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Presented by:

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Topic: Development of solarpower plant for a primary school in the municipality of Sidi Bel Abbès (Innovative Projects for the Green Economy)

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STATEMENT OF THE AUTHOR

I, Abdou Amadou Abdou Salami, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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DEDICATION

This Master thesis is dedicated to the Almighty Allah. And dedicated to my loving mother Ms. Zeinabou Alio, also to my father Abdou Amadou

Abstract

In the same field, CES-MED pilots a project regarding renewable energy for Mediterranean zones which among them there is Algeria/Sidi Bel Abbes, the global aim of this thesis was to study and design a stand-alone pv system with backup supply of batteries for a primary school at the municipality of Sidi Bel Abbes, The aim of this study was to develop a stand-alone pv power system solution with best techno economic analysis and optimum configuration of RET for supply electricity in order power a primary school at the municipality of Sidi Bel Abbes. First, through field research, an analysis was made of the actual electrical demand of the school. Secondly the research used empirical and modelled data of solar irradiance and stream flow rate to ascertain the renewable energy potential, the design is carrying out software PVsyst, bluesol and manually by several methods, the study valided the optimum design, the best effective system, From the result of thesis we can easily observe that almost the study proved that the use of stand-alone system in Sidi Bel Abbes/ Algeria is financially acceptable and viable

Resumé:

Dans le même domaine, le CES-MED pilote un projet concernant les énergies renouvelables pour les zones méditerranéennes dont l'Algérie/Sidi Bel Abbes, l'objectif global de cette thèse était d'étudier et de concevoir un système photovoltaïque autonome avec alimentation de secours en batteries pour une école primaire de la commune de Sidi Bel Abbes, le travail a pour objectif de développer, maitre en place une mini centrale photovoltaïque autonome avec la meilleure analyse technico-économique et une configuration optimale de RET pour l'approvisionnement en électricité afin d'alimenter une école primaire de la commune de Sidi Bel Abbès. Tout d'abord, grâce à des recherches sur le terrain, une analyse a été faite de la demande électrique réelle de l'école. Deuxièmement, la recherche a utilisé des données empiriques et modélisées d'éclairement solaire et de débit de courant pour déterminer le

potentiel d'énergie renouvelable, la conception exécute le logiciel PVsyst, bluesol et manuellement par plusieurs méthodes, l'étude a validé la conception optimale, le meilleur système efficace, à partir de le résultat de la thèse, nous pouvons facilement observer que presque l'étude a prouvé que l'utilisation du système autonome à Sidi Bel Abbes/Algérie est financièrement acceptable et fiable

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List of abbreviations:

PV: Photovoltaic Module

PWM: Pulse width modulation

MPPT: Maximum Power Point Tracking

Gi: Perfect current source.

Rsh: Shunt resistor which takes into account the inevitable leaks of current which occurs between
the opposite positive and negative terminals of a cell.
Rs: Series resistance which is due to the different electrical resistances that the current encounters
on its path (contact resistance)
D: Diode materializing the fact that the current flows in only one direction.
R: Resistance which imposes the operating point on the cell according to its
current-voltage characteristic at the considered illuminance.
I0: The saturation current of the diode
Vd: This is the voltage across the diode (Vd = V + Rs.Is)
A: Quality factor of the p-n junction of the diode
UT: Thermal cinquefoil in volte UT = K.T / q
K: Boltzmann constant (1.381 * 10-23 J / K)
T: Effective temperature of the cell in Kelvin
P: Power measured at the terminals of the PV cell (Watt)
V: Voltage measured at the terminals of the PV cell (Volt)
I: Intensity measured at the terminals of the PV cell (Ampere)
Vopt: The optimal voltage
Iopt: The optimal current
G: irradiation which represents the light power received per unit area (W / m2)
Apv: Effective cell area
Vsoc: the total open-circuit voltage of cells in series
Iscc: short-circuit current of cells in series
Ns: Number of cells in series
Ipcc: the total short-circuit current of the cells in parallel
Vpoc: the open-circuit voltage of cells in parallel
Np: Number of cells in parallel
Ihcc: the sum of the short-circuit currents of the cells in parallel
Vhoc: the sum of the open-circuit voltages of cells in series
Vcomax module: Maximum open circuit voltage of the module used
Vco: Open circuit voltage of the panel used
Tmin: Lowest temperature recorded at the installation site
TSTC: the STC temperature at 25 ° C

TCVco: the temperature coefficient of Vco for the panel used

Nmaxs: the maximum number of modules to be wired in series

Inverter VDCmax: Maximum input voltage at which the inverter operates

Vmpmin module: The leasteffort that a module can produce during the Summer

Vmp: The least effort that a module can produce during the summer

Tmax: Highest temperature recorded at the installation site

Add = 25 ° C: In floor installation, the temperature of the modules is 25 ° C higher than the temperature
ambient

TSTC: the STC temperature at 25 ° C

TCVmp: the temperature coefficient of Vmp for the module used

Nmins: the minimum number of modules to be wired in series

Inverter Vmin: Minimum input voltage at which the inverter operates

Nchainsmax: Maximum number of chains in parallel

Imax: is the maximum current admissible by the inverter

IMPP: is the maximum power current of the modules

Iz: the admissible current in the cable

In: the nominal fuse current

Np_p: Number of chains

Isc: module short-circuit current

ρ: Resistivity of the conductive material (ρ = 0.02314 Ω.mm2/m to cook it)

L: Cable length (m)

S: Cable section (mm2)

I: Current flowing in the cable (A)

ε: Voltage drop, $\varepsilon \leq 0.03$

Vc: Voltage at the origin of the cable (V)

b: Coefficient which is equal to 1 in three-phase and 2 in single-phase

IB: The maximum current of the inverter

Cu: Price of 1KWh of electricity from Sonelgaz

RR: Return rate

Tax included: The total cost of the installation

Chapter one

1.1 Introduction

Energy is a crucial input and essential in the Economic, social and Industrial Development, it is a measure of development and civilization. today's increasing environmental concerns and growing energy needs, alternative sources of energy have to be explored. With the rapidly exhausting reserves of nonrenewable energy sources, it has become a leading matter to investigate sources of renewable energy and implement systems that develop them. In this approach, the Algerian government adopted, in February 2011 and revised in May 2015, the national programs for Energy Efficiency and the development of renewable energies, one such alternative source is solar energy.

Solar energy is green, pure, competitive and sustainable. It can be installed on anything from a rooftop to a large power plant. The source of this energy, which is the sun, is safe and limitless, this is good hope in achieving the sustainable goal, using our progressing technology, we can convert this energy directly into electricity (photovoltaics application or CSP) without causing harm to the environment thus helps solve today's energy challenges.

Photovoltaics (PV) is the direct conversion of sunlight into electricity: electricity can be defined electrons movement inside materials; Certain materials, like silicon, GaAs etc, naturally release electrons when they are exposed to light, therefore these materials can be used to produces electricity. The materials undergo some treatments from which we obtain solar cells. Several cells are connected in series and parallel and put in frame (panels) to increase the capacity of voltage and current respectively. By this way, it is only possible to produce electricity in form of direct current, which must be converted to alternating current (AC) electricity to run certain d household appliances or to inject it into the grid. An inverter connected to the PV panels is used to convert the DC electricity into AC electricity. The amount of electricity used over a given period of time is measured in kilowatt-hours (KWh).

solar energy is becoming popular owing to abundance, availability and ease of harnessing for electrical power generation. This thesis focuses on photovoltaic energy generation to supply electrical energy for primary school in municipality of Sidi bel Abes.

In this thesis, we will discuss the potential of exploiting solar energy in the municipality of Sidi Bel Abbès, membership of the Covenant of Mayors of the European Union (CES-MED) project for the development of its Action Plan in favour of Sustainable Energy (PAED). Under the objective of cleaner energy saving Mediterranean cities (CES-MED), for this venture is to deduce the feasibility of installing a solar power plant on the municipality of Sidi Bel Abbès. (Clima-med, 2012)

1.2 Background information

Sun, the most important renewable energy resource, it is direct origin of photovoltaic energy and SCP and indirect origin of wind, hydro. the earth's surface received abundantly energy from the sun each day but very few of it is used.

The government reacted and adopted since 2011, in February and revised in May 2015, the national programs for Energy Efficiency and the development of renewable energies. These two programs reflect the national vision based on dependency on fossil resources by an increased introduction of energy efficiency and the development of available renewable energy resources such as solar and their use to diversify energy sources and prepare for the post

fossil energy period. Local communities are required depending on their means and local conditions to implement the government's program through actions and contribute to the achievement of national objectives. Depending on the context of each municipality, local authorities are required to integrate the national strategy for development and sustainable energy and to locally develop projects aimed at reducing the consumption of fossil fuels, developing the share of renewables energies, and the reduction of greenhouse gas emissions. To this end, the sustainable energy action plan constitutes a real roadmap for the municipality in the short and medium term for the integration and development of renewable energies in its territory. Membership of the Covenant of Mayors of the European Union (CES-MED) constitutes a lever for the transfer of know-how and good practices and to benefit from the experiences of other municipalities that have already implemented their action plan for sustainable energy.

The municipality of Sidi Bel Abbès signed the Covenant of Mayors (CdM) which constitutes proof of the involvement of the municipality in the CES-MED project for the development of its Action Plan in favour of Sustainable Energy (PAED).

The project of installing a mini solar power plant for a primary school in the city of Sidi Bel Abbès is part of the CES-MED project, it is considered as a pilot project (Clima-med, 2012)

We notice that solar energy spreads in different areas and to broaden its integration; it is to introduce it into the field of education. Given the impact that this kind of project has on schoolchildren in the future, Schools are ideal bases for carrying out this kind of energy saving project, schoolchildren are a young population and lack information on renewable energies and make them contribute to the protection of the national and global environment.

The energy issue is very important to the municipality because of the share of energy in the municipal budget devoted to the many schools at the expense of the municipality

According to united nation not access to clean energy; energy scarcity defines as a lack of sufficient energy resources. Today, the availability of friendly energy is the prime requirement for all. So, using as much as possible of existing clean energy resources is crucial to filling this gap. Sun is an inexhaustible reserve, other reserves such as geothermal, biomass, wind and hydro are useful too to be directly use and they are also exploitable. In this context, Mediterranean "(CES-MED) is an EU-funded initiative aimed at ensuring the training and technical assistance to local and national authorities in the Southern region of the ENPI, in order to help them respond more actively to the challenges of sustainable policies. This effort involves greater awareness of local populations with regard to local sustainable policies, sharing knowledge and establishing lasting partnerships between authorities' local authorities in the EU and the ENPI southern region. The CES-MED project produced two reports national synthesis in Algeria that can be used as reference documents for the implementation of PAED actions developed by Algerian municipalities. The first is on sources of financing for energy efficiency and energy development renewables in local communities in Algeria, while the second deals with the analysis institutional and regulatory development of energy efficiency and energies renewable at local authority level. The project of the installation of mini solar photovoltaic power plant for a primary school is part of the project CES-MED is a pilot project. The convention of mayors of the European Union (CES-MED) constitutes a lever for the transfer of know-how, good practices and to benefit from experiences of other municipalities that have already implemented their sustainable energy action plan. Schools are ideal bases for implementing experimental projects in this domain. Although the schools are similar at the national level, especially at the regional level between Sidi Bel Abbes and Oran. We have reduced the distance and the effort by taking as a model a school located in Oran in the town of Es-Sénia similar to that of Bel-Abbès to study the project. We can emphasize that the aim of our work is to master the different aspects techniques and practices to carry out the project and lead to choices and methods allowing to achieve as many objectives as possible with the greatest profitability. The project "Promoting the development of sustainable energies in cities (Clima-med, 2012)

1.3 Problem statement

Nowadays, global energy consumption has increased due to population growth, the fossil fuels become insufficient, and management problems of fossils fuels resources that can be mobilized aggravating the situation, access to pure and permanent energy become one of the major challenges of this century that humanity must quickly recover.

Algeria is heavily dependent on fossil fuels, with 94% of its energy currently coming from natural gas, which is 50% of the national GDP. Fossil fuels are facing serious problems due to population growth and resource depletion. Recent studies suggest that around 51% comes from wind and solar energy. Despite the renewable energies in Algeria, it offers one of the highest solar potentials in the world due to its favorable geographic location. Energy use in Algeria can be divided into the three sectors of industry, transport and housing as well as services: 24%, 33% and 43% respectively. The government shows his interest on renewable energy, program to improve the situation of mixed energies, 92% of which natural gas has absorbed since 2010.(A. Boudghene Stambouli, Z. Khiat, 2012)

1.4 Objectives

1.4.1 Primary objectives

The work objective is to study, design and analyze a stand-alone solar energy system, to power a primary school at the municipality of Sidi Bel Abbes which will rely completely on solar energy on the daytime and night time with backup of batteries.

1.4.2 Secondary objectives

1- Unlimited solar energy as source with high and tested technology

- ✓ Improve the living environment of the citizens of the municipality: by reducing the level of pollution in the face of various contaminations of waterways, air and soil.
- ✓ Reducing the energy bill: by reducing the energy consumption of lighting

public, schools and mosques, which weigh heavily on the budget of the municipality.

- ✓ Reduce energy consumption of fossil origin and greenhouse gas emissions

in public buildings, schools and mosques on the territory of the municipality.

- ✓ Develop a communication plan for the local population and all socio-professional categories of the territory and the region for information and awareness of energy efficiency and the development of renewable energies and Environmental Protection
- ✓ Set up pilot energy renovation operations for schools, supported by

raising awareness among schoolchildren about renewable energies.

- ✓ Ensure the promotion of renewable energies in schools, showing the strong potential of

solar energy and the ease of its development.

- ✓ Sensitize young people to the issue of energy management and climate change

economic and environmental ones:

  - Reduce the municipality's energy bill;
  - Energy autonomy;
  - Preserve fossil sources;

those at the societal level:

  - Ensure the promotion of renewable energies in schools
  - Sensitize schoolchildren to energy management and climate change

1.4.3 Vision of the project

All the activities of the territory of the municipality are targeted to integrate the measures of reduction in the consumption of fossil fuels, introduce energies renewables in the territory while ensuring the protection of the local environment (air, water, soil, waste) and contribute to the protection of the national and global environment through information and awareness-raising actions for all stakeholders to reduce the energy consumption and production of renewable energies locally.

1.5 Justification

Our stand-alone system, composed of PV system components with batteries, is a reliable municipality solution that reduces energy reliance on the primary grid. It is such of awareness to the population on using renewable energy for their quotidian usage therefore it can assist the government in implementing a new strategy of renewable energy in Algeria. This research will provide the growth of the small-scale industries in the municipality of sidi bel abbes. This solution can be extended to other well-defined load constructions and especially in remote areas. Moreover, it can be used for some students or actors in solar energy to addressee some issue regarding photovoltaic system.

1.6 Scope of study

Solar energy is very wide and useful in industries, houses and agriculture field. So, this research will focus photovoltaic system for commercial use it will provide the facility in the municipality also general people can setup small equipment on the roof of the building and get clean energy continuous basis.

Not at all the complicity of renewable energy and all the types of photovoltaic systems but stand-alone with battery backup.

1.7 Conclusion

Regarding the above we can highlight an overview about the problem statement, the currently dependency of Algeria on fossil fuels and the targeted objective to achieve. Many topics on this field are going deeper, the subsequent chapter explores the literature providing a complete overview about our topic.

Chapter two

2. Literature of Review

2.1 Introduction

Solar energy is widely spoken worldwide, this part of our work will highlight some research conduct by others researchers on the same field which is convenable to our research, it will include also the energy situation of Algeria and some identical projects conducted related to the topic.

2.2 Solar radiation

2.2.1 Sun

The sun, the central nucleus of solar system its indeterminate energy originating from thermonuclear fusion is greater than the need for beings on planet earth. After the diffusion of this in all directions from the sun a small portion arrives on the earth's surface. It would be quite interesting to know some notions about radiation of sun (characteristic, coordinated, nature….), the different physical processes that will be subject to this radiation.(Ristinen & Kraushaar, 2006)

2.2.2. Different Solar Radiation

An excellent natural source of energy, the sun is about 150 million kilometers from Earth, it emits isotopic base radiation when four hydrogen nuclei fuse to form one helium nucleus, helium is 0.7% by mass less than four hydrogen nuclei, this difference in mass as energy is ejected and goes to the sun's surface, this is the thermonuclear reaction when solar energy occurs at 5800 ° K of the temperature on the sun's surface. 98% of this emitted energy lies in the wavelength band between 0.25 and 3 μm. Radiation travels through space as an electromagnetic wave, it becomes less intense depending on the wavelength, and when the rays reach the edge of the earth's atmosphere they are considered to be parallel. surface. (Wenham et al., 2007)

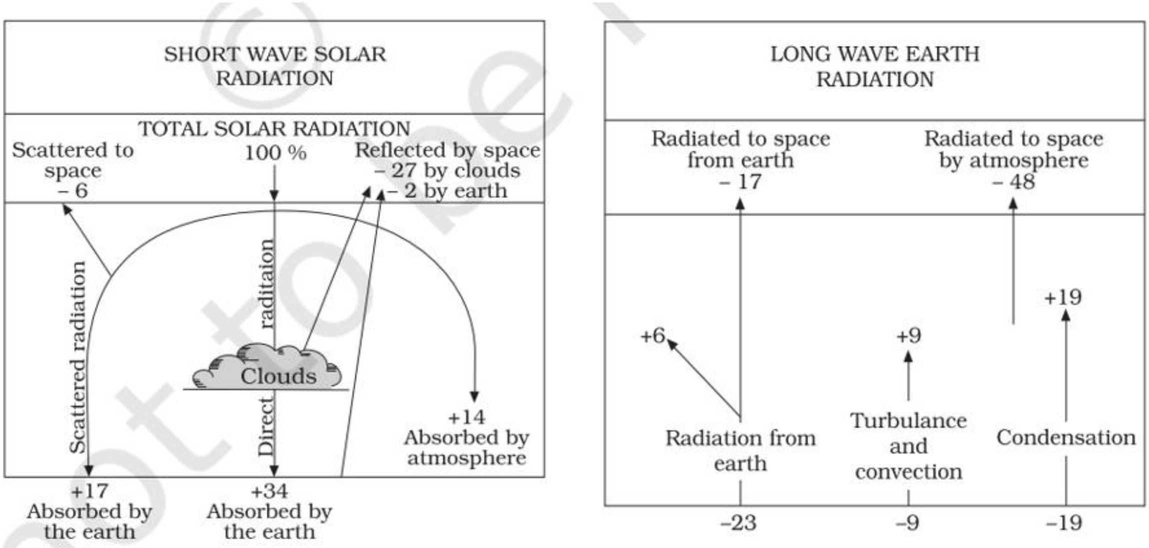


Figure 1 heat budget of the earth

The electromagnetic radiation emitted by the sun with a wide range of wavelengths, some can be converted into useful forms of energy, such as heat and electricity by different types of technologies. Solar radiation can be divided into two main regions: ionizing radiation (X-rays and gamma) and non-ionizing radiation (UVR, visible radiation and infrared). Highly harmful ionizing radiation does not enter the Earth's atmosphere.

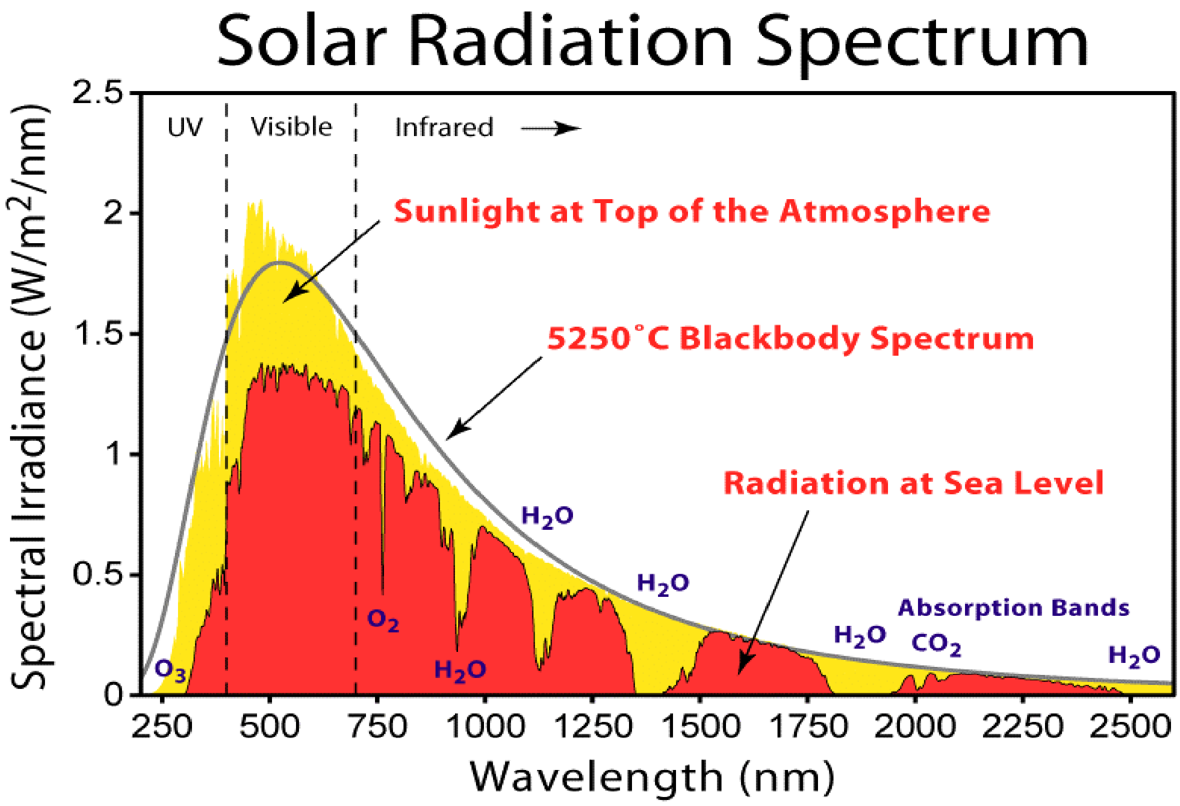


Figure 2: different solar radiation

As the picture shows, non-ionizing radiation in turn can be divided into three parts (UV, Visible, Infrared) on the wavelength, from 100nm to 2500nm of which 400 to 700nm is the visible range for the human being and most useful.

2.2.3 Diffusion of solar radiation:

(Advanced Tutorials: Solar Radiation for Solar Power Systems (freesunpower.com)

When sunlight penetrates the atmosphere, some of it is absorbed, scattered and reflected by air molecules, water vapors, clouds, dust and pollutants. This is known as diffuse solar radiation. The scattered solar radiation has no clear path. The incoming solar radiation. The earth's surface without scattering is called direct solar radiation. The direct and diffuse solar radiation from the sun is called total radiation or global solar radiation.

