led to several conclusions and proposed solutions aimed at enhancing system efficiency and productivity.

In particular, we compared the output of single-axis (azimuth) tracking solar panels with fixed solar panels using three databases: solar radiation, sun tracking, and fixed sun inclination, which were essential for our simulation. We modeled a pulse-operated 12V DC motor for tracking solar panels and utilized Simscape Multibody for animation. The simulation included two sets of solar cells to analyze their outputs.

Our findings indicated that energy production increases during morning and evening periods, with each panel type exhibiting unique characteristics suitable for specific environmental conditions. Monocrystalline and polycrystalline panels demonstrated higher productivity due to their efficiency and compatibility with local environmental data gathered during the simulation.

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Appendices

Appendices 1 : Tables of characteristics of photovoltaic panels that used in Ouad Nachou

- **Electrical characteristics of monocrystalline silicon panels**

Type	SOLARIA S6M-2G
Peak power	245 W_C
Peak power tolerance	0/+5 W_C
Module performance	15(%)
Max voltage (V_{mpp})	30.33(%)
Max intensity (I_{mpp})	8.08 A
Open circuit voltage	37.82 V
Short circuit current	8.52 A
Max system voltage	
100 V	

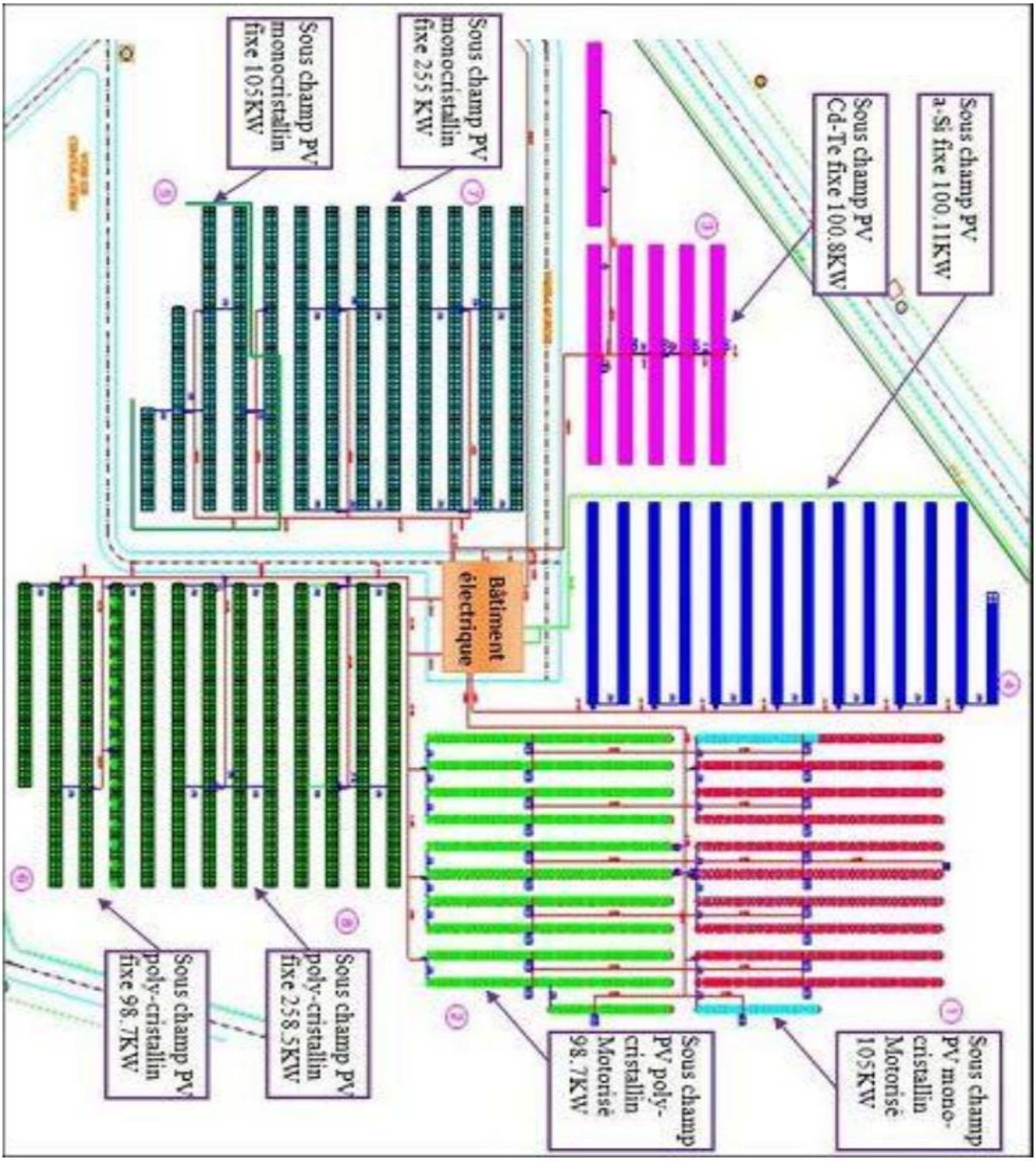
- **Electrical characteristics of polycrystalline silicon panels**