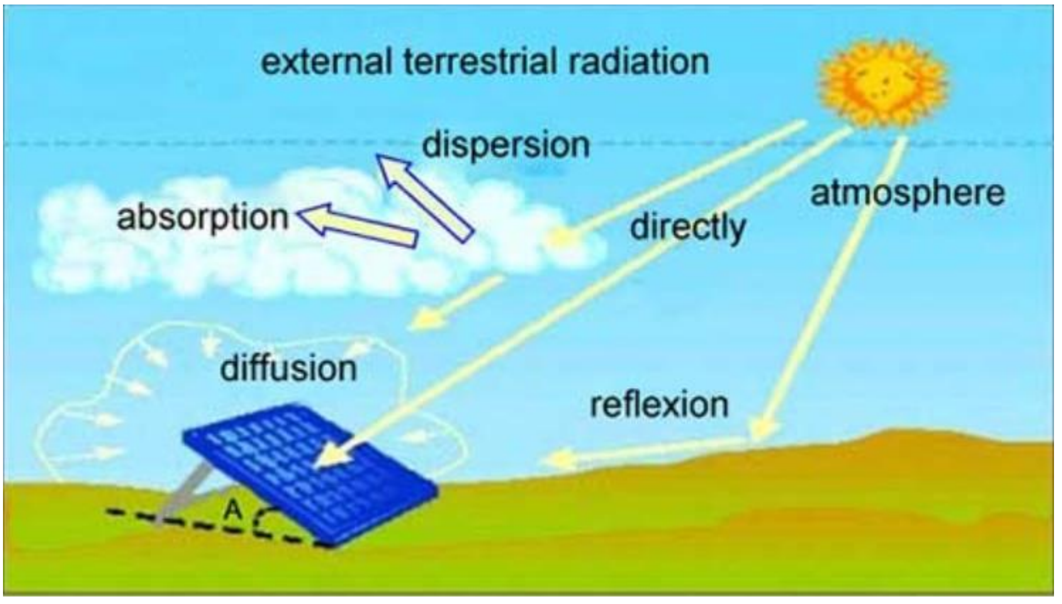


Figure 3 solar radiation diffusion

2.2.4 Solar intensity

Based on the elliptical shape of the earth, for any location on the earth's surface, the amount of energy it receives will vary on an hourly, daily, and seasonal basis. This is the angle of the position of the sun in the sky relative to a point on the earth's surface which determines the intensity of sunlight reaching that location; it is possible to measure by instrument, to calculate by formula or to estimate by different models the intensity of solar radiation; the intensity of solar radiation received also depends on the amount of atmosphere it passes through. 987 Following this figure below, explain the intensity of solar radiation received during a year VS the monthly average daily solar radiation.

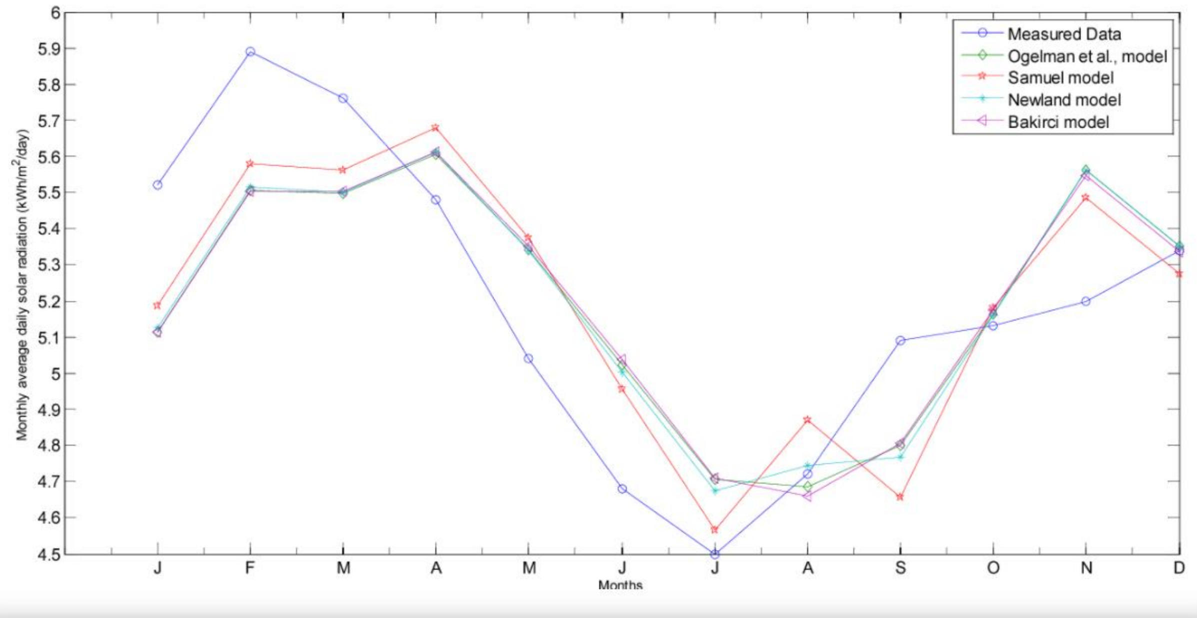


Figure 4 estimated values of monthly average daily solar radiation. (Dejene Nage, 2018)

Direct solar radiation is generally strongest on the earth's surface at noon, as it is most perpendicular to the sky and the least permeating through the atmosphere. For places located at 23.5 ° north and north latitude, it is most intense on June 21 (summer solstice) at noon. At this point, the sun is at the highest point in the sky it will reach during the year, and that is when sunlight penetrates even the smallest part of the atmosphere. The summer solstice is also the longest day of the year. For the same places, December 21st, the winter solstice, is the shortest day of the year and the day with the least amount of sunlight. Higher latitudes have more hours of sunshine in summer and fewer hours of sunshine in winter compared to lower latitudes. For one point on the equator, the sun is around May 20-21. September is most intense as these are the days when the sun is directly over them. (Freesunpower, n.d.)

2.2.5 Solar constant

The earth is about 150 million kilometers from the solar flux or intensity of solar radiation, leaving the surface of the sun and reaching the earth's atmosphere in about 8 minutes, so it reaches a speed of 72x1012 m / s, is given like (Using Stefan-Boltzmann's law when the temperature is known:

$$H_s = l\sigma T^4$$

l = Emissivity of the object (the sun is a black body so l = 1)

σ = Stefan-Boltzmann constant = 5.67 x 10 ~ 8 W / m2-K4 T

T = Object temperature = 5762 ° K

Hs = 5.67 x 10 ~ 8 x (5762) 4 = 6.25 x 107 W / m2.

This quantity is considered constant at the surface of the sun, so the total initial radiation power emitted by the sun = P0 = Hs x 4πR2

4πR2 = Surface of the sun

R = 6.96x108 the solar radiant

4πR2 = 4π (6.96 x 108) 2 = 6.08 x 1018, so Po = 6.25 x 107 x 6.08 x 1018 = 3.8 x 1026 W.

Po = 3.8 x 1026 W / m2.

If the sun emits isotropic radiation, this power is emitted equally in all directions of space. As the distance from the sun increases, this power is distributed over smaller and smaller spherical surfaces. The inverse square law is used to calculate the decrease in radiation intensity due to an increase in distance from the sun is:

Inverse square law: $I = ((4\pi R^2) H_s) / (4\pi r^2)$

I = Irradiance at the surface of the outer sphere.

However, the radiant flux at the atmospheric surface is given by

$H_o = (R^2 H_s) / r^2 = (6.96 \times 10^5)^2 / (1.5 \times 10^8)^2 \times 6.25 \times 10^7 \simeq 1346 W / m^2$

The value of the flux is called the solar constant.

The solar constant ISC is the average intensity of radiation falling on an imaginary surface, perpendicular to the sun's rays and at the edge of the Earth's atmosphere. The most used ISC value is that adopted by the World Meteorological Organization 'OMM' in October 1981 with an uncertainty of 1%, the solar constant is: Isc = 1346W / m2

The earth revolves around the sun in an elliptical orbit, so the distance between the sun and the earth varies a bit throughout the year. This variation in distance produces an almost sinusoidal variation in the intensity of the solar radiation I'sc which reaches the earth. The value of any day can be calculated by

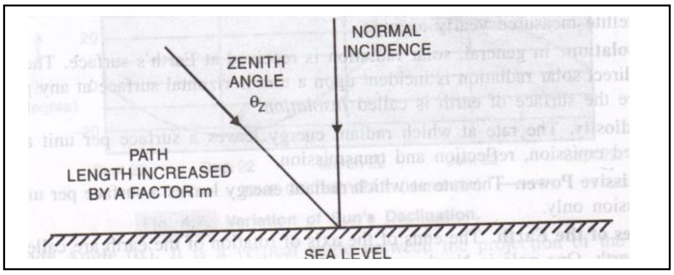
I'sc = Isc [l + 0.033 (cos360n / 365)] (4.3)

Where 'n' is the day of the year. I'sc is the maximum possible energy that can be obtained from the Sun at the edge of the Earth's atmosphere

the distance traveled by the beam's radiation through the atmosphere before it reaches the earth's surface, called mass (AM) m, plays a role in the variation of solar radiation over the course of a day,. It is defined as the ratio of the mass of the atmosphere through which the beam radiation passes to the mass it would pass through if the sun is directly overhead (at its zenith). Zenith angle θ_z, is the angle made by the sun's rays with the normal to a horizontal surface. The air mass is given by

$$m = AM = \frac{1}{cos\theta z} = sec\theta z$$

At sea level $m = 1$ when sun is at zenith, $m = 2$ when zenith angle is 60°



2.2.6 Solar angles

Incidence of sunlight and direction of the apartment During the day, the angle of incidence of sunlight on the solar module changes, which affects the power output. The output of the "100-watt module" will gradually decrease from zero at sunrise, increase at noon with the position of the sun at maximum output, then gradually decrease in the afternoon and return to zero at night. Although this variation is partly due to the changing solar intensity, the changing solar angle (relative to the modules) also has an influence.

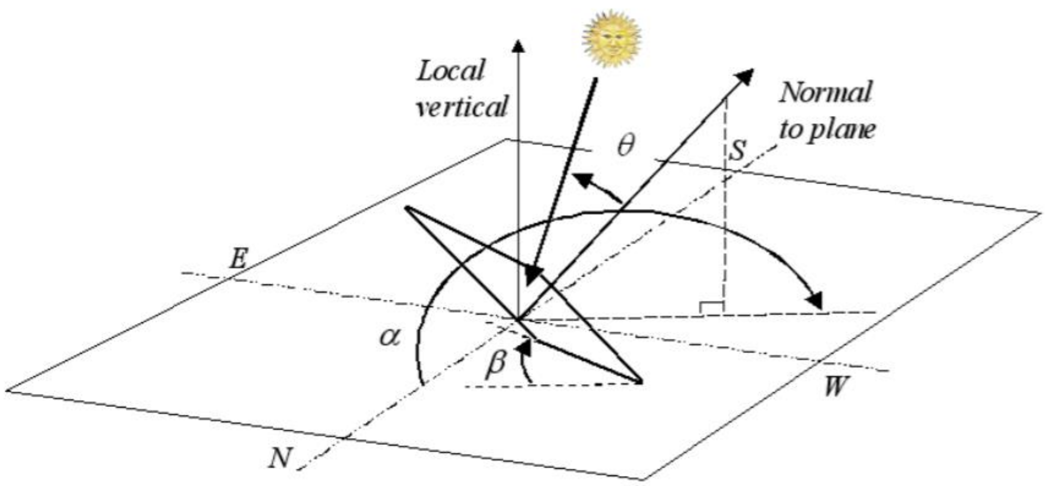


Figure 6 solar angles

- **ϕ - Latitude,**

the angular position north or south of the equator, positive north; 90 ° ≤ϕ≤ 90o

• δ declination, , that is the angular position of the sun at noon in relation to the equatorial plane, positive north.

23.45o ≤ δ ≤ 23.45o. The declination can be found from the following equation:

$$\delta = 23.45\sin\left[360 \times \frac{284 + n}{365}\right]$$

where n is the number of days in the year.

Month	*n* for *i*th Day of Month	For the Average Day of the Month Date	*n*, Day of Year	*δ*, Declination
January	*i*	17	17	−20.9
February	31 + *i*	16	47	−13.0
March	59 + *i*	16	75	−2.4
April	90 + *i*	15	105	9.4
May	120 + *i*	15	135	18.8
June	151 + *i*	11	162	23.1
July	181 + *i*	17	198	21.2
August	212 + *i*	16	228	13.5
September	243 + *i*	15	258	2.2
October	273 + *i*	15	288	−9.6
November	304 + *i*	14	318	−18.9
December	334 + *i*	10	344	−23.0

[a] From Klein (1977)

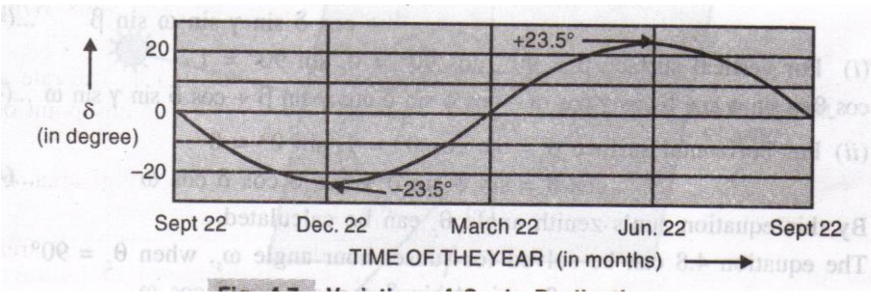


Figure 7 variation of sun's declination angle value for hole the year

Slope

the angle between the plane in question and the horizontal 0 ≤ β ≤180o, (β> 90o means that the surface has a downward component)

• γ azimuthal angle of the surface, the deviation of the projection in a horizontal plane from the normal to the surface in relation to the local meridian. with zero to the south, east negative and west positive; 180 ° ≤γ≤ 180o

• ω hour angle, the angular displacement of the sun to the east or west of the local meridian due to the rotation of the earth around its axis at 150 per hour negative morning, positive afternoon (or is the rotation angle of the earth from Sun noon) Since the earth rotates 360o /

24 h = 15o h - 1., the hourly angle is given by ω = (15o h - 1) (tsolar −12 h) = (15o h - 1) (zone −12 h) + ω + (Ψ −Ψ zone)

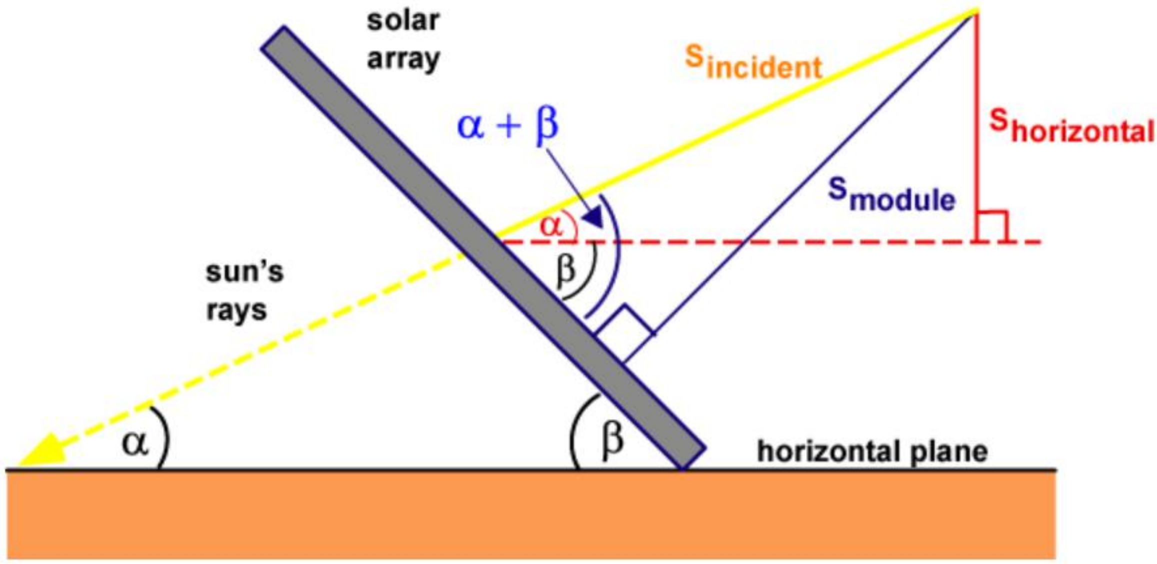


Figure 8 different sun's angles.

- **θ Angle of incidence,**

is the angle between the incidence of the ray on a surface and the normal to this surface. The equation that relates the angle of incidence of the radiation and the other angles is: $\cos \theta = \sin \delta \sin \phi \cos \beta \sin \delta \cos \phi \sin \beta \cos \gamma + \cos \delta \cos\phi \cos \beta \cos \omega + \cos \delta \sin \phi \sin \beta \cos \cos + \cos \sin \beta \sin \delta \sin\omega$ ……….. (a)

Eq. (a) can be written: $\cos \theta = (A - B) \sin + [C \sin \omega + (D + E) \cos \omega] \cos \delta$ …….(b) or

$A = \sin \cos\beta$

$B = \cos \phi \sin \beta \cos\gamma$

$C = \sin\beta \sin \gamma$

$D = \cos\phi \cos\beta$

$E = \sin \sin \beta \cos\gamma$

and $\cos \theta = \cos \theta z, \cos \beta + \sin \theta z \sin\beta \cos (\gamma s\ \gamma)$

• Variation of the day length. the number of hours between sunrise and sunset and is given by N =

• θz zenith angle, the angle between the perpendicular and the line to the sun, ie the angle of incidence of the radiation on a horizontal surface.

• αs angle of position of the sun, the angle between the horizontal and the line to the sun, ie the complement of the zenith angle.

• γs solar azimuth angle, the angular offset of the beam projection shown in Figure 3.6 in the horizontal plane from the south. The shifts in the east of the south are negative and in the west of the south positive.

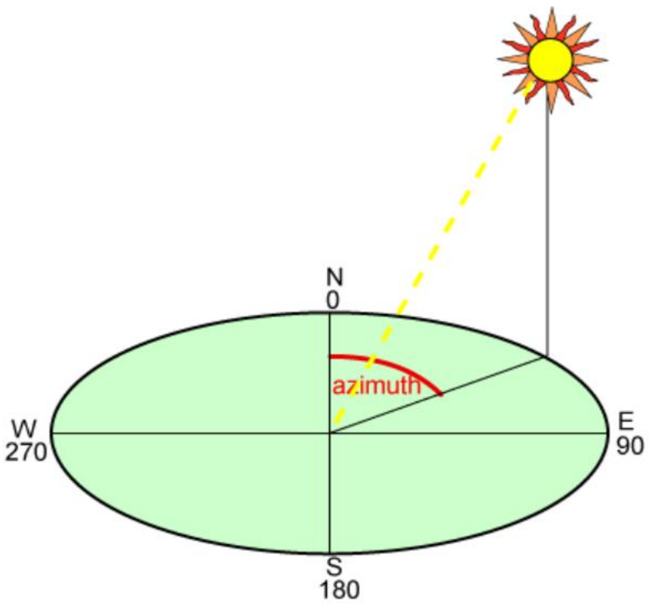


Figure 9 Azimuth angle

2.3 Different forms of renewable energy

Renewable energy is a specific type of energy production that is obtained from an inexhaustible, abundant and continuous energy resource, the sun. These energies are pure (non-polluting), quickly becoming economical but also efficient, and this includes solar, biomass, wind power, hydraulics, geothermal energy, etc. In the past, this energy was little used because of its cost. But some of the energy sources are smart financial choices for hospitals, businesses, and homes. Renewable energies are very beneficial because of their partly negative ecological impact compared to fossil fuels. In particular, solar power is the best option for homeowners who want to reduce their environmental footprint while saving money. Renewable energies have increased demand for alternative energy and accelerated the transition to a cleaner environment and more sustainable electricity methods. However, it is important to note that there are many types: solar, wind, tidal, electric, etc. Each has its own set of pros and cons. (Kumar et al., 2020)

There are different forms of renewable energy. Here are the common types:

2.3.1. Solar energy

This type of renewable energy comes directly from the capture of solar radiation. Specific sensors are used to absorb the energy from the sun's rays and redistribute it in two main operating modes:

- Solar photovoltaic (photovoltaic solar panels): solar energy is captured for the production of electricity.
- Solar thermal (solar water heater, heating, thermal solar panels): the heat from the sun's rays is captured and redistributed, and more rarely is used to produce electricity.

2.3.2. Wind energy

In the case of wind power, the kinetic energy of the wind drives a generator that produces electricity. There are several types of renewable wind energy: onshore wind turbines, off-shore wind turbines, floating wind turbines… But the principle remains broadly the same for all these types of renewable energies.

2.3.3 Hydroelectric power

The kinetic energy of water (rivers and streams, dams, ocean currents, tides) drives turbines that generate electricity.

Marine energies are part of hydraulic energies.

2.3.4 Biomass

Energy comes from the combustion of materials of biological origin (natural resources, crops or organic waste). There are three main categories:

- ✓ Wood
- ✓ Biogas
- ✓ Biofuels.

2.3.6. Geothermal power

Energy comes from heat emitted by the Earth and stored underground. Depending on the resource and the technology used, the calories are directly exploited or converted into electricity. (Klass, 1984)

2.4 types of photovoltaic system

The photovoltaic system aims to generate electricity from the sun's energy, and to perform this function, photovoltaic systems can be divided as follows

2.4.1 Grid-connected photovoltaic systems

It is the most widespread solar system in the world, and it is the system connected to the public electricity grid of a country which consists of solar panels, the inverter on the grid and loads. This system is characterized by the absence of batteries to store energy, and it is stored on the network and retrieved when needed. under pressure.

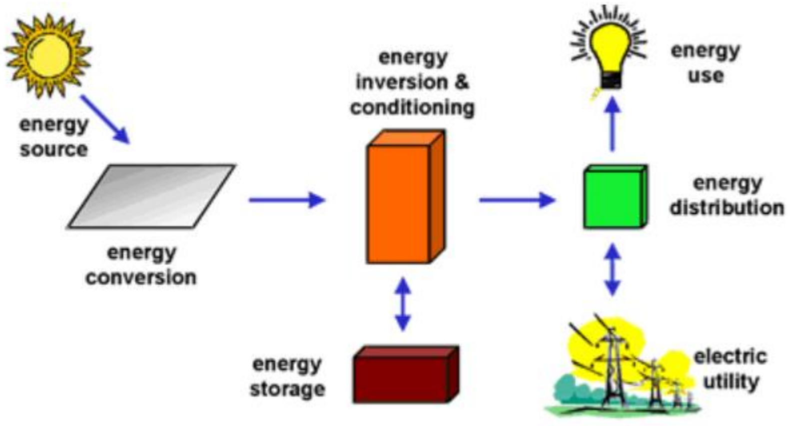


Figure 10 Major Photovoltaic System Components

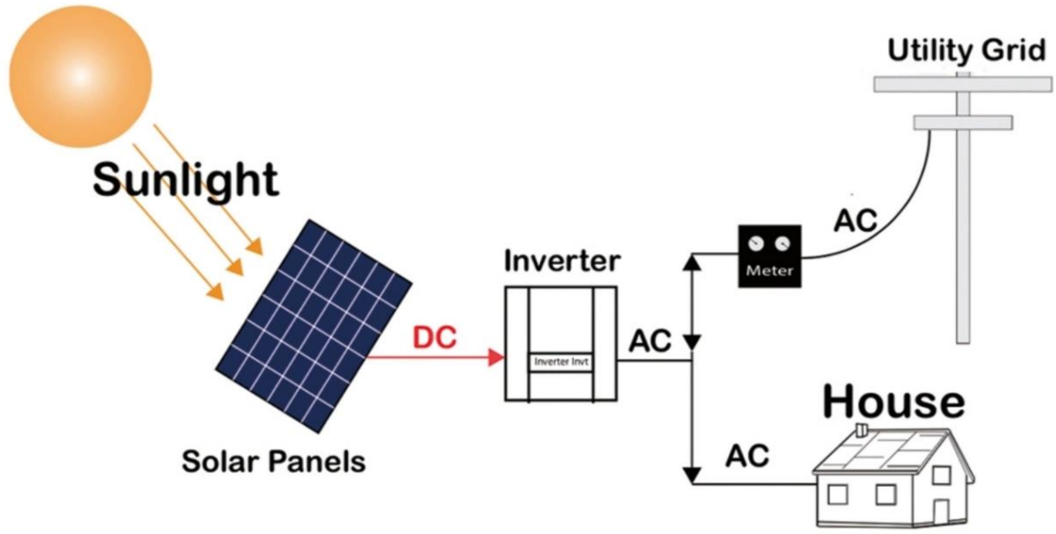


Figure 11 Diagram of Grid-Connected Photovoltaic System.

2.4.2 Stand-Alone Photovoltaic Systems

Off-grid solar systems are designed to operate independently of the utility grid and are generally designed and sized to supply certain DC and / or AC electrical loads. And in it, the energy produced must be directly consumed and / or store in accumulators (rechargeable battery) to allow meet all needs. For example, solar home systems (in areas isolated), the solar street lighting system. It is not recommended in the case of a public electricity network, because its lifespan is low, the initial installation cost is high, and the maintenance cost is relatively high. A stand-alone PV system consists of solar panels, a solar charge controller, off-grid batteries and inverter and loads.

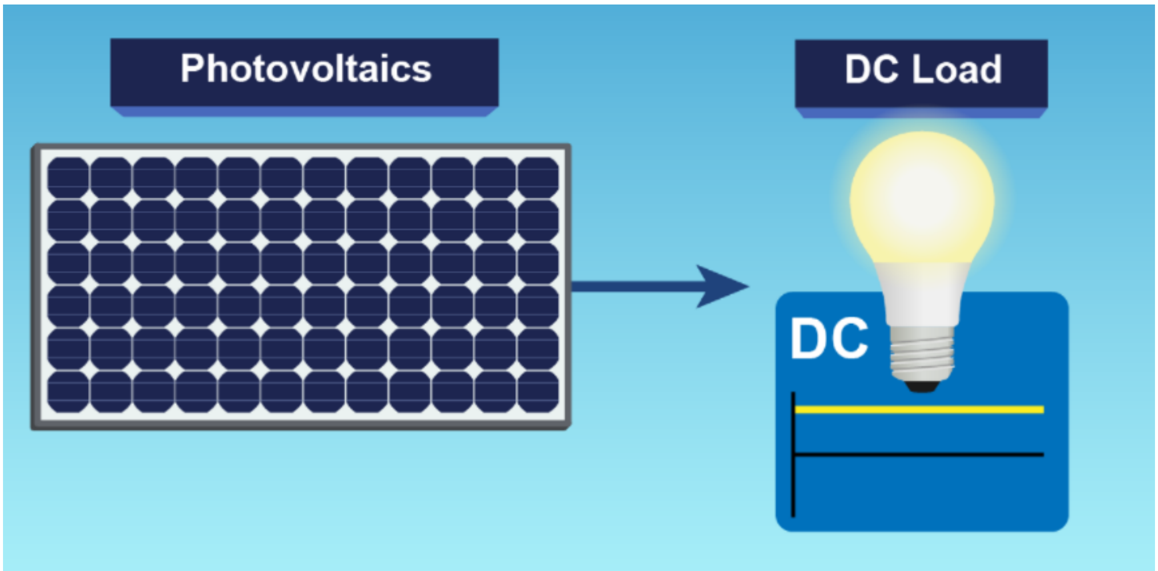


Figure 12 Direct-Coupled PV System

2.4.2.1 Hybrid system

In a hybrid system, a combination of solar PV power with another source of production of electrical energy, such as wind, biomass or diesel, the main objective is to bring more reliability into the overall system in an affordable way by adding one or several energy sources

In many stand-alone photovoltaic systems, batteries are used for energy storage. Figure 13 shows a diagram of a typical stand-alone PV system supplying DC and AC loads Figure 14 shows how a typical hybrid PV system can be configured.

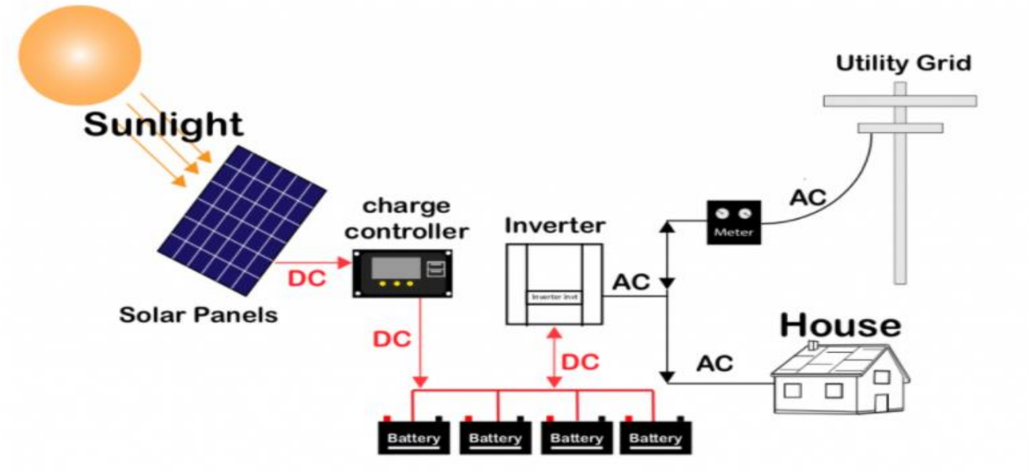


Figure 13 Stand-Alone PV System with Battery Storage Powering DC and AC Loads

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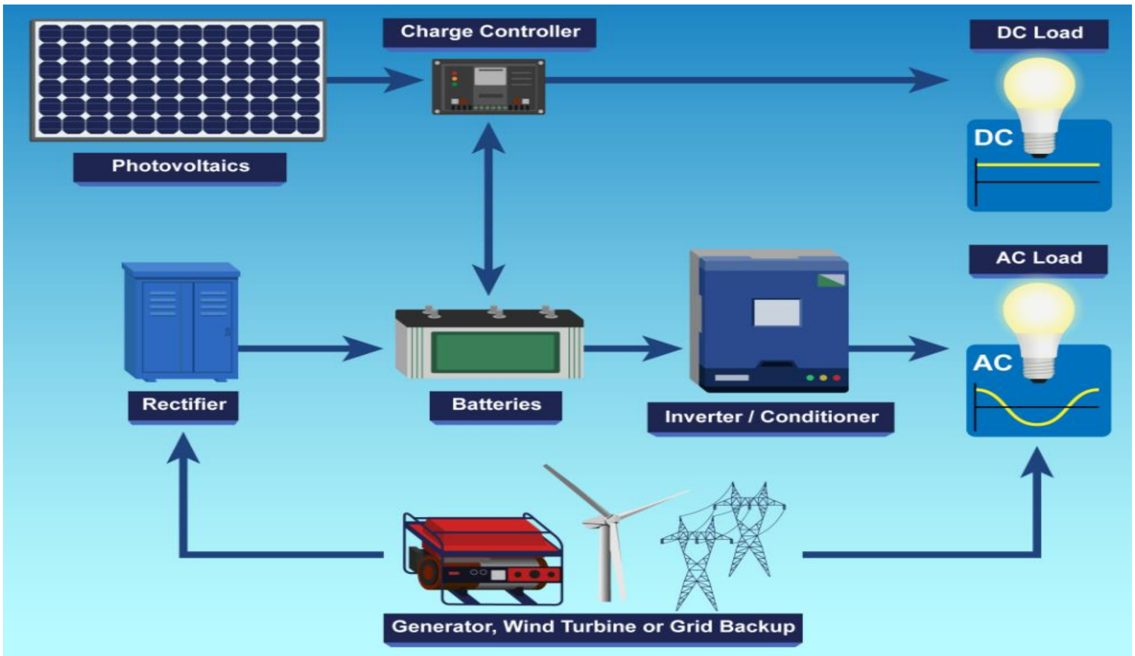


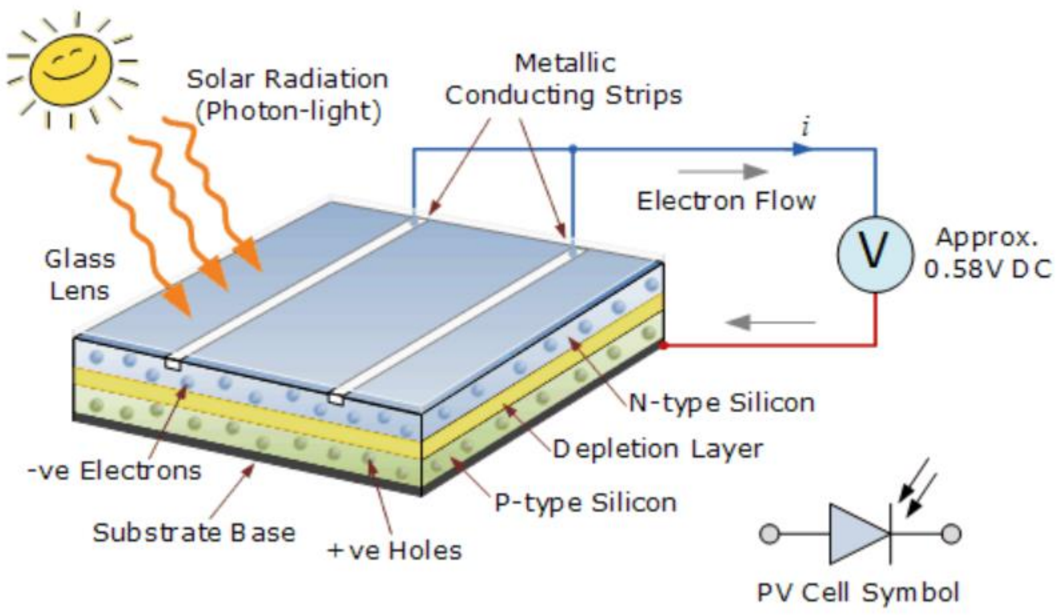
Figure 14 diagram of hybrid solar system

2.5.1 Photovoltaic technology

Semiconductors such as GaAs, mostly silicon, are excellent materials for the production of solar cells. The latter are an indispensable component in photovoltaic systems because they convert sunlight into direct current (DC) or groups of photovoltaic cells are electrically connected in series and in parallel with modules and solar collectors, which can be used to charge batteries, operate motors and drive any number of electrical consumers. Photovoltaic systems can generate alternating current (AC) using appropriate energy conversion systems, which is compatible with all conventional devices and can be operated in parallel and connected to the distribution network.

2.5.3 Basic of photovoltaic: solar cell

The photovoltaic cell is the basic element of photovoltaic solar modules, an essential element in converting sunlight into electricity that could be used in social and industrial energy consumption, it plays the most important role in converting sunlight into electricity. This is a silicon-based semiconductor device that, under normal conditions, will deliver a voltage of around 0.5-0.6V per cell when struck by the sun. Silicon, which is the most widely used material in the manufacture of solar cells due to its global occurrence and ease of processing, there are new multifunctional technologies focusing on GaAs, AIGaAS in GaAs, etc. which are more efficient. The photovoltaic cell consists of two layers of silicon (semiconductor material): a boron-doped layer that has fewer electrons than silicon, therefore zone is positively doped (zone P), a phosphorus-doped layer, which has more electrons than silicon, this zone is therefore negatively doped (N zone).



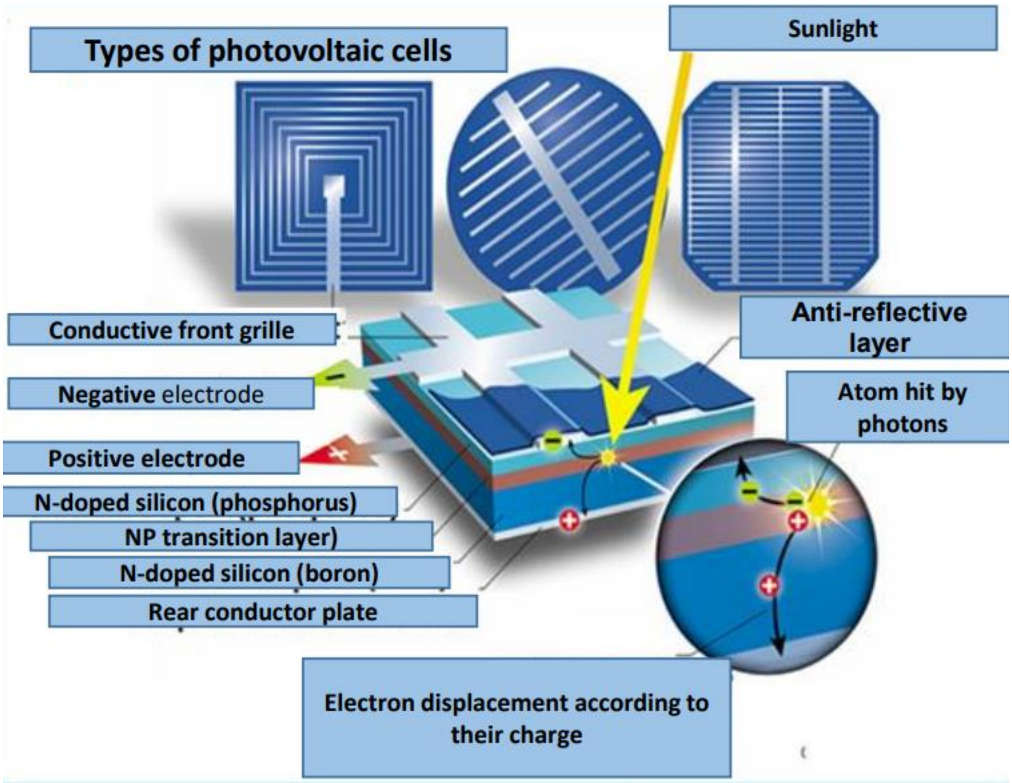


Figure 15 solar cell structure

2.5.4 The type of solar cells

There are different technologies, which are defined by the type of semiconductor and the process of the cell manufacturer, the use of special ovens and other instruments with different efficiency, can give crystalline solar cells, thin-film solar cells.

2.5.4.1 Monocrystalline solar cells

Typically, silicon growth ingots in monocrystalline form, wafers 125 x 125 mm or larger with a "pseudo-square" shape are manufactured using a very complicated process from pure silicon, as it is therefore the most efficient (15-20%) and expensive; (Advanced tutorials: Solar radiation for solar power systems (freesunpower.com)) Long silicon rods are produced that are cut into 0.20.4 mm thick slices or wafers, which are then converted into individual cells that are connected between yes in the solar panel.

2.5.4.2 Polycrystalline solar cells

also called multicrystalline, is made by growing cells into large blocks of many crystals. Multicrystalline wafers are typically 100 x 100 mm or larger and have a square structure, less efficient than monocrystalline, it is the most widely used worldwide due to its average cost and less difficult manufacturing process. (Sa, 2007)

2.5.4.3 Amorphous solar cells

Unlike glass, it is a thin layer of silicon, cadmium selenide / sulfide (Culnse / CDS), by using thin film deposition techniques on a base material like metal or glass to make a solar panel, it is less efficient and cheaper than the first second Thin-film solar cells are produced to a small extent due to the low production costs.

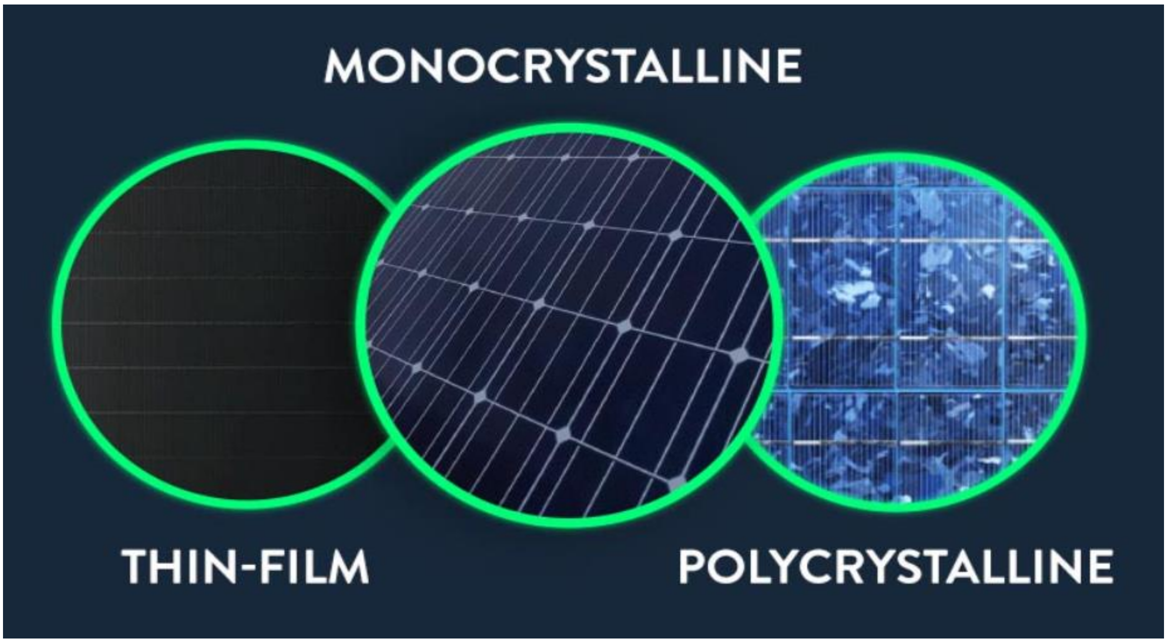


Figure 16 types solar cells

2.5.5 Solar cell modulation

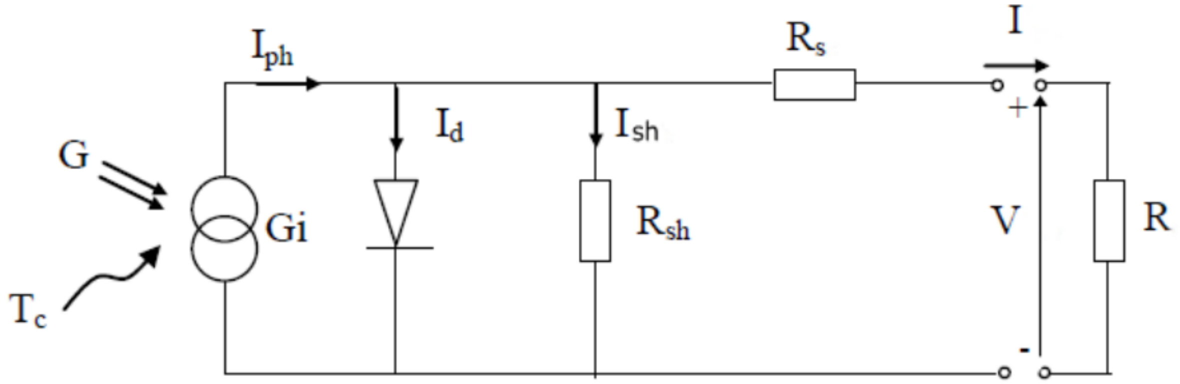


Fig: 2.17 solar cell model

Gi: Perfect current source.

Rsh: Shunt resistor which takes into account the inevitable leaks of current which occurs between the opposite positive and negative terminals of a cell.

Rs: Series resistance which is due to the different electrical resistances that the current encounters on its path (contact resistance)

D: Diode materializing the fact that the current flows in only one direction.

R: Resistance which imposes the operating point on the cell according to its current-voltage characteristic at the considered illuminance.

Magnetic equation of current of this circuit can be done by following

$I= I_{ph} - I_d - I_{sh}$……… (1)

Diode current can be determined by following

$I_d = I_0\ [e^{\frac{VD}{A.Ut-1}}]$……… (2)

I0: The saturation current of the diode

Vd: This is the voltage across the diode (Vd = V + Rs.Is)

A: Quality factor of the p-n junction of the diode

UT: Thermal cinquefoil in volte UT = K.T / q

K: Boltzmann constant (1.381 * 10-23 J / K)

T: Effective temperature of the cell in Kelvin

q: Charge of the electron (1.602 * 10-19 C)

Resistance current is as following:

$I_{sh}=\frac{(V+Rs\ .Is\ )}{Rsh}$ ……… (3)

We can subtitud (2) and (3) into (1) to determine equation I=f(V) which be can used to presente module's curbe I-V in reel condition of the weather

$I= I_{ph} - I_0\ [e^{\frac{VD}{A.Ut-1}}]- \frac{(V+Rs\ .Is\ )}{Rsh}$ ………(4)

Characteristic of solar cell:

As any electrical energy generator, the characteristics that are taken in account energy generation are (I_{cc}, V_{co}, P_{max}, η), they can be used to compare the efficiency of different cells During sunshine. (Wenham et al., 2007)

2.7.5.1 Open circuit voltage

Open circuit open voltage, the voltage when there is no any load connected, it is high voltage that a solar can deliver, it can be same as the diode voltage when Icc = 0

Considering the equation (4) we can simplify by taking in account $R_{sh} \gg R_s$ and I = 0, so that we can have open circuit voltage (V_{oc}) as:

$V_{oc} = V_d = \frac{A.K.T}{q} \ln(\frac{Iph}{I0} + 1) \approx \frac{A.K.T}{q} \ln(\frac{Iph}{I0})$ ………………… (5)

2.5.5.2 Short circuit current

The current when the two borne (- & +) have been connected together, it is the highest value of current that the solar cell can deliver for open circuit voltage equal to zero (V_{oc} = 0)

In Equation (4), applying a short-circuit to the output terminal of the cell, the voltage of output V = 0 and the average current through the diode are usually neglected, so the short-circuit current Isc is expressed by:

$$Icc = \frac{Iph}{1+\frac{Rs}{Rsh}} \approx I_{ph} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

2.7.5.3 Maximum power

Under fixed ambient operating conditions (lighting, temperature, etc.), the electrical power (P) available at the terminals of a cell PV is equal to the product of the supplied direct current (I) by a given direct voltage (V):

$$P = V \times I \ldots\ldots\ldots (7)$$

With:

P: Power measured at the terminals of the PV cell (Watt)

V: Voltage measured at the terminals of the PV cell (Volt)

I: Intensity measured at the terminals of the PV cell (Ampere)

So;

$$P = V \times I = V.I_{ph} - V.I_0 \left[e^{\frac{V+Rs+Is}{A.Ut}} - 1\right] - \frac{V.(V+Rs.Is)}{Rsh} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

In order to improve the efficiency of the PV system, it is necessary that the operating point of the system be the MPP (maximum power point) value of the PV cell. The MPP value is produced when:

$$Pmax = V_{opt} \times I_{opt} \ldots\ldots\ldots (9)$$

With:

Vopt: The optimal voltage

Iopt: The optimal current

II.10.4. Energy efficiency: is the ratio between the maximum power and the power at the entrance to the solar cell.

$$\eta = \frac{Pmax}{Pin} = \frac{Vopt.Iopt}{Apv.G} \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

With:

G: irradiation which represents the light power received per unit area (W / m2)

Apv: Effective cell area

Fig. presents the current - voltage and power - voltage curve of a cell photovoltaic with the important points that characterizes it.