ATERSA type	A-235P
country of origin	Spain
Peak power	235 W_c
Peak power tolerance	0/+5 W_C
Module performance	14.43(%)
Max voltage (V_{mpp})	29.04 V
Max intensity (I_{mpp})	8.10 A
Open circuit voltage	36.94 V
Short circuit current	8.64 A
Max system voltage	100 V

- **Electrical characteristics of amorphous silicon panels**

Type	SCHOTI AS1 103
Peak power	103 W_C (Stabilized value)
Initial Peak power	125 W_C (Stabilized value)
Module performance	7.1(%)
Max voltage (V_{mpp})	30.9V (Stabilized value)
Max intensity (I_{mpp})	3.33A (Stabilized value)
Open circuit voltage	41.1V (Stabilized value)
Max system voltage	3.94 (Stabilized value)
Max system voltage	100V

• **Electrical characteristics of thin-film silicon panels**	
Type	FIRST SOLAR FS-380
Peak power	80 W_C
Peak power tolerance	+/-5(%)
Module performance	11.1(%)
Max voltage (V_{mpp})	84.5V
Max intensity (I_{mpp})	1.65A
Open circuit voltage	60.8
Max system voltage	1.88
Max system voltage	1000V



Appendices 2 : Segmentation and distribution of the photovoltaic station[23].

Summary

Abstract

In this study, we studied the Ouad Nachou photovoltaic station with a capacity of 1.1 MW as a model for studying fixed and variable angle photovoltaic panels (solar tracking). We simulated 4 types of photovoltaic panels present at the station and compared each type in the steady state and in the sun-tracking state, where we found that there was an increase in energy from the photovoltaic panels that track the sun, and the mono-crystalline and polycrystalline types benefited the most from the trackers.

key words : Photovoltaic panels, sun tracking, simulation, comparison, types of photovoltaic

الملخص

في هذه الدراسة قمنا بدراسة محطة الكهروضوئية واد نشو ذات مقدار 1.1 MW كنموذج لدراسة الالواح الكهروضوئية ثابتة الزاوية و المتغيرة الزاوية (تتبع الشمس) و قمنا بمحاكاة 4 انواع الالواح الكهروضوئية الموجودة في المحطة و مقارنة كل نوع في حالة الثابتة و في الحالة المتتبعة للشمس ، حيث وجدنا ان زيادة في الطاقة من قبل الالواح الكهروضوئية المتتبعة للشمس ، وكان النوعين monocristallin و polycrystalline اكثر استفادة من اجهزة التتبع

الكلمات المفتاحية : الالواح الكهروضوئية ، تتبع الشمس ، محاكاة ، مقارنة ، انواع الواح كهروضوئية

Résumé

Dans cette étude, la station photovoltaïque Ouad Nachou d'une capacité de 1,1 MW a été étudiée comme modèle pour l'étude des panneaux photovoltaïques à angle fixe et variable (suivi solaire). Nous avons simulé 4 types de panneaux photovoltaïques présents à la station et comparé chaque type en régime permanent et en régime solaire, où nous avons constaté qu'il y avait une augmentation de l'énergie des panneaux photovoltaïques solaires et que les panneaux monocristallins et solaires les types polycristallins ont davantage bénéficié du suivi.

mots clés : Panneaux photovoltaïques, suivi du soleil, simulation, comparaison, types de panneaux photovoltaïques