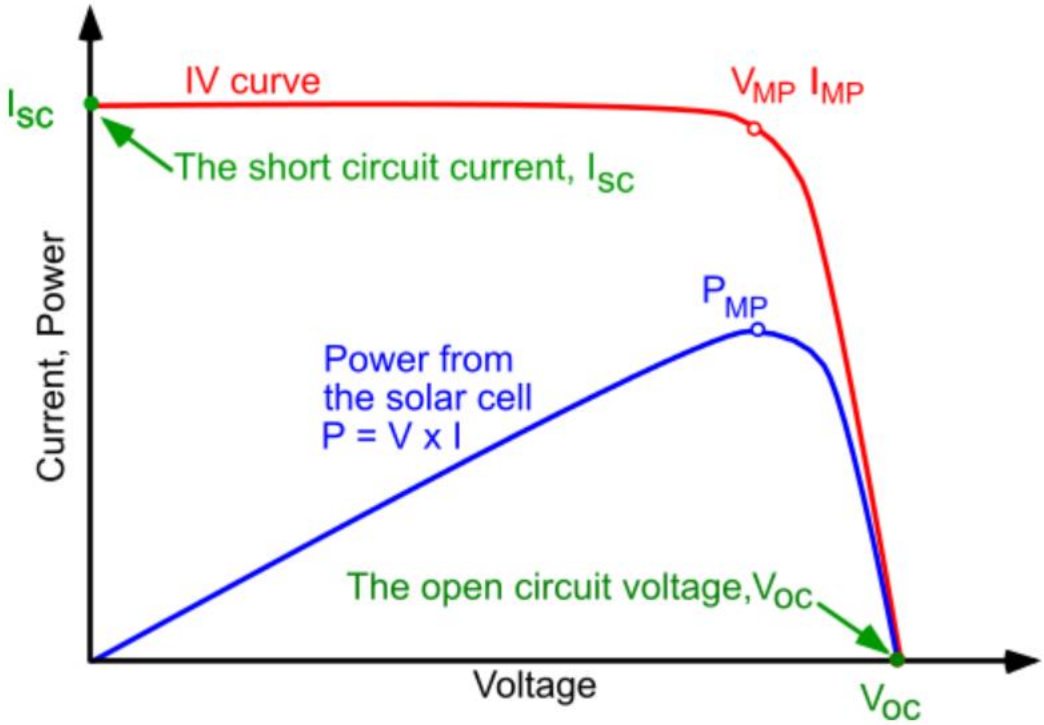


Figure 17 photovoltaic I-V and P-V characteristic

2.5.6 Influence on PV module parameters:

PV modules are designed to operate under the influence of different conditions climatic. According to studies, the PV module is affected by climatic parameters and main parameters that affect the PV unit instrument are radiation and temperature

2.5.6.1 Influence in irradiance

The reaction of a photovoltaic cell to different solar radiation and a constant temperature of 25 °C shows that the solar radiation has a significant influence on the short-circuit current Fig. (The short-circuit current increases with increasing solar irradiation), while the influence on the voltage in no-load operation is quite small. and the optimal output of the photovoltaic cell (Popt) practically proportional to the illuminance. (Yatimi & Aroudam, 2016)

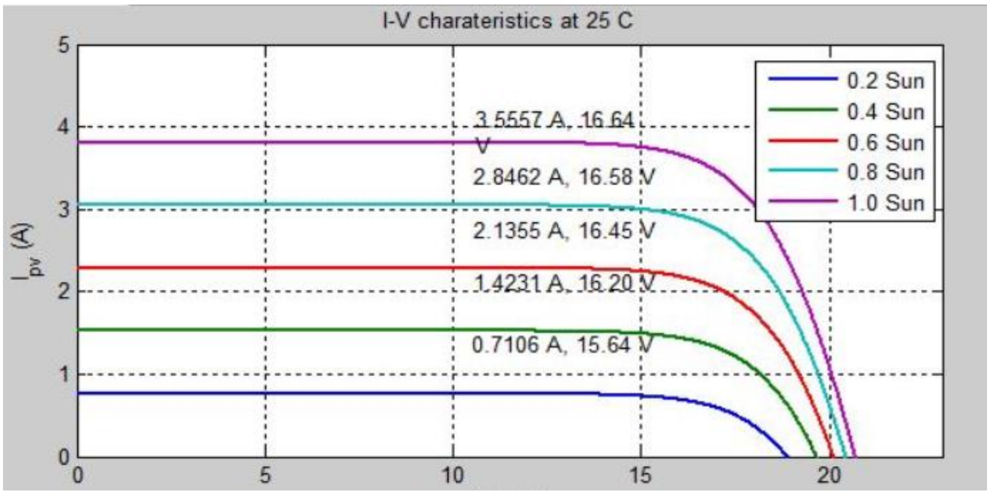


Figure 18 intensity variation vs irradiance

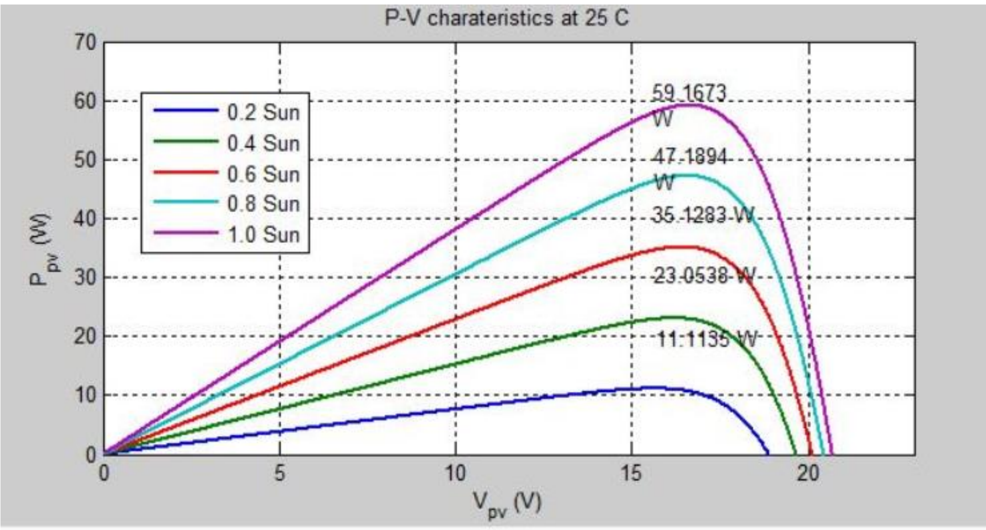


Figure 19 solar cell's power variation

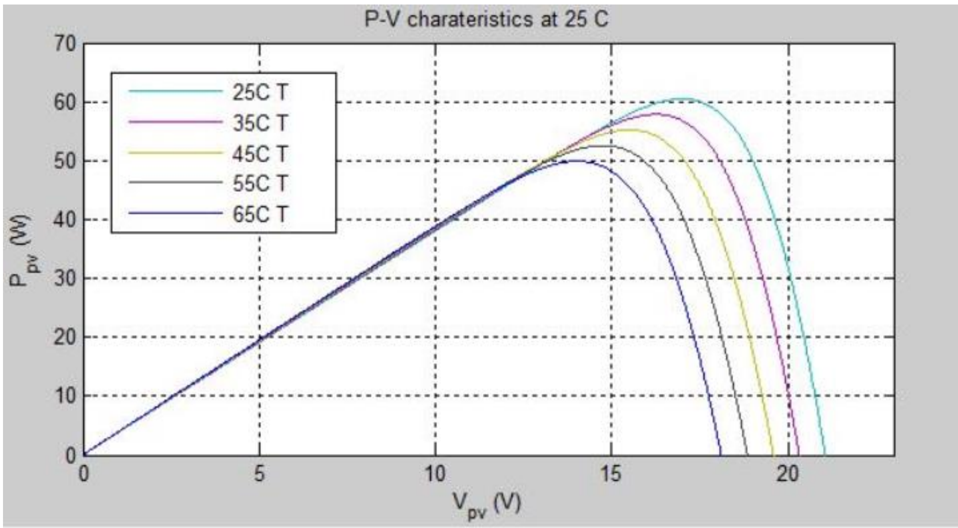


Figure 20 solar cell's power variation vs temperature

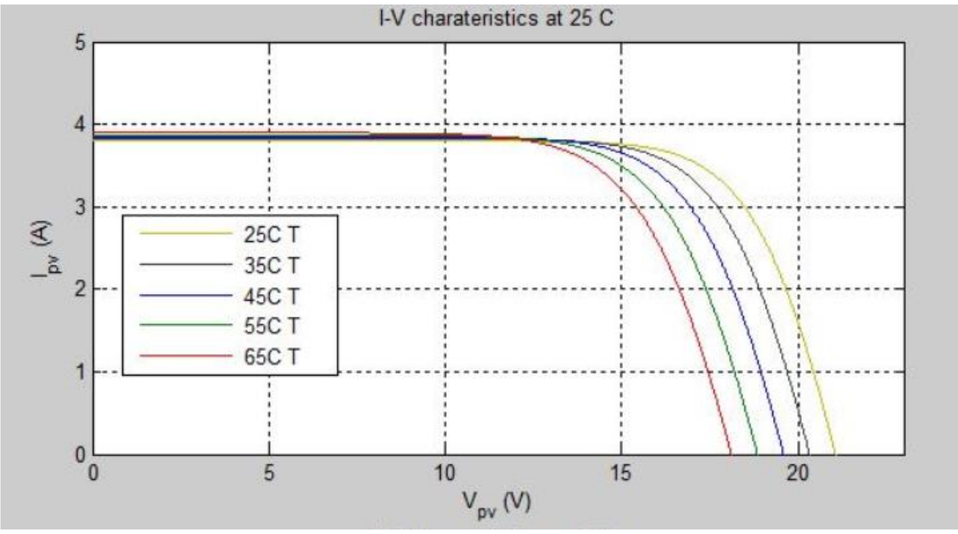


Figure 21 solar cell's intensity variation vs temperature

2.7.7 Association of photovoltaic cells

The PV cell is by definition a set of cells assembled to generate a usable electrical power when exposed to light, and to produce more energy the solar modules must be grouped according to the needs of the applications referred to in series or in parallel or in hybrid (series and parallel).

2.5.7.1 Serial association

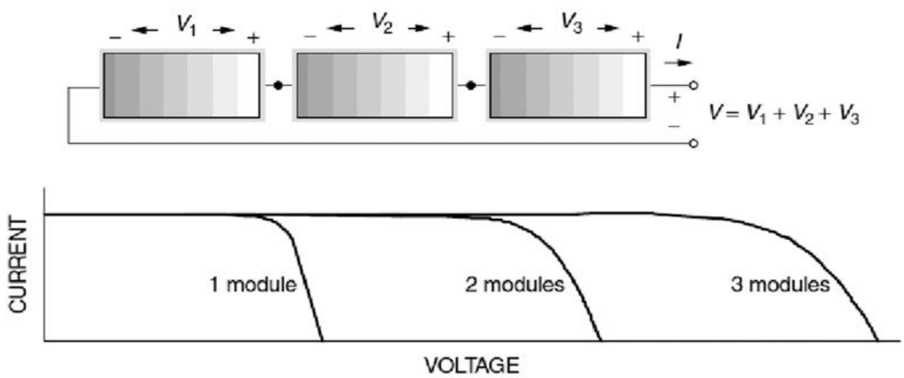


Figure 22 Solar cells serial connection

shows a series association of solar cells. Here, the same current

passes through each solar cell and the total voltage is the sum of the voltages generated by each

cells. The following equation illustrates the electrical characteristics in series association.

Vsoc = Ns × Voc ……… (11)

Iscc = Isc ……… (12)

With :

Vsoc: the total open-circuit voltage of cells in series

Iscc: short-circuit current of cells in series

Ns: Number of cells in series

2.5.7.2 Parallel association

If higher currents are required in a system, these can be achieved by parallel association of solar cells, as shown in

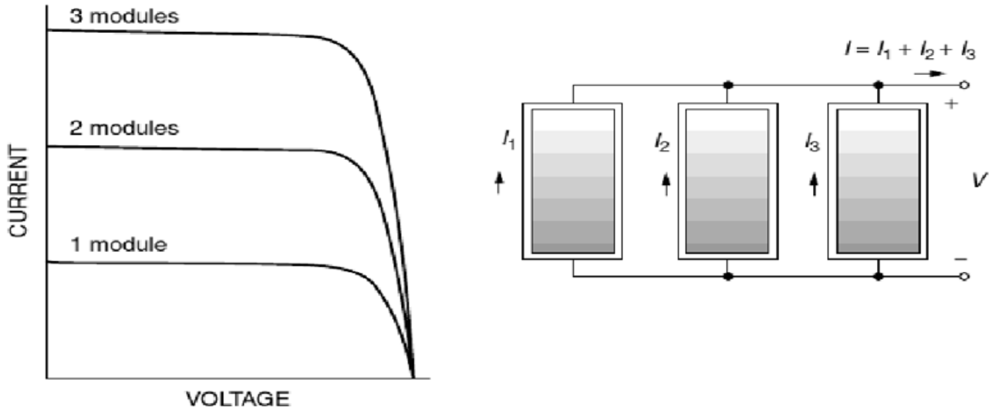


Figure 23 solar cells parallel connection

In parallel association, the voltage across each solar cell is equal, while the total current is the sum of all currents generated by each of the cells. The equation The following illustrates the electrical characteristics in parallel association.

Ipcc = Np × Icc ……… (13)

Vpoc = Voc ……… (14)

With :

Ipcc: the total short-circuit current of the cells in parallel

Vpoc: the open-circuit voltage of cells in parallel

Np: Number of cells in parallel

2.5.7.3 Hybrid association (series and parallel)

they systems can use a mixture of series and parallel combinations to obtain the voltages and currents required, as in. The following equation illustrates the electrical characteristics in hybrid combination.

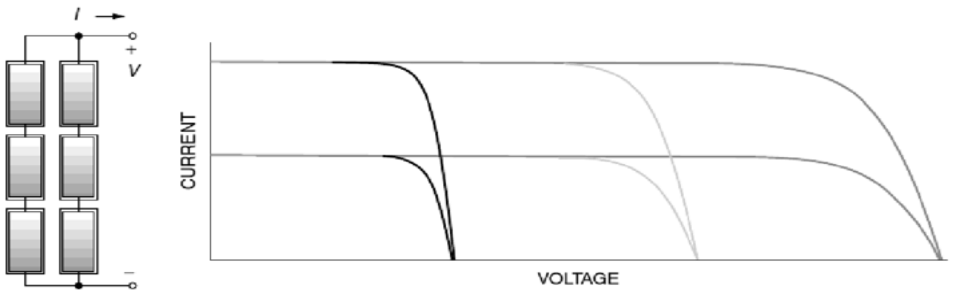


Figure 24 solar cells mixt connection

Ihcc = Np × Icc ……… (15)

Vhoc = Ns × Voc ……… (16)

With:

Ihcc: the sum of the short-circuit currents of the cells in parallel

Vhoc: the sum of the open-circuit voltages of cells in series

2.5.8 Solar panel

The solar cell can deliver around 0.5 to 0.6 volts when the sun hits it, but this is not enough to turn on a device. currently). The series and parallel connection of the cells is covered on the back by the back foil and on the front by the glass, which plays the role of protection and anti-reflective coating, and all of them are combined in an aluminum frame to form a solar panel.

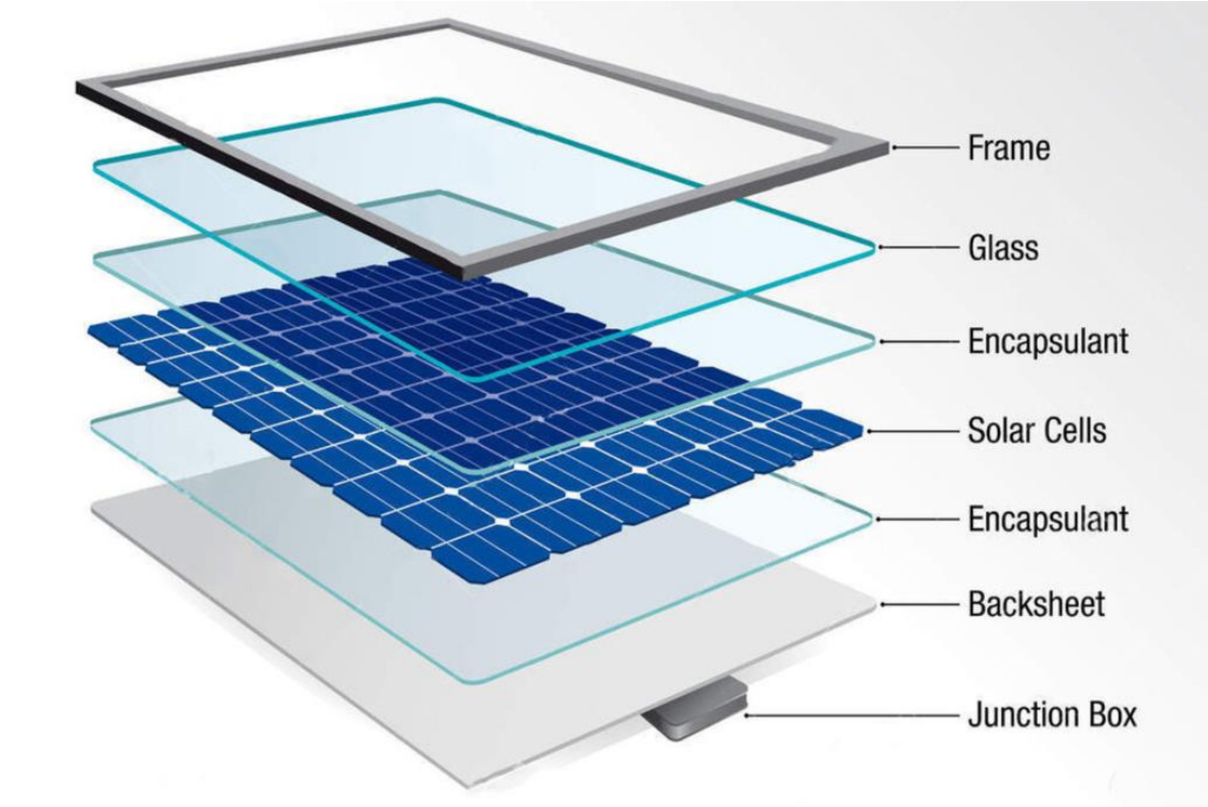


Figure 25 Solar panel structure

2.5.8.1 Module & array and circuit design

Solar cells are rarely used individually, but cells with similar properties are connected and encapsulated into modules, which in turn are the building blocks of solar modules. they are connected in series to achieve the desired voltage (Mack, 1979) . In general, about 36 cells in the series are used for a nominal 12V charging system. At maximum solar radiation (100 mW / cm2), the maximum current that can be delivered by one cell is about 30 mA / cm2.Therefore, the cells are connected in parallel to get the desired current. (A database of specifications for 125 commercial modules is available online from Sandia National Laboratories (2002).)

2.5.8.2 Identical cells

Ideally, the cells of a module would have identical properties and the module's IV curve would have the same properties and shape that of the individual cells, with a change in the axis scaling. Therefore, for N cells in series and M cells in parallel, the output voltage is N x volume of a single module and the current M x is the current of a module.

2.5.8.3 Non-identical cells and modules

In practice all cells have unique properties and the performance of the module is limited by that of the cell with the lowest performance; the same effects and waveforms occur when the cells in the above diagrams are replaced by modules. This is called a mismatch:

2.5.8.4 Galvanic isolation

The encapsulation system must be able to withstand voltage differences at least as large as the system voltages. Except in special cases, metal frames must also be earthed, as the internal potential and the connection potential can be much higher than the earth potential. (Australian Standards, 2005)

2.5.8.5 Mechanical Protection

Solar modules must have sufficient strength and rigidity to allow normal handling before the If glass is used for the top, it must be toughened because the middle areas of the module get hotter than the areas near the frame. This creates tension on the edges and can lead to cracks. In an array, the modules must be able to absorb a certain amount of torsion in the mounting structure.

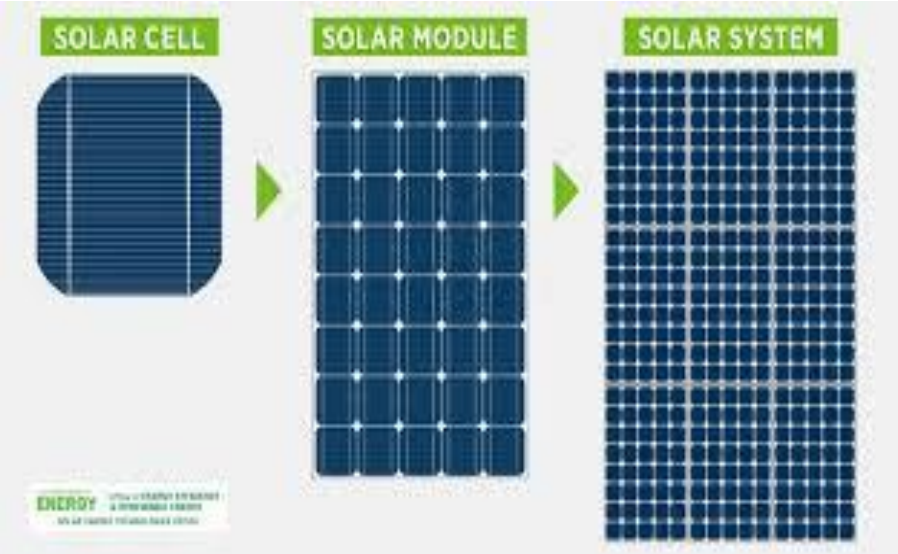


Figure 26 solar array structure

2.5.8.6 Shadow: by pass diodes

Cell serialization can be dangerous if either of them is in the shade. it will heat up and risk self-destruction. Indeed, a "masked" cell sees the intensity that passes through it decrease. Therefore, it blocks the flow of the "normal" intensity generated by the other modules. increases the cell, which leads to overheating. This is the effect of the inverse autopolarization.This cell is known as the "hot spot". To eliminate this problem and to protect the "masked" cell, anti-parallel "bypass" diodes are placed in 18 or 24 cells to avoid shaded cells. Depending on the number of cells, a solar panel has one to three bypass diodes (an average of 36 cells for 3 bypass diodes).. (Iftikhar, 2012)

2.5.9 Charge controller

Depending on the weather and other factors, solar energy is unpredictable and can damage the battery connected to the modules when the charge level is reached, which is why a charge regulator is used as charge-regulating battery protection. In order to guarantee this function without interference, the electrical properties must match the output of the solar panel or be higher than the properties of the battery, the starting charging voltage of the batteries must be lower than the voltage of the photovoltaic. Panel In summary, when designing a solar system, the charge controller imposes its properties on the other components of the system; Its nominal voltage must correspond to the system voltage and the nominal current must be the maximum current that the photovoltaic generator can deliver. To perform this function, the charge controller is usually based on three levels, bulk, absorption and float and looks like this:

BULK: initial charge or initial charge, during this level the voltage must rise, the controller allows all current from the module until the State of charge usually 14.4 to 14.6 volts, which is about 80% of the state of charge, then it does the absorption;

ABSORPTION LEVEL: During this phase the control unit holds the last voltage and reduces the current coming from the field until the battery reaches 100% of the state of charge; the current will gradually decrease when the batteries are 100% charged.

FLOAT: After the absorption time, the voltage should drop (13.4 to 13.7 volts) and the batteries should draw little float current until the next cycle.

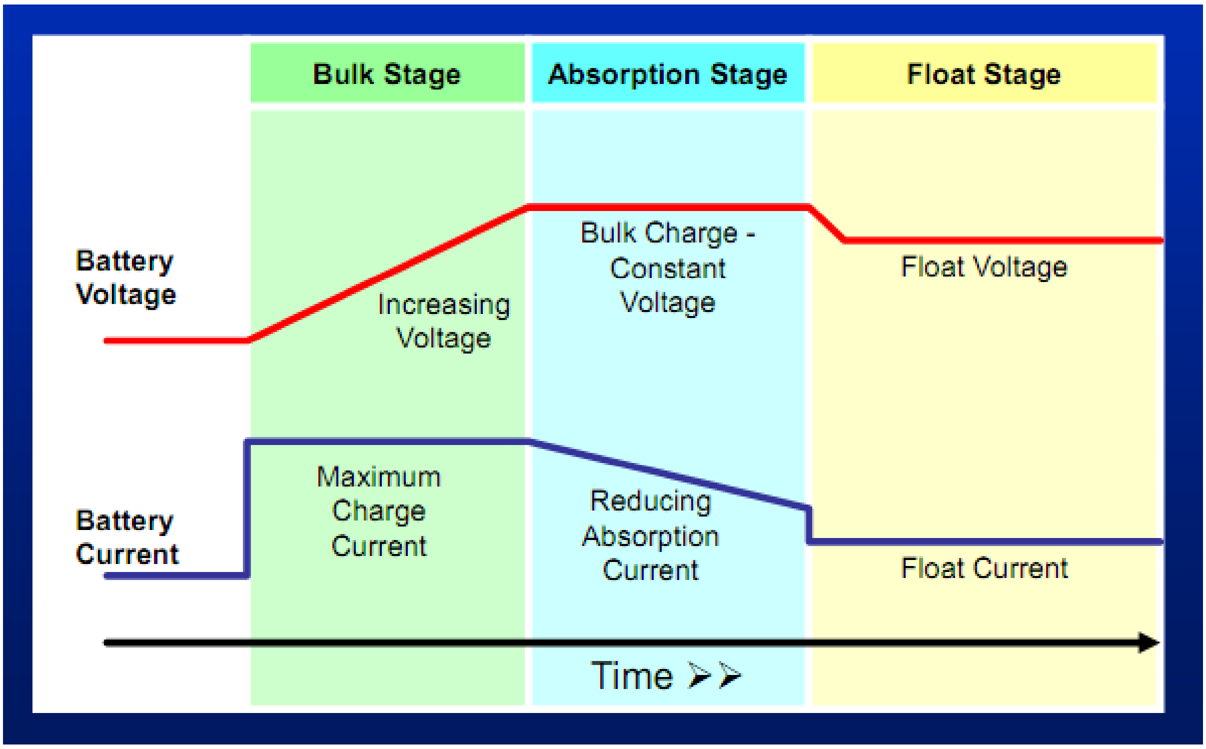


Figure 27 differents stages of charge controller

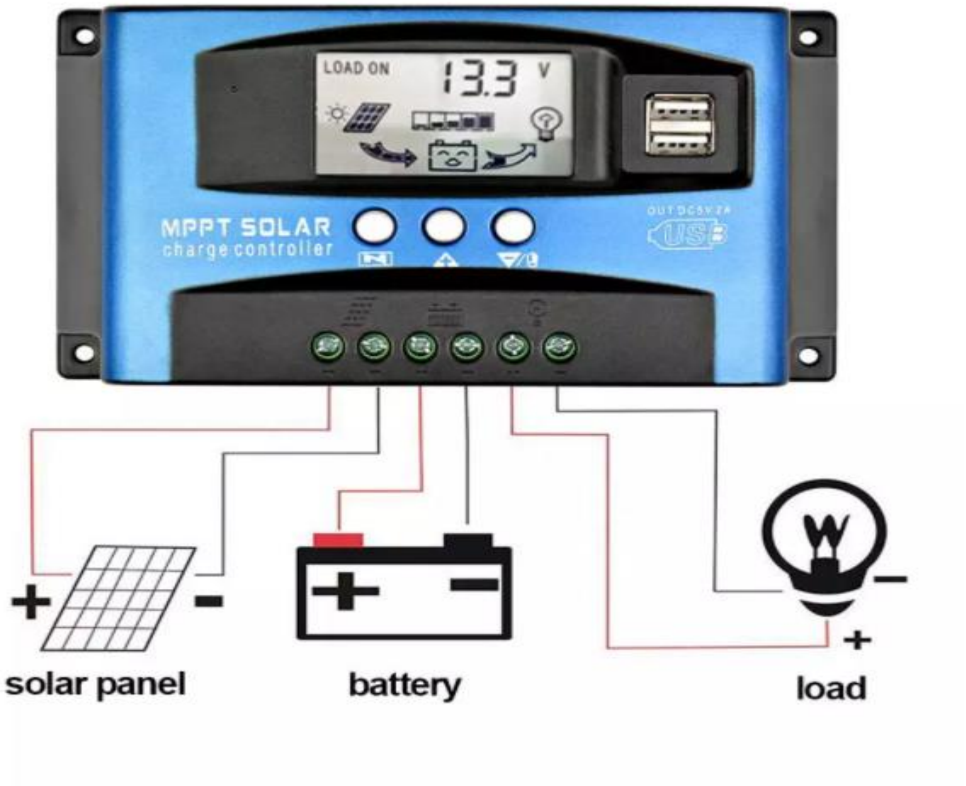


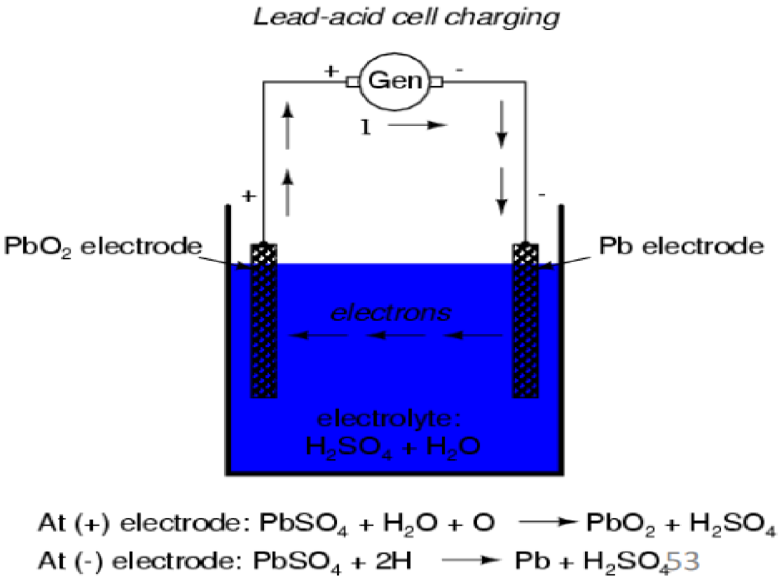
Figure 28 charge controller picture

The charge controller is installed between the solar panel and the batteries and automatically maintains the battery charge with the 3-step charging cycle described above. For reasons of reliability and efficiency, most multi-stage charge controllers use a Maximum Power Tracker (MPPT) to always bring the output of the solar modules to the maximum capacity of the batteries. Is connected directly to the modules at the input and to the batteries at the output. For safety reasons, it is strongly recommended to connect the battery first and then the PV after charging. (Freesunpower, n.d.)

2.5.10 Battery

Photovoltaic modules generate energy when exposed to sunlight, thousands of modules cannot operate a single device at night or when the sun is not available, hence the use of batteries Photovoltaic batteries are usually used for storage purposes, for stabilization or for voltage and power supply used. Overvoltage, it is not a generator but an energy storage box;

Therefore, energy storage is imperative to meet consumer needs. The battery is a pair of electrodes (positive and negative) separated by insulation, all immersed in an electrolyte solution and enclosed in a box, a nominal cell voltage is + 2 V depending on the type of



battery

Figure 29 battery mechanism There are many types of battery with different technologies but among all the lead acid battery continues to be the workhorse of the PV system today in the world because…

The requirements for selecting the quality battery for long-term storage are:

- Long service life
- Very low self-discharge
- Long switch-on time (long charging times)
- High storage efficiency when charging
- Low price
- Low maintenance

Bat efficiency is: Eout / On (Advanced Tutorials: Solar Radiation for Solar Energy Systems (freesunpower.com)) For this purpose there are many types of batteries defined as: flooded types, Gel and AGM.(Wenham et al., 2007)

2.5.10.1 Flooded types

(Advanced Tutorials: Solar Radiation for Solar Power Systems (freesunpower.com)) These are lead acid batteries that have caps for adding water. Many manufacturers manufacture these types for the use of solar energy. Perhaps the most famous are Trojan, Surrette and Deka, this types release a gas, so, a ventilation system must be used purify the place.

2.5.10.2 Gel

(Advanced tutorials: Solar radiation for solar power systems (freesunpower.com)) Not to be confused with maintenance-free batteries, sealed gel batteries have no ventilation openings and do not release gas during process charging, as is the case with flooded batteries. not required and can be used indoors. This is a great benefit as it allows the batteries to maintain a constant temperature and perform better.

2.5.10.3 AGM

(advanced tutorials: solar radiation for solar power systems (freesunpower.com)) In my opinion, absorbed glass mat batteries are the best for using solar energy. Electrolyte They are leak-proof / leak-proof, do not give off gas when charging and have excellent performance. They have all of the advantages of sealed gel types and are of higher quality, hold better in voltage, discharge slower, and last longer. Concorde Battery's Sun Xtender series is a great example of AGM batteries. Get What You Pay For. You can find this type of battery in airplanes, hospitals, and remote cellular / telephone tower installations. I spoke mainly of temperature and humidity; In fact, battery readings are generally reported at 77 degrees F.When batteries cool down, their voltage drops and their performance suffers. This is one of the main reasons I prefer AGM batteries as they can be stored indoors where temperatures fluctuate less.

Table 1 types of battery

HVD, LVD are example only

Forget about the terms "Deep Cycle type" and "Shallow Cycle type".
These will confuse you. The operation of solar PV system is *shallow cycle* operation.

	Automotive Type	Industrial Type
Flooded (Liquid) • Need to top up distilled water • Durable • Relatively strong against overcharge (HVD ~14.4V)	• Available • Low cost • Acceptable for small application • Limited range of capacity (~150Ah) • LVD: ~11.7V , HVD: ~14.4V	• Available • Durable • Wide range of capacity (~2000Ah, 2V unit) • LVD: ~11.5V , HVD: ~14.4V
Maintenance free (Liquid) • Easy to handle • Weak against over charge • Need to use lower HVD than flooded type (~14.1V) • No boost charging • Limited range of capacity (~150Ah)	• Available • Acceptable for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.7V , HVD: ~14.1V	• Available • Recommended for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.5V , HVD: ~14.1V
Maintenance free (Gel) • Sealed • Easy to handle • Weak against over charge • Need to use lower HVD than flooded type (~14.1V) • No boost charging • Limited range of capacity (~150Ah)	N/A	• Available • Recommended for small application • Good for maintenance free system • Need good charge controller to avoid overcharge • LVD: ~11.5V, HVD: ~14.1V

The figure below gives

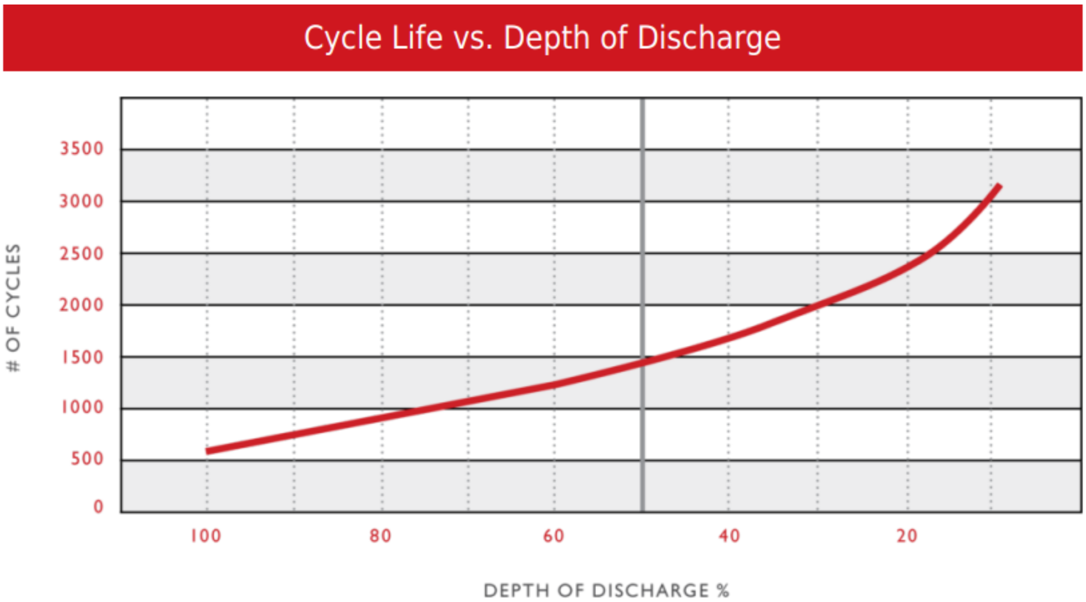
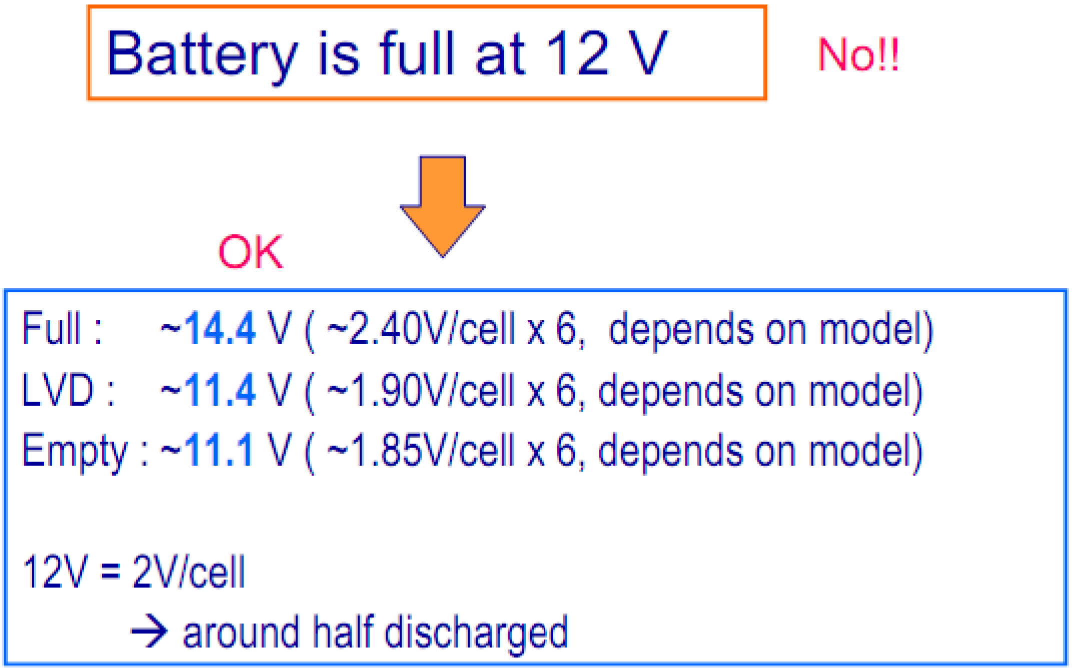


Figure 30 battery's cycle life vs depth discharge

(Advanced Tutorials: Solar Radiation for Solar Power Systems (freesunpower.com)) Another important thing to consider is how deep you discharge your batteries. This is called the DOD (depth of discharge). In other words, how much you drop the voltage before the next charge cycle. The figure above shows how important it is to use at a high depth of discharge. They will last a lot longer if you don't unload them too deeply. This is called surface cycling. However, they can withstand discharges of up to 20% or so, but I wouldn't do that too often.

2.5.10.4 State of charge

(Advanced Tutorials: Solar Radiation for Solar Power Systems (freesunpower.com)) We can determine the state of charge (SOC) by measuring the terminal voltage or density (SG) of the electrolyte for an accurate result, the battery must be at rest for several hours, at 25 ° C, it is also possible to determine the state of charge by reading the voltage on the interface of the charge controller.



Remember, this measurement is most accurate when the batteries have not been used for at least 1 hour and have not been charged or discharged. And it is important to know that a higher operating temperature shortens the service life, it halves every 10 ° C above 20 ° as we can see in the following figure.

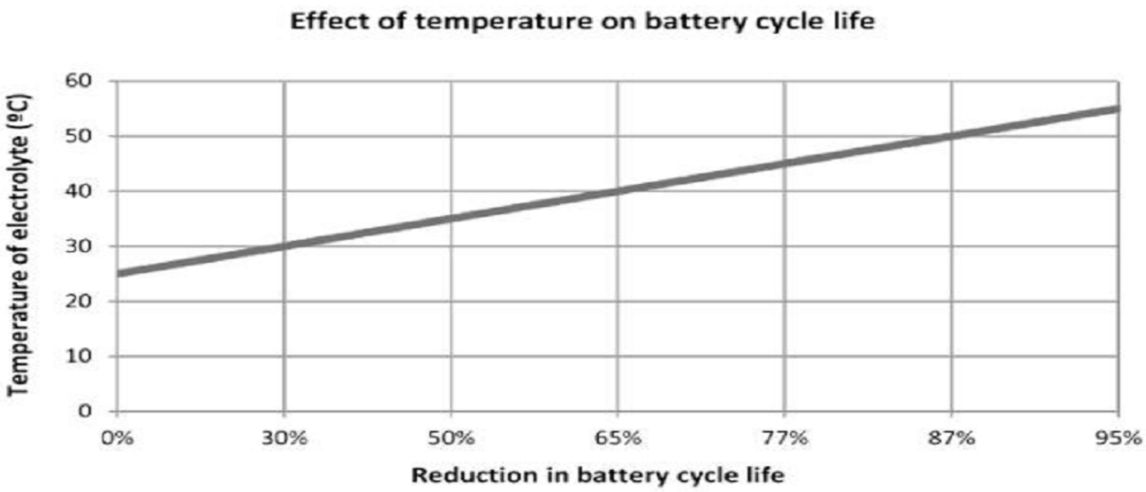
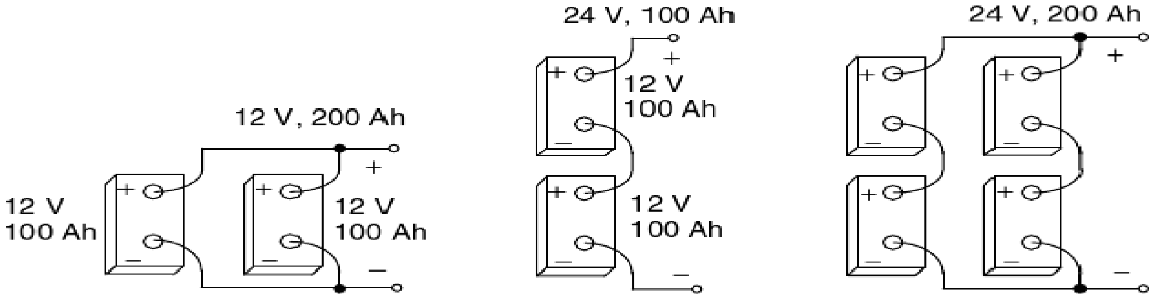


Figure 31 effect of temperature on battery's life

2.5.10.5 Battery connection:

Battery connections

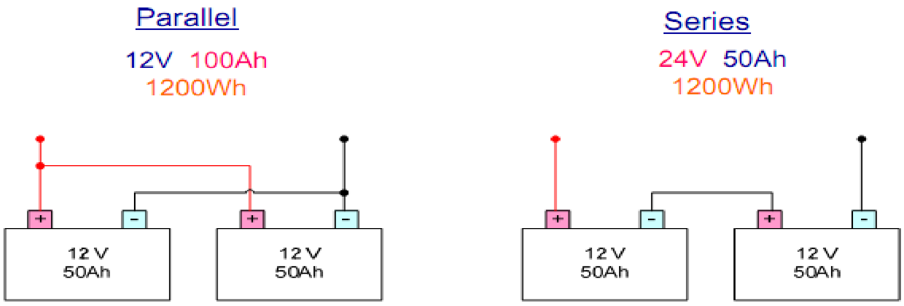
a) For batteries wired in parallel, amp-hours add up
b) For batteries in series, voltages add up
c) For series/parallel combinations, both voltages and amp-hours add up



(a) Parallel, Amp-Hrs add (b) Series, Voltages add (c) Series/Parallel

(Sa, 2007)

- ✶ Parallel connection sums Ah
- ✶ Series connection sums Voltage
- ✶ Total energy storage (Wh) is same
- ✶ Do NOT mix different type, model, age of batteries



- Maximum parallel connection need to be limited up to **4**
  - Difficult to control equal charging current due to slight difference of voltage, internal resistance and capacity
- For more than 4 parallel connection, need independent current control function

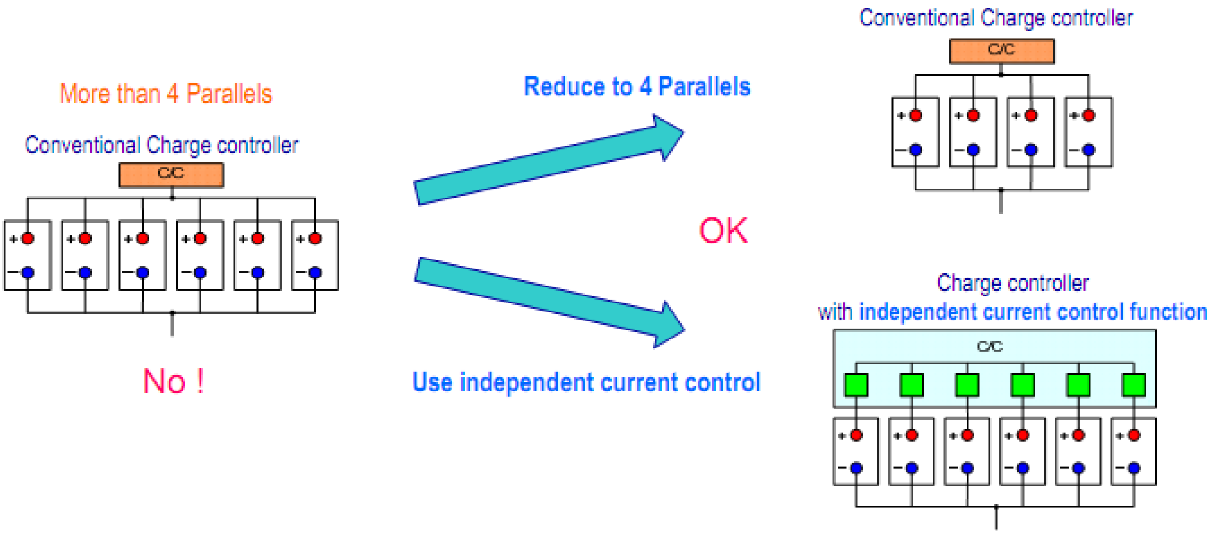


Figure 32 batteries connections

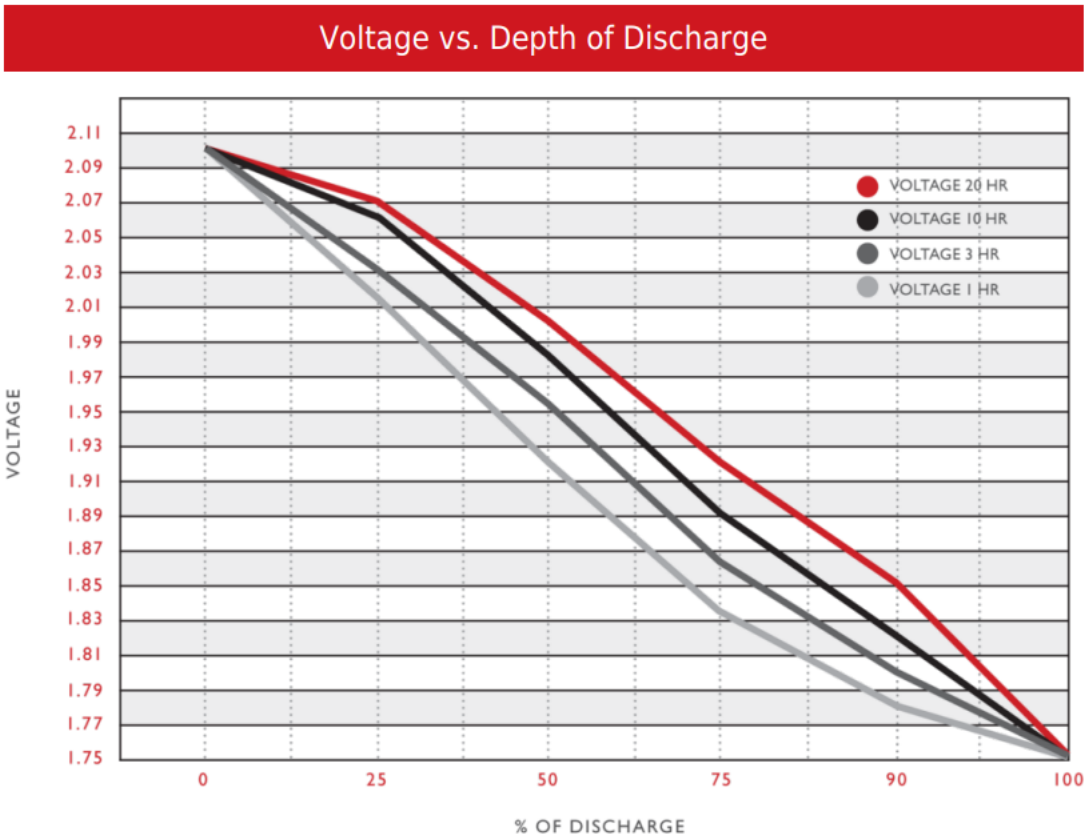


Figure 33 effect of depth of discharge on battery

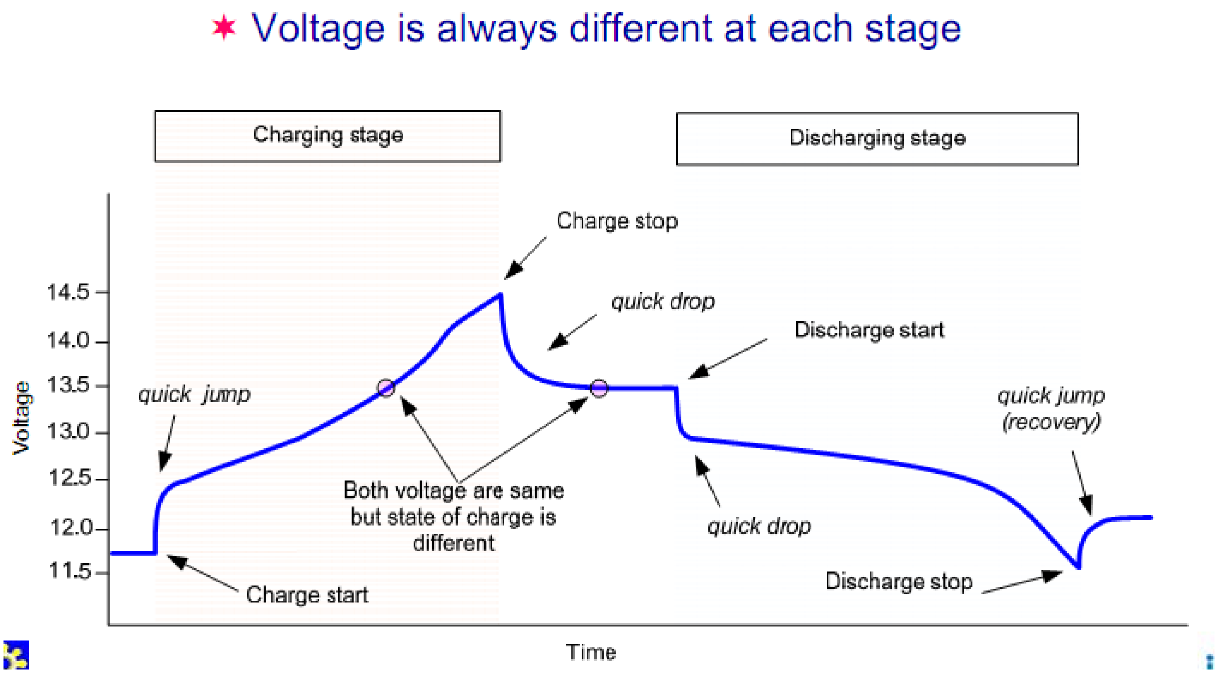


Figure 34 battery's charge & discharge

2.5.11 Inverter

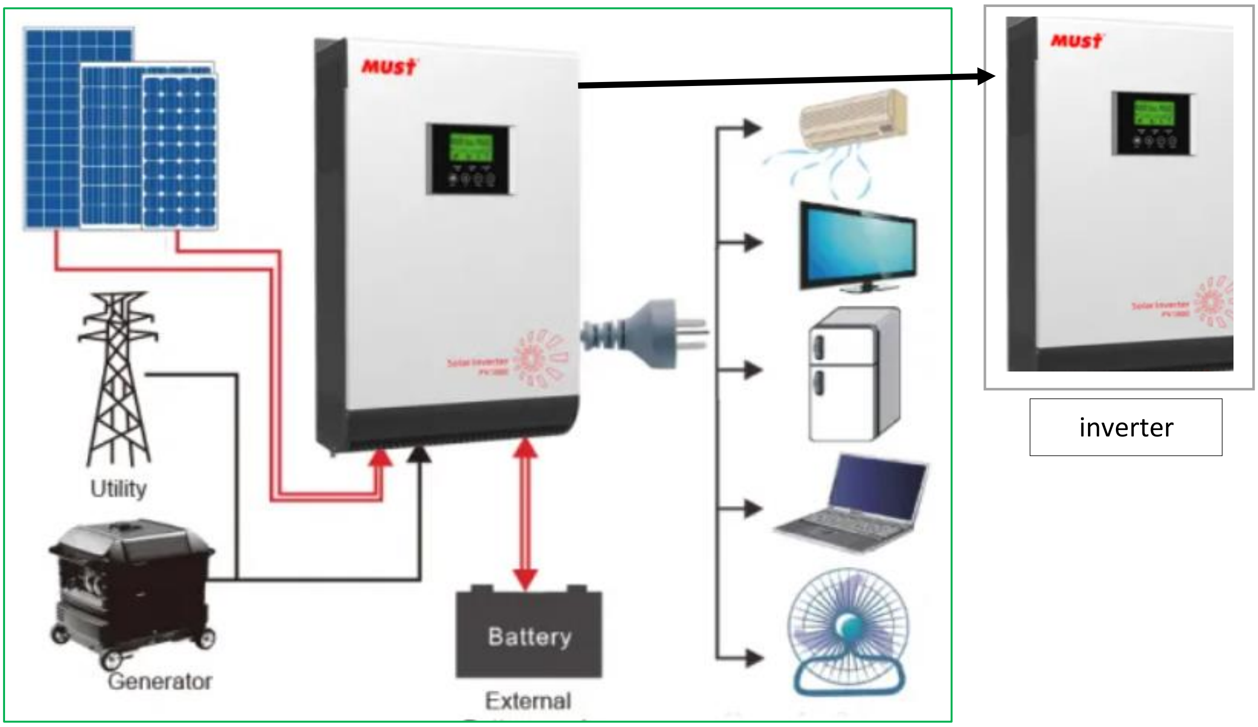
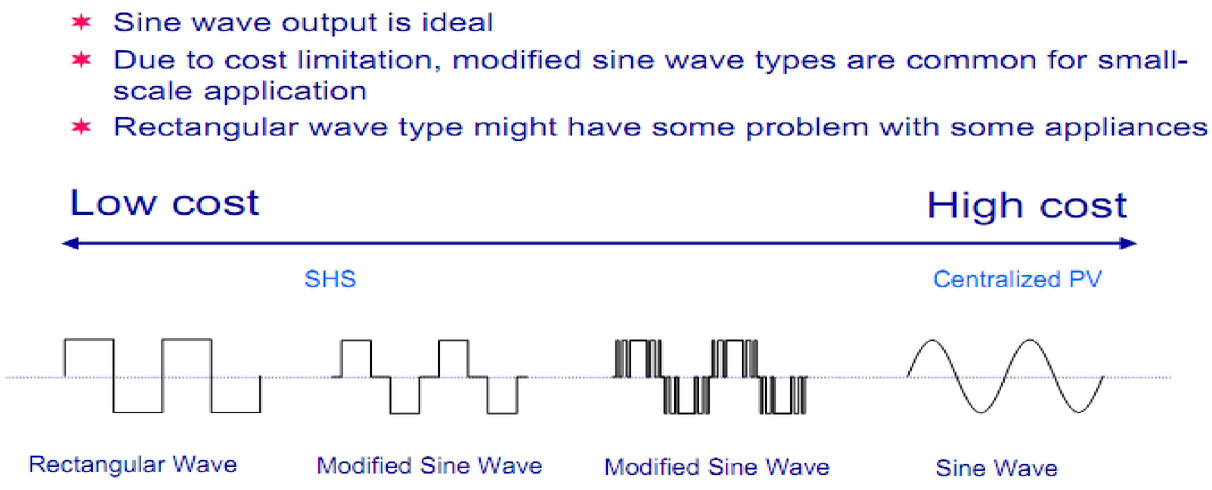


Figure 35 inverter's picture

Solar panels can only generate power in DC mode, although many modern devices or networks need the power in AC mode, it is necessary to use a converter device: an inverter. The inverter, an electronic instrument, is used to convert direct current into alternating current. The photovoltaic system after its appearance in 1838 went through a great development with the invention of the inverter in particular and power electronics in general. (Power, 2021)

The inverter plays a central role in the solar power system; after converting the low voltage DC to high level, the multifunction inverter can also charge the batteries if it is connected to the power grid or other Continuously calculates the operating point (voltage) that the maximum power to be fed into the Network generated: This is the MPPT (Maximum Power Point Tracker), this process depends on sunlight and temperature. An inverter typically has an efficiency of more than 94% and contains safety functions. how to open the earth fault and anti-earth circuit; Depending on the initial quality, it should be replaced approximately every 10 years. Depending on the manufacturer, the inverter can deliver waves in three operating modes: square sine wave inverter, modified sine wave inverter and real sine wave inverter, with the true sine wave inverter being the best and most reliable. However, since the square wave type can be a problem with some devices, the modified sine wave inverter is also inexpensive and more recommended for some applications such as small facilities like camping cabins.



In design we need to consider a marge of 30% of power deliver by PV array to ensure the security the inverter that contain fragile instruments.

2.6 Conclusion

the course of this chapter allowed us to make an overview on the last technology of different components of photovoltaic system, much remains to be innovated for more performance and efficiency of renewable energy.

Chapter III Methodology

3.1 Introduction

Designing a solar system, it is much more important to satisfy the customer by achieving all the requirement for this there might have some methodologies to following in other to organize the work and to ensure all the steps. To attain the proposed objectives of this project we may have the accurate data on the accurate position. Therefore, this chapter discuss on appropriate procedures that have been follow to achieve the aim of this study.

Several technical tools have been used to determine geographical and weather data among them, there is HOMER, MATLAB, Bluesol, and retscreen.

3.2 Location assumption

Sidi Bel Abbes province of Algeria situated at north-south of the country

Figure 36 Sidi Bel Abbes location cordinates

With the energy data

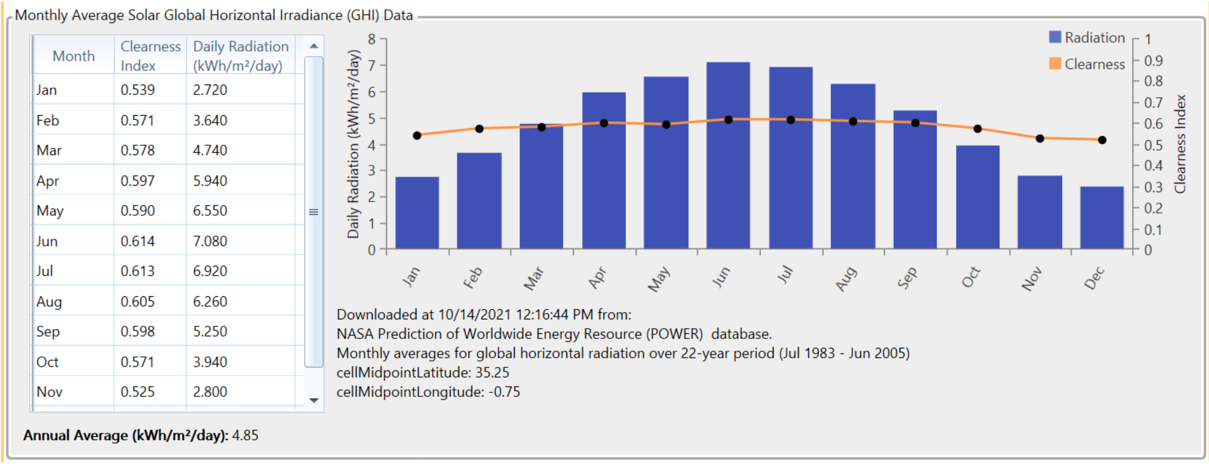


Figure 37 Sidi Bel Abbes radiations information

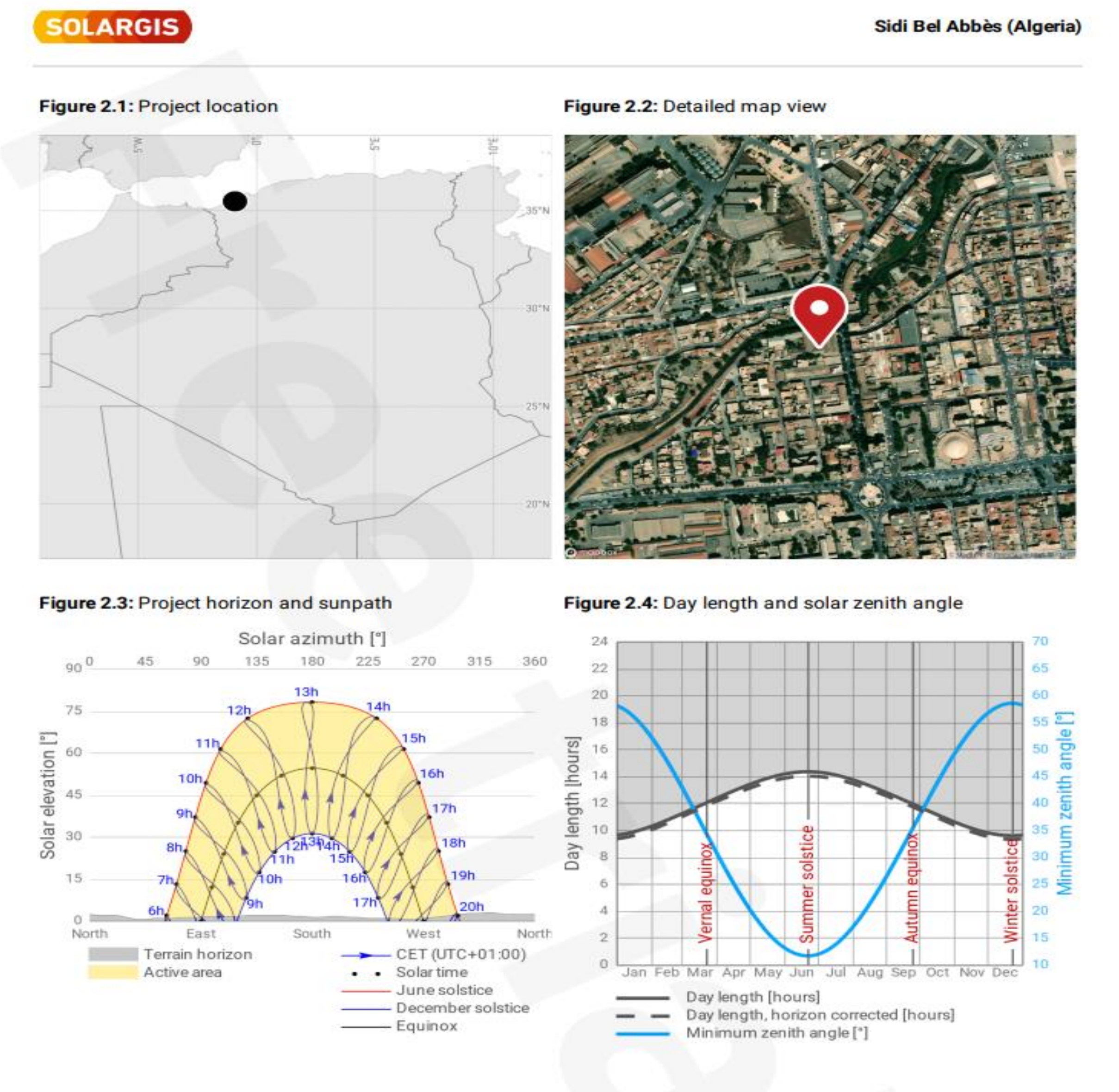


Figure 38 SUN PATH AND DAY LENGTH

4 Solar and meteo: Monthly statistics

The most important project-specific meteorological parameter that determines solar electricity production is solar radiation, which fuels a PV power system. Power production is also influenced by air temperature. Other meteorological parameters also affect the performance, availability and ageing of a PV system.

Table 4.1: Solar radiation and meteorological parameters

Month	GHI kWh/m²	DNI kWh/m²	DIF kWh/m²	D2G	TEMP °C	WS m/s	CDD degree days	HDD degree days
Jan	87.5	130.6	32.1	0.367	10.3	2.8	0	238
Feb	104.1	132.0	37.4	0.360	11.3	2.8	1	191
Mar	153.4	161.7	55.1	0.359	13.6	2.7	5	142
Apr	177.6	166.1	65.1	0.366	15.7	2.7	24	91
May	207.3	177.9	77.8	0.375	19.5	2.4	83	38
Jun	223.6	190.6	80.9	0.362	23.9	2.3	177	2
Jul	228.2	184.3	88.8	0.389	27.4	2.1	291	0
Aug	205.3	176.5	78.0	0.380	27.5	2.0	296	0
Sep	164.4	158.9	60.9	0.371	23.4	2.1	163	1
Oct	130.5	149.5	48.2	0.369	19.7	2.1	82	30
Nov	90.8	124.0	34.9	0.385	14.3	2.6	8	118
Dec	78.7	124.0	29.8	0.378	11.4	2.7	0	205
Yearly	**1851.4**	**1876.1**	**689.1**	**0.372**	**18.2**	**2.4**	**1128**	**1055**

Table 4.2: Other meteorological parameters

Month	ALB	RH %	PWAT kg/m²	PREC mm	SNOWD days
Jan	0.16	74	12	46	0
Feb	0.18	72	12	41	0
Mar	0.20	70	13	41	occasional
Apr	0.20	67	15	34	0
May	0.20	63	18	23	0
Jun	0.21	56	21	6	0
Jul	0.22	52	24	2	0
Aug	0.21	54	26	4	0
Sep	0.20	62	24	20	0
Oct	0.19	65	20	29	0
Nov	0.17	70	15	45	occasional
Dec	0.16	73	13	38	0
Yearly	**0.19**	**65**	**18**	**329**	**0**

Figure 39 montly statistical by solargis

7 PV performance: Energy conversion and system losses

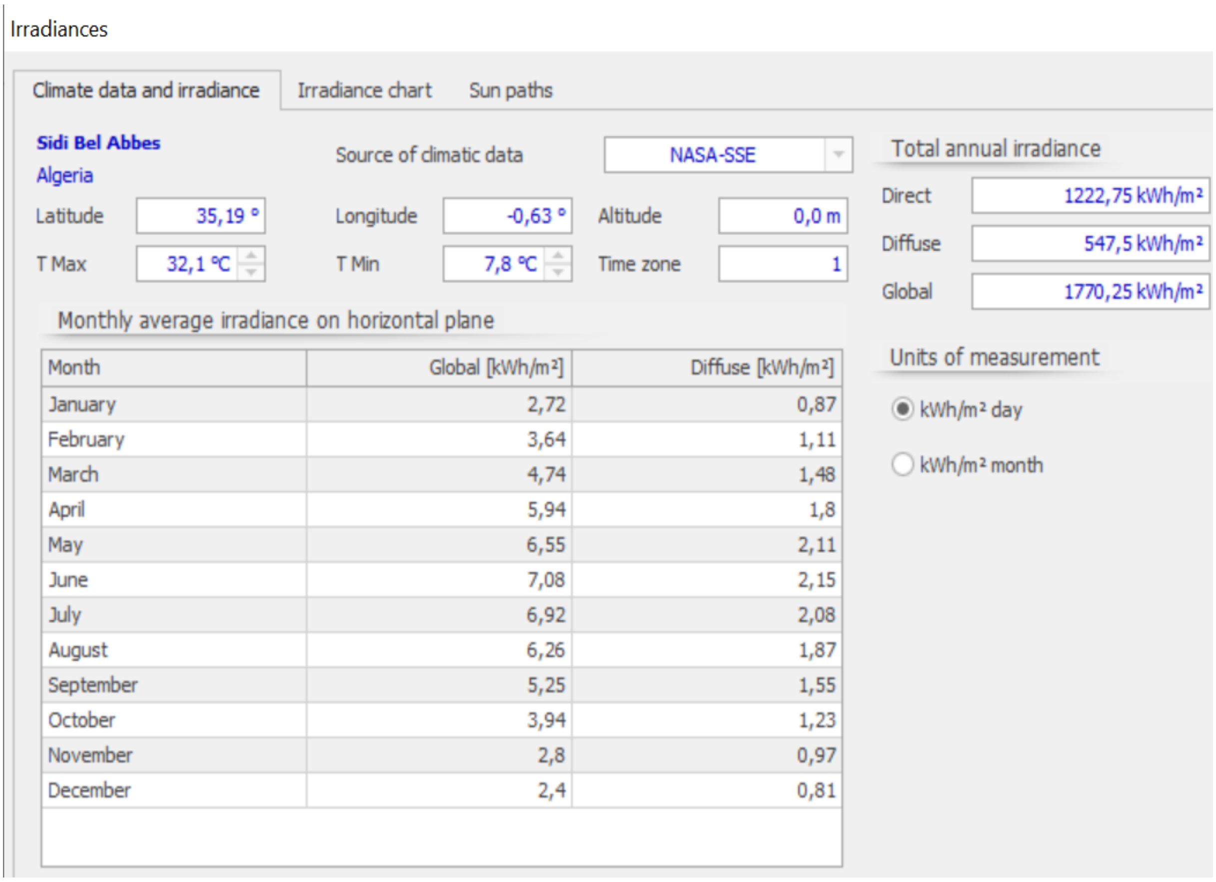
Theoretical yearly specific estimate of solar electricity production by a photovoltaic system without considering the long-term ageing and performance degradation of PV modules and other system components. Long-term average performance ratio (PR) is calculated for a start-up production of a PV system.

Table 7.1: Energy conversion and related losses

	Energy input kWh/m^2	Energy loss/gain kWh/m^2	Energy PVOUT specific kWh/kWp	Energy loss/gain kWh/kWp	Energy loss %	PR %
Global horizontal irradiation (GHI) theoretical	**1851.4**					
Horizon shading (terrain + horizon objects)	1851.4	0.0			0.0	
Global horizontal irradiation site specific	**1851.4**	**0.0**			**0.0**	
Conversion to surface of PV modules	2112.5	261.1			14.1	
Global tilted irradiation (GTI)	**2112.5**					**100.0**
Dirt, dust and soiling	2038.6	-73.9			-3.5	96.5
Angular reflectivity	1993.0	-45.6			-2.2	94.3
GTI effective	**1993.0**	**-119.5**			**-5.7**	**94.3**
Spectral correction			1991.3	-1.7	-0.1	94.3
Conversion of solar radiation to DC in the modules			1807.9	-183.4	-9.2	85.6
Electrical losses due to inter-row shading			1807.9	0.0	0.0	85.6
Power tolerance of PV modules			1807.9	0.0	0.0	85.6
Mismatch and cabling in DC section			1780.9	-27.0	-1.5	84.3
Inverters (DC/AC) conversion			1702.6	-78.3	-4.4	80.6
Transformer and AC cabling losses			1678.8	-23.8	-1.4	79.5
Total system performance (at system startup)			**1678.8**	**-314.2**	**-15.8**	**79.5**
Losses due to snow			1678.8	0.0	0.0	79.5
Technical availability			1645.2	-33.6	-2.0	77.9
Total system performance considering technical availability and losses due to snow			**1645.2**	**-33.6**	**-2.0**	**77.9**
Capacity factor			**18.8%**			

Figure 40 pv performance by solargis

Figure 41 Sidi Bel Abbes irradiance information



Month	Global [kWh/m²]	Diffuse [kWh/m²]
January	2,72	0,87
February	3,64	1,11
March	4,74	1,48
April	5,94	1,8
May	6,55	2,11
June	7,08	2,15
July	6,92	2,08
August	6,26	1,87
September	5,25	1,55
October	3,94	1,23
November	2,8	0,97
December	2,4	0,81

Figure 42 Sidi Bel Abbes data

After simulation, we have notice that the site has potential solar energy resource which can be used for electrical energy generation, and the essential result have been summary in table below:

Table 2 location information

Country	**Algeria**
Region	Sidi bel Abbes
latitude	35°11′23″ N
longitude	0°37′51″ W
Inclinaison angle	32
Average irradiance	6kwh/m^2
Average hours of sunshine	7 hours/per day
Maximal temperature	+38.6°C
Minimal temperature	+1.3°C
La source : https://www.infoclimat.fr	

3.3 Collection of data

To really satisfy the expectation, we have to conduct the series seances of data collection which does not be easy because of covid 19 situation, despite of all we succeeded to have the loads used and the time of usage in other to make the energy assessment, moreover knowing the emplacement of equipment also is necessary for reliability of the system.

According to the weather and environment there might have some assumption of efficiency and performance factor to cover all mis having the site and enhance the reliability of the system.

3.3.1 Estimation of efficiency and performance ratio (pr)

The performance ratio defined as the overall yield of the photovoltaic chain under real operating conditions. It allows, from the theoretical yields of the components at STC (Standard Test Conditions) providing in particular the Peak Power, to calculate the yield under real conditions.

Taking into account some environments, technical and economics parameters, the performance ratio will be estimated between: **0.7 <= PR <= 0.8**

In this case with assistance of solargis software result on performance evaluation we consider the is: PR=0.8

We consider the initial efficiency such as:

Overall efficiency:82%

Battery efficiency:80%

Battery DOD: 75%

Inverter efficiency: 90%

3.4 Data overview of the school

The school is composed of 3O classes each class has 12 Lamps of 36W each,
And out lighted with 40 lamps of 36W each, there is administration with 10 classes each has 12 lamps of 36W each, we count a room of conference with 30 lamps of 36w each
Hospital has 6 lamps of 36W each two toilets with 10 lamps of 36W each,
There 15 computers of 170W each and printer of 200W
Photocopy machine has 700W
Two data show with 270W each
Air condition 1800W
Two pumps with 440W and heater with 350W
All the data collected have been summarize in tables below:

Table 3 loads & energy required

laods	quantity	Watt by unit (w)	Nigth time (h)	Day time (h)	Total watt (w)	Day energy (kwh)	Nigth Energy (kwh)
Lamps	516	36	0	7	18576	130.03	0
Lamp out class	64	36	5	7	2304	16.128	11.52
Total					20880	147.31	11.52
						158.55	
Inductive loads							
laods	quantity	Watt by unit (w)	Nigth time (h)	Day time (h)	Total watt (w)	Day energy (kwh)	Nigth Energy (kwh)
computer	15	170	0	7	2550	17.85	0
printer	1	200	0	7	200	1.4	0

Photocopieuse	1	700	0	4	700	2.8	0
Data show	2	270	0	3	540	1.62	0
Air condition	1	1800	0	7	1800	12.6	0
pumps	2	510	1	3	1020	3.08	1.02
Pump small	1	370	2	3	370	1.11	0.74
heater	2	420	3	4	840	3.36	2.52
Total induction loads					8020	46.92	4.28
						51.2	
total					**28900**	**194.23**	**15.52**
						209.75	

Apart of the loads, the distances between equipment one to another have been given

Distance between panels array and charge controller is 30m

Distance between charge controller to batteries is 5m

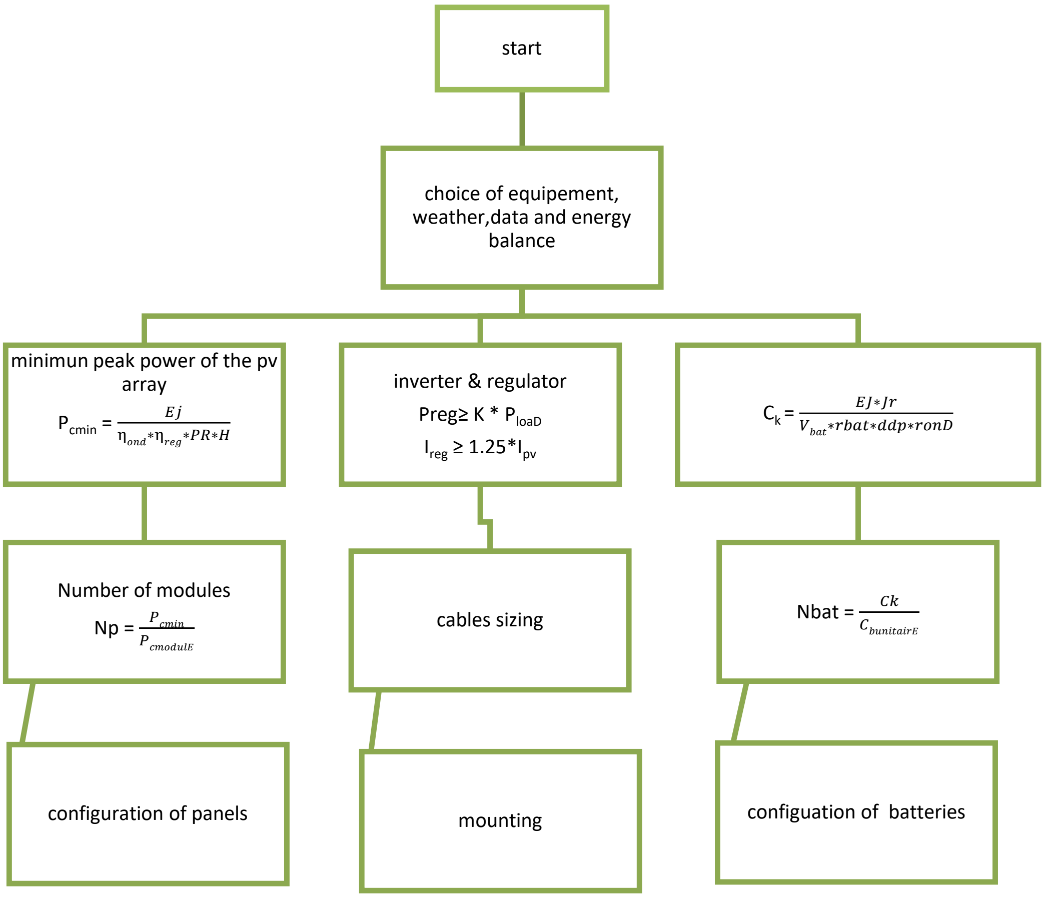
Distance between batteries and inverter is 5m

Distance between inverter to distribution box 5m

3.4 Methodology & methods

The study will begin with different manual methods and then the simulation after it ends by optimizing the best.

Table 4 design structure



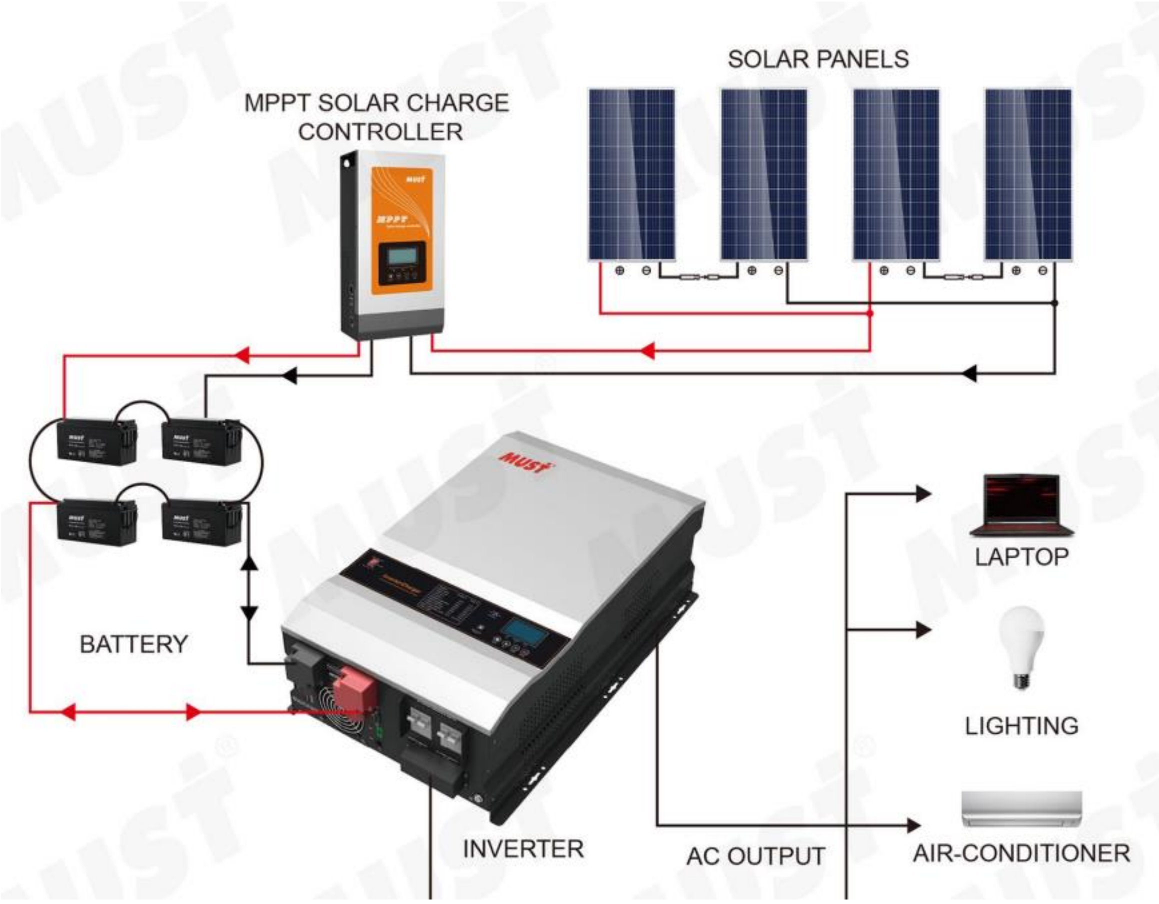


Figure 43 system diagram

Chapter IV

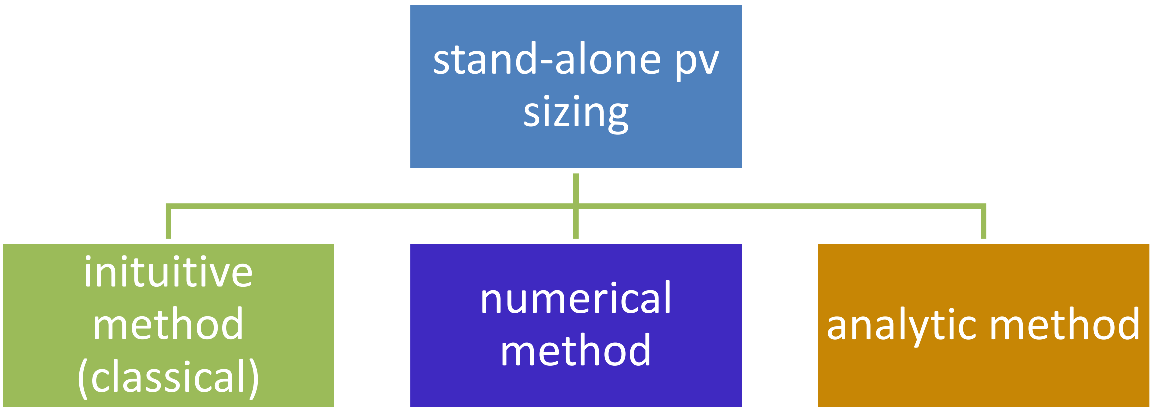
4.1 introduction

During this phase of our study, we will design all the system with different methods and by using also the software. We will also size all the components then after comes the mount which is the ends of the phase.

4.2 Manual system design

There is several methods of pv system design some are more accurate then the others as this figure below:

Table 5 diferents methods diagram



4.2.1 Energy balance

Total power of the equipement can be found

P_t (w) = $\sum_{i=1}^{n} Pi$ with Pi power of each equipement

Each equipement has usage coefficient, so

The tolat real power of equipement is

P_{tr} = $\sum_{i=1}^{n} Pi*\alpha$ with α the equipement usage coefficient

Total energy equipement:

E = P*t

Daytime energy consumption (wh)

Ed (wh) = $\sum_{i=1}^{n} Pi$ *td where td is the number of hours each piece of equipement operating during the sunny period.

Night time time energy consumption

En (wh) = $\sum_{i=1}^{n} Pi$ *tn where tn is the number of hours each equipement operation at the night.

Day time energy consumption: Ed = 194.23KWh

Nigth time energy consumption: En = 15.52KWh

Total power of the appliances: Pt= 28.9KW

Total energy consumption: Ej' = Ed + En = 209.75Kwh

4.2.2 Peak power computation

4.2.2.1 Storage Assessment

For viability of stand-alone solar sizing, it is recommended to size the system with the sunshine of the worst of the year to avoid all storage energy interruption, and to enhance the security, a coefficient of management can be provided.

4.2.2.1.1 Production storage:

This is the type of storage that allows loads to be fed in a staggered manner. The storage is done at a time when the sun is available (during the day for example for solar without clouds) but does not coincide with the period of consumption of the users (e.g. at night for lighting)

S_p (wh) = α_n*E_{nd}, with α_n being here night time autonomy coefficient (to be optimized for maximum safety when needed)

4.2.2.1.2. Management storage

This is the type of storage that makes it possible to smooth out production by compensating for the intermittence of the resource.

Sg (wh) = α_d* E_d, with α_d being here a management coefficient to be chosen between 10% et 20%.

The total energy storage requirement St (wh):

St(Wh) = Sg(Wh) + Sp(Wh) = αd * Ed(Wh) + αn * En(Wh)

4.2.2.2. Estimating the coefficient, the optimal couple (α_d; α_n)

The couple (α_d; α_n) depend on the gross coefficient X_0 daytime use,

$X_0 = \frac{Ed}{Ej}$

It is possible to determine (α_d; α_n) by using the simulator MATLAB with criteria of optimization: LCOE, Battery life and LLP,

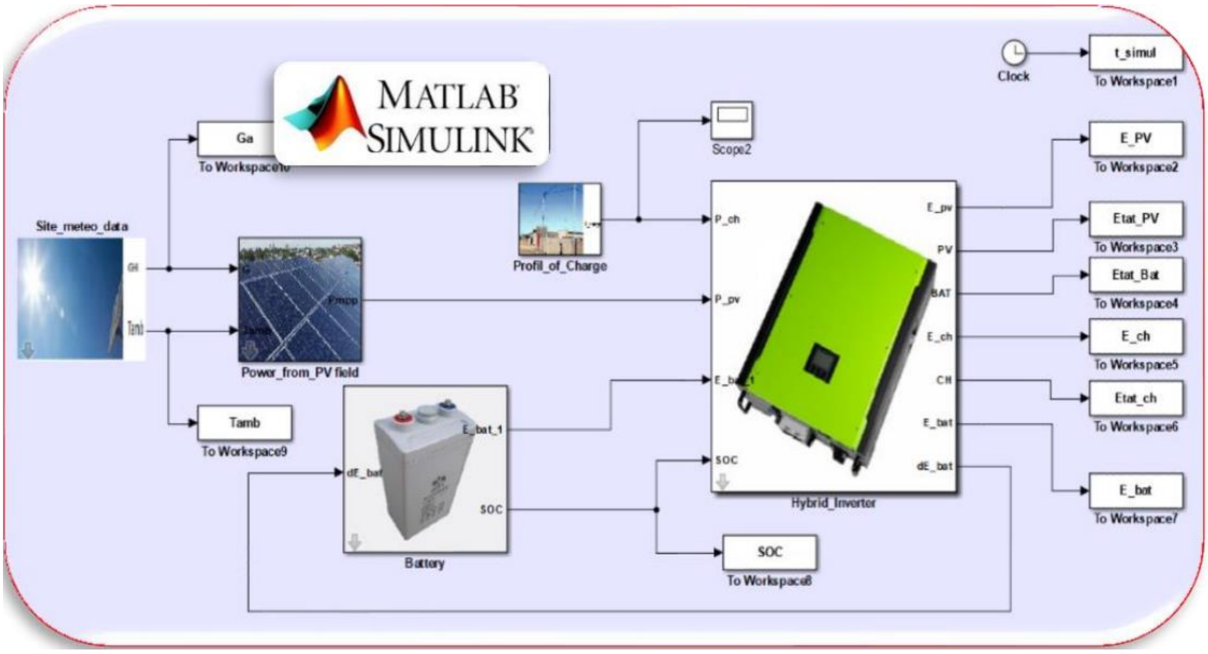


Figure 44 result of simulation

The out results are based process such as:

Table 6 matlab output

X_0	Couple (α_d ; α_n)
X_0 ∈ [0, 25%]	(0.0; 1.2)
	(0.1; 1.1)
	(0.2; 1.0)
X_0 ∈ [25%, 75%]	(0.1; 1.1)
	(0.2; 1.1)
	(0.3; 1.0)
X_0 ∈ [75%, 100%]	(0.4; 1.0)
	(0.5; 1.1)

X0 = $\frac{Ed}{Ej} = \frac{Ed}{Ed+En} = \frac{194.23}{194.23+15.52}$ = 0.9337 = 93%

xo ∈]7**5**%, 100%], so ***xo*** = (0.4 ; 1.0) and α_d = 0.4 ; α_n = 1.0

Storage Assessment:

So; Sg = 0.4*194.23 = 77.69 KWh

Sp = 1.0*15.52 = 15.52KWh

Estimated total energy storage requirements St (Wh):

St(Wh) = Sg(Wh) +Sp(Wh = 38.40 + 15.56 ≈ 94 KWh

St = 94 KWh

$$\begin{cases} X = \frac{Ed}{Ed+St} = \frac{194.23}{194.23+94} = 0.67 \\ Ed = \frac{Eddc}{\eta conv} \text{ ; ; With } \eta conv = 1; \text{ SO } Ed = Ed_{dc} \\ Ej = Ed + St, \quad Ej = 194.23+94 = 288.23 \text{ kwh} \end{cases}$$

Taking into account all of the above: x, PV controller type, PR, Ir, the minimum peak power of the solar array is given by the expression below:

$$P_{cmin} = \begin{cases} \frac{Ej}{\eta inv*PR*Ir} \text{ x } [\text{ x } + \frac{(1-X)}{\eta bat}] \text{ x } \frac{Umpp,champ}{Ubat} & \text{if it is PWM controller} \\ \frac{Ej}{\eta inv*PR*Ir} \text{ x } [\text{ x } + \frac{(1-X)}{\eta bat}] & \text{if it is MPPT controller} \end{cases}$$

$$P_{cmin} = \begin{cases} \frac{288230}{0.9*0.8*6} \text{ x } [\, 0.67 + \frac{(1-0.67)}{0.8}\,] \text{ x } \frac{40.5}{12} = 202.5 \text{ Kwp} & \text{if it is PWM controller} \\ \frac{288230}{0.9*0.8*6} \text{ x } [\, 0.67 + \frac{(1-0.67)}{0.8}\,] = 73 \text{ Kwc} & \text{if it is MPPT controller} \end{cases}$$

The efficiency of the energy chain allows us to know the minimum E_{Pv} energy to be supplied by the PV array.

$$E_{pv} \geq \frac{1}{\eta reg} (Ed + \frac{St}{\eta bat}) \text{ or } Epv \geq \frac{Ej}{\eta reg}(x + \frac{1-X}{\eta bat})$$

$$Epv \geq \frac{288.23}{0.9} (0.67 + \frac{1-0.67}{0.8}) \rightarrow Epv \geq 346.67 \text{ KWh}$$

The output of the pv array depends also on its operating point, therefore, it is related to type of controller (PWM or MPPT)

Note: the size of the project is much more important to consider the MPPT controller,

The MPPT controller operates the pv modules at their optimal operating point: maximum power point as you can see the figure below:

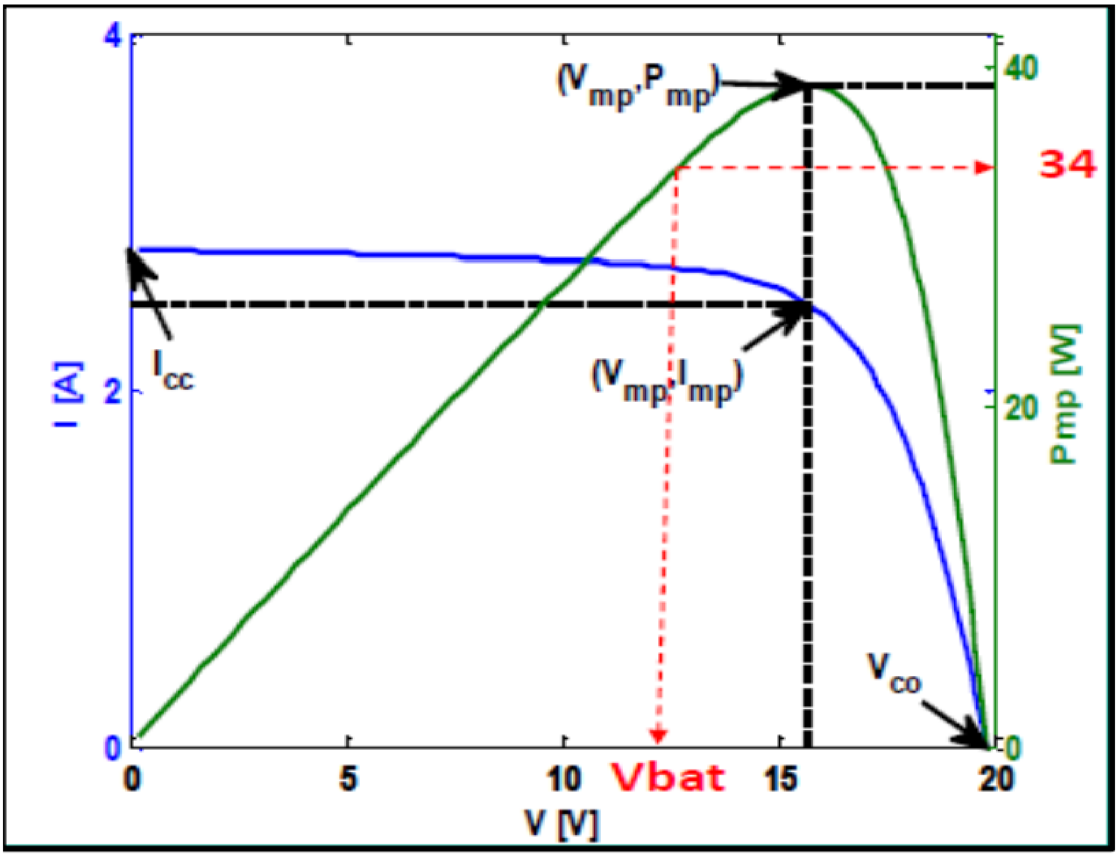


Figure 45 maximum power point tracker

The PWM operates the solar array generally in a lower voltage than MPP point that is the vicinity of the battery bank voltage, and the PV array deliver the same current in the both cases, therefore the PWM deliver less power than MPPT.

4.2.3 Panels sizing

The temperature also influences the voltage of module depending on the material of the panel and this anc found within the electrical characteristics of panel as TF (temperature factor), by what we can calculate the maximal and minimal voltage of a panel.

Choosing a PV module might be highly recommended to take in consideration the market availability, yield and adaptation to site, therefore the characteristics below correspond to our criteria:

Table 7 Panels characteristics:

Max power (pmax) [w]	340
Open circuit voltage (VOC)[V]	41.34
Short Circuit current (ISC)[A]	10.16

Max power voltage (vmp) [V]	34.21	
Max power current (Imp) [A]	9.83	
Module efficiency [%]	17.01	
Power tolerance	-3 to 4%W	
Max system voltage	1000V/1500VDC(IEC)	
Max series fuse rating	15A	
Operating temperature	-40°C To + 85°C	
STC	Ir 1000W/m^2, cell temperature 25°C, AM 1.5	
Temperature coefficient of Pmax	µ (Pm)	-0.403%/C
Temperature coefficient of Voc	(Voc)	-0.33%/C
Temperature coefficient of Isc	(Isc)	0.049%/C
Front load	5400pa	
PRICE	$0.168/WP	

Source: https://www.enfsolar.com/

Connecting the modules in parallel or series will depend on characteristics of controller/inverter and chosen Pv module, like:

- ✓ If it is MPPT controller:

Module Vcomax = Vco × [1+(Tmin- TSTC)× (TCVco)] $\Longrightarrow$ Vcomax = 46.2 x [1+(1.3 -25)*0.0033] = 49.8

Vcomin = Vco_min × [1+(Tmax- TSTC)× (TCVco)] $\Longrightarrow$ Vco_min = 37.1 x [1 + (38.6 +25 -25)*0.004] = 31.37

$I_{minMPP,\ inverter}$, I_{maxMPP}, inverter and $I_{MPP,\ modul}$ this for number of modules on strings

$$\frac{I\_minMPP,inverter}{I\_MPP,modul} < Np < \frac{I\_maxMPP,inverter}{I\_MPP,modul} \quad \frac{92.7}{8.98} < Np < \frac{114}{8.98} \quad 10 < Np < 13$$

We consider Np = 12

$I_{minMPP,\ inverter}$, I_{maxMPP}, inverter and $I_{MPP,\ modul}$ this for number of modules in series

$$\frac{V\_minMPP,inverter}{V\_MPP,modul} < Ns < \frac{v\_maxMPP,inverter}{V\_MPP,modul} \quad \frac{200}{37.1} < Np < \frac{1000}{37.1} \quad 5 < Ns < 27$$

We consider Ns = 19;

Therefore, NpxNs = 228, are the total number of modules of 330/wp for the solar array.

4.2.4 Storage capacity

The storage capacity of the batteries:

$$Cb = \frac{St\ (wh)}{Ubat*rbat*ddp} = \frac{94000}{12*0.8*0.75} = 13055Ah$$

Cb = 13055Ah

4.2.4.1 Battery sizing

Depending on the availability on the market, a type of battery is chosen that is characterized by its unit voltage Vbi and its capacity Cbi(Ah), on the table below:

Table 8 battery's specification

specification	Lead acid (gel)
Price per KWh	74.5/kwh
Price per (unit)	$224/Unit
Cell number	6/Unit
Nominal voltage	12V
Nominal capacity	250Ah@20h
Design life	20 years
Cycle life	1500@50%DOD
Operating temperature	-25 to +60

Source: https://www.enfsolar.com/

- ✓ the number of batteries in series will be : Ns = Vbat/Vbi

Regarding the charge controller available and its characteristic on table: the nominale voltage for battery (system voltage) will be: 384V

Nb_s = 384/12 = 32

- ✓ and the number of strings in parralel will be: Np = Cb(Ah)/ Cbi(Ah)

Nb_p = 13055/250 = 52.23

Nb_t = Nb_s x Nb_p = 52.23 x 32 = 1671 batteries

Thus the battery park will be composed of 52.23 strings of 32 batteries in series giving the total number of 1671 batteries of 250Ah/12V

Energy stored: Nb_p*battery capacity*system voltage = 32*250*12 = 96Kwh

4.2.5 Sizing charge controller

The controller must withstand at least the following currents: Maximum short-circuit current generated by the generator:

$\boldsymbol{I_{Gen} = I_{cc} \times N_{p\_p}}$ ⇒ 9.27*12 = 111.24A

$\boldsymbol{V_{Gen} = V_{oc} \ x \ Ns\_p}$ ⇒ 19*46.2 = 877.8 V

Rated current of all (simultaneous operation) of the receivers supplied by the regulator:

$\boldsymbol{IR = Ichargesregulateur}$ ⇒ 200A

The characteristics of the controller will therefore be: Controller current rating :

$\boldsymbol{Inr \geq Max\ IGen; IR}$; ⇒ Valided

Table 9 Charge controller characteristics:

model	MPPT solar charger	
price		$4300
input		
Match solar panel parameters	Solar panels power	84480WP
	Max. power voltage range Vmp	DC5OOV – DC 750V
	Open circuit voltage Voc	< DC 880V
	Over voltage protection $V_{over-pv}$	DC880V
	Low voltage protection V_{low-pv}	>battery Low voltage protection (settable)
Charging characteristics	Applicable battery type	Sealed, colloidal, open lead-acid battery
	Battery rated voltage	DC384V
	Start charging $V_{star}t_{-pv}$	$V_{pv} > V_{bat}$
	Floating voltage	DC465V (settable)
	Battery Lower Voltage protection	settable
	Rated charging current	200A
	Over current protection	240A
	Charging mode	Three stages: constant current (fast charging), constant pressure, floating charging
Display/communication	Display mode	Touch screen
	Communication protocol	Modbus RTU/Modbus TCP
	Communication mode	
	App cloud monitoring	Support wifi/GPRS/ethernet

Others features	Protection function	Input and out overvoltage and undervoltage Protection, anti reverse connection protection, etc
	MPPT efficiency	>= 99.5%
	Cooling mode	fan
	Working environment temperature	-20°C to 50°C
	Storage temperature	-40°C to +75°C
	IP protection	IP20 (customizable outdoor IP65)

Source: https://www.enfsolar.com/

4.2.6 Sizing inverter

Selecting an inverter for stand-alone systems is based on the following:

Nominal system DC voltage (battery),

AC output voltage

Peak AC power required for cumulative load

We have to notice that some appliances demand a huge amount of current during start up, so the must be to cover this amount

Surge current requirements, if any

Additional features (battery charger, etc), so inverter's electrical characteristics are:

$V_{inv} \geq V_{syst}$

$P_{inv(kva)} \geq P_{peak\ (array)}$)* Pf (power factor); for domestic appliances where starting current is not high

$P_{inv(kva)} \geq 2^* P_{peak\ (array)}$)* Pf for commercial appliances

$P_{inv(kva)} \geq 3^* P_{peak\ (array)}$)* Pf for industrial appliances where there is need of high value of starting current

$I_{inv} \geq I_{surge\ (array)}$.

Apart of the electrical characteristics, some characteristic for safety and viability needs to be taking in account.

Table 10 inverter characteristics

Items	
PRICE	$3200

input	
Max DC power	84KW
MPPT voltage range	200V to 1000V
Max;DC voltage	1100V
Nominal DC voltage	600V
Max. DC current	114A
Nominal DC current	60A
Rated DC current	120A
output	
Max. AC power (kw)	77.7KW
Nominal AC voltage	230 -400
phase	34W+GND
Max. AC current	92.6A
Power factor	0.8
Frequency (HZ)	50/60+- 0.2%
Wave form	Sine wave, THD>3% at linear load
Maximun efficiency	95%%

Source: https://www.enfsolar.com/

4.2.7 Cables sizing

When design an electrical system, it is very important to size the wiring cables for safety reason and also for viability the system, when sizing cables there is three essential criteria should be observed:

- The cable voltage rating (taking into account the maximum open-circuit voltage)
- The current carrying capacity of the cable and
- The minimizing of cable losses.

From battery to inverter

From inverter to sub distribution box

From sub distribution box to load

In this we need to calculate admissible current, the current permanent following the cable and also the current of surge to provide the right fuses breaker

Admissible current can be found as following:

$Iz \geq 1.45 \times In$ … … … (6)

$Iz \geq (N_{p\_p} - 1) \times 1.25 \times Isc$ … … … (7)

With:

I_z: the admissible current in the cable

I_n: the nominal fuse current

N_{p_p}: Number of chains

I_{sc}: module short-circuit current

- To ensure protection against roture current overcurrents, the choice of fuse is

does the following:

And surge current as following:

$I_b < I_n < I_{RM}$ … … … (8)

With:

I_b: the maximum working current in the conductors

I_{RM}: the maximum return current (this current can be indicated in the technical data sheet of the

PV, in the event that there is no egg laying $I_{RM} = 2 \times I_{sc}$)

Isc = 9.27 A

Np_p = 12

Np_s = 19

Iz ≤ (12 -1) x 1.25 x 9.27 = 127.46 A

Iz ≤1.45 x 87.9

I_{RM} = 2 x 9.27 = 18.54A

4.2.7.1 Array cable protection

If array overcurrent protection is required for a system, the nominal rated current for the overcurrent protection device will be as follows:

$$1.25 \times I\text{SC} - \text{ARRAY} \leq I\text{TRIP} \leq 2.4 \times I\text{SC ARRAY}$$

Where:

• I_{SC}_ARRAY = short-circuit current of the array.

• I_{TRIP} = rated trip current of the fault current protection device.

Isc_array = Np_s x Isc = 12 x 9.27 = 116.4 A

1.25 x 116.4 ≤ I   ≤ 2.4 x 116.4 So 145.5A ≤ I_{TRIP} ≤ 279.36A; therefore the fuse chosen is 250 A

4.2.7.2 Array cable

The circuit protection can be smaller than the admissible current of the cable but never larger

Assume 5% voltage drop in distribution system AC side

2-3% voltage drop in DC Side

1% drop from charge controller to battery.

Area of the wire

$s = \frac{2\rho l I}{\%v.V}$

Where

ρ Resistivity of copper 0.0179

L – single length of wire

I I_{mpp} current admissible

Voltage admissible cable Vmpp

Voltage drop (%v)	I_{mpp} current (A)	Vmpp voltage (V)	L (m) length	Section (m²)	
0.05	92.6	400	5	0.82	Invertter to box
0.03	120	946.2	30	0.75	Panels to c charge
0.02	120	946.2	5	0.75	Battery to inverter
0.01	200	384	5	9.32	C charge to batter

%v Voltage drop (%v)

The voltage drop along a cable is given

by: $\mathbf{Vd} = \frac{2 \times LCABLE \times I \times \rho}{\text{A CABLE}}$

• Voltage drop (in percentage) = Vd /Vbatt × 100

Where:

• LCABLE = route length of cable in metres (multiplying it by two adjusts for total circuit wire length since a complete circuit requires a wire out and another wire back along the route).

• I = current in amperes.

• ρ = resistivity of the wire in Ω/m/mm2

• ACABLE = cross sectional area (CSA) of cable in mm2 .

• Vbatt = the nominal voltage of the battery which is the dc system voltage.

4.2.8 Cost estimation of the system

Table 11 Total cost of the system

panels	unit	Quantity	total
panels	$56	228	$12760
Charge controller		1	$4300
inverter		1	$3200
battery	$163	1671	$272300
Cables & others		1	$2000
O &M		1	$3600
Total			$299000

The total power of array can be also calculated such as:

$$P_{pv} = \begin{cases} U_{bat} * I_{mpp,cham} & \text{if it is PWM controller} \\ U_{mpp,champ} * I_{mpp,champ} & \text{if it is MPPT controller} \end{cases}$$

The energy of PV array depends also on solar radiation (Ir), and the performance ratio (PR)

$E_{pv} = P_{pv,stc} \times PR \times Ir$

$U_{mpp,champ} = N_{p\text{-}s} \times V_{panel} = 19*34.1 = 704.9$ volt

$I_{mmp,champ} = N_{p\_p} \times I_{panel} = 12*9.83 = 106.8$ Ampere

$P_{pv} = 704.9*106.8 = 75283.32$ W

$E_{pv} = 75283.32*0.8*6 = 361360$ Wh = 361.36kwh

$$\text{payback period} = \frac{\text{initial investment}}{\text{annual return}}$$

Initial investment = Total cost of system = $299000 ≈ 41 200 000DZD

annual return: as the school will be feed completely from the system, so there is no bill from the grid

the annual return will be: energy supply/day x 365/year x energy cost in Algeria

The annual return = 361*365*4.17 ≈ 550000DZD

Payback period = $\frac{41200000}{550000}$ ≈ 75 years basing on Algerian (sonelgaz) energy price

4.2.8 Conclusion

This method look very expensive due to addition of energy for smoothing, and all the produced DC from array is converted to AC, this make highly the system cost; but there is two options again to satisfy the energy required with less cost:

- ✓ Supplying energy separately with inductive loads and classics (light) loads
- ✓ Reducing energy for smoothing:

4.2.3 System sizing watthour method

Day time energy consumption: Ed = 194.23KWh

Nigth time energy consumption: En = 15.52KWh

Total power of the appliances: Pt= 28.9KW

Total energy consumption: Ej' = Ed + En = 209.75Kwh

Day time wh requirement:

$\frac{194230}{0.82}$ = 236865 Wh = 237 Kwh

The following two equations (3) can be used to calculate the storage days needed

For 99% availability

Storage days = 24 - (4.73) (PSH) + (0.3) $(PSH)^2$ = 11

For 95% availability

Storage days = 9.43 – (1.9) (PSH) + (0.11) $(PSH)^2$ = 4

Where, PSH is the lowest monthly average peak sun-hours 2.5kwh/m^2

Battery backup

$\frac{15520}{0.8*0.9*0.75}$=28741 Wh= 29Kwh, the battery park,

Total energy requirement

Day time wh requirement + battery backup

237 + 29 = 266 Kwh

The average hours of sunshine per day of SIDI bel Abbes: 6h

The total watt:

$\frac{266000}{6}$ = 44.33 KW ≈ **45kw**

Inverter sizing:

For domestic inductive loads

Demand*2= 29000*2= 58000 So the inverter size will 60Kw

The power factor is 1 so the inverter will be 60kva

The inverter which such power requirement has voltage of 350V which might be the system voltage.

Noted: the charge controller integrated or not, sometimes imposes its voltage, current to the system

Total number of panels: Np_t = (total required power)/(panel power → 45000/330 = 137 panels

Number of panels in series: Np_s = (system voltage)/(panel voltage) → 350/37.1 = 11 panels

Number of panels in parallele Np_p = (total number of panels)/(panels in serie) → 137/10 = 13 panels

Total power from array Pt = Np_t*Np_p* wp = 46200W

Battery configuration:

Total: Capacity required: total backup (kwh)/battery voltage → Cb = $\frac{battery\ backup}{battery\ voltage} = \frac{29000}{12}$ = 2417 Ah, battery of 250Ah/12V is chosen

Number of battery in series: Nb_s = (system voltage)/(selec battery voltage) → 240/12 = 20

Number of battery in parallel: Nb_p = (total capacity required (Ah))/(Capacity of battery (Ah)) → 2417/(250) = 10

Total number of batteries: Nb_t = Nb_s x Nb_p → 20*10 = 200 batteries

Total energy stored: battery capacity x Nb_p*system voltage → 250*10*48 = 120 Kwh = 120kwh

Charge controller required: system voltage x 1.1 = 60A

Inverter: 60kva/ 48V and 60A

Charge controller characteristics

Rated power	60kw
Max open circuit voltage	750V
Nominal system voltage (battery)	240V
Maximum battery charge current	200A
price	$3000

Source: https://www.enfsolar.com/

Iinverter characteristics

Max DC voltage	3OOV
Rated DC voltage	220V
Rated DC current	380A
Max AC power	60KW
MPPT voltage range	368.6 to 391.4
Rated AC voltage	380V
Rated AC current	116A
price	$2200

Source: https://www.enfsolar.com/

4.2.3.1 Validation of the system conponents

$E_{pv} = P_{pv,stc} \times PR \times Ir$

$U_{mpp,champ} = N_{p\text{-}s} \times V_{panel} = 11*37.1 = 408.1$ volt

$I_{mmp,champ} = N_{p\_p} \times I_{panel} = 13*8.9 = 115.7$ Ampere

$P_{pv} = 408.1*115.7 = 46227W$

$E_{pv} = 46227*0.8*6 = 361360$ Wh = 222kwh

A: Cost of arrays = No. of PV modules × Cost/Module

B: Cost of batteries = No. of Batteries × Cost/Module

C: Cost of Inverter = No. of inverters × Cost/Inverter

D: Cost of charge controller = No. of charge controller x cost/charge controller

E: Cost of cables & others

F: [Additional cost installation may be taken as 5% of total system cost]

Total cost of system = A + B + C + D + E +F

panels	Cost/unit	quantity	total
panels	$63	140	$8820
Charge controller	$3000	1	$3000
inverter	$2200	1	$2200
battery	$224	200	$44800
Cables & others	$2000	-	$2000
O &M	$	-	$3050
Total			$64000

payback period = $\frac{initial\ investment}{annual\ return}$

Initial investment = Total cost of system = $64000 ≈ 9 000 000DZD

annual return: as the school will be feed completely from the system, so there is no bill from the grid the annual return will be: energy supply/day x 365/year x energy cost in Algeria

The annual return = 222*365*4.17 ≈ 338000DZD

Payback period = $\frac{9000000}{338000}$ ≈ 26 years basing on Algerian (sonelgaz) energy price

4.2.3.2 Conclusion

This method looks more interested than the previous one eventhouth payback period is bigger, the stored energy is not much high than the system size, the thing that is normal because there is big consumption during night time.

It is also possible to make the system more effective by separating the phases.

4.2.4 Third method: by separating the loads

For reason of high cost and issues of maintenance it is recommendable to decentralize the system, therefore we will divide the system in four phases

- ✓ Phase one for inductive loads (which need and inverter)
- ✓ Three phases for classical loads (no need of inverter)

For this method we use excel to introduce all the data and formulas to design the system and result output is shown on tables 12 and 13; the database is updatable.

For inductive loads which will necessarily need inverter the result on figure 12 is look like:

Table 12 design for inductive loads

consumption Analyse													
laods	quantity	Watt/unit	Nigth time	Day time (h)	Total watt	Day energ	Nigth Ener (kwh)		DATA				Prices
computer	15	170	0	7	2550	17850	0		eff_inv =	0,9		CC	$1000/Unit
printer	1	200	0	7	200	1400	0		pr =	0,8		PANEL	$56/Unit
Photocopieuse	1	700	0	4	700	2800	0		Ir =	6		Battery	$163/Unit
Data show	2	270	0	3	540	1620	0		over_eff =	0,82			
Air condition	1	1800	0	7	1800	12600	0		DOD =	0,75			
pumps	2	510	1	3	1020	3060	1020		Icc_max (A) =	70			
Pump small	1	370	2	3	370	1110	740		Icc_min(A) =	70		C. cntler :	8.324 KW
heater	2	420	3	4	840	3360	2520		Vcc_max(V) =	430			99%
Enargy balance conputation									Vcc_min(V) =	72			
total power =	8020		Xo =	0,910981697	sg (kwh) =	17520			Isc_mod (A) =	10,16		panel (w):	340
Ed =	43800		Alpha d =	0,4	sp (kwh) =	4280			Voc_mod (V) =	41,34			
En =	4280		Alpha n =	1	st (kwh) =	21800			Vrated (V)=	34,12			
Ej' =	48080		X =	0,67	Ej (kwh) =	65600			Irated (A)=	9,83			
Modules sizing									conclusion				
PC (w) =	16446,75926	N_s =	1,741655	N_p =	27,77406	Np_T =	48,37282		So we will have pv array with 7 Panels in series and 7 Strn				
battery sizing									total of 49 panels which gives 16.66 and 6 batteris in seri				
Cb (Ah) =	3027,777778	Nb_s =	6,00	Nb_p =	12,11	Nb_t =	72,66667		and 12 string total 72 batteri of 250Ah which stored 36kwh				
C_bat (Ah) =	250		Eff_bat =	0,8	6,889764	<N_s<	6,889764		With invert-c controller of 8.32 kw; 80A; 72V (batr) 430V_P				
V_bat (V) =	12				2,110199	<N_p<	10,40155		Taking all environtal and technical paramiter in consiration				
V_sys (V) =	72								Total price here is $15500				

Source: https://www.enfsolar.com/pv/panel/2

Here there is need of inverter and charge controller with small capacity which consequently reduces the system cost and reduce also some complicated maintenance and cost of transport

4.2.4.1 Validation of the conponents:

A) $E_{pv} = P_{pv,stc} \times PR \times I_r$

$U_{mpp,champ} = N_{p\text{-}s} \times V_{panel} = 7*34.12 = 238.84\text{volt}$

$I_{mmp,champ} = N_{p\_p} \times I_{panel} = 7*9.83 = 68.81$ Ampere

P_{pv} = 238.84*68.81= 16435 W

E_{pv} = 16435*0.8*6 = 78888 Wh = 78.88kwh

For classic loads using direct current which is not necessary to use inverter only charge controller and batteries.

Table 13 design for classics loads

consumption Analyse												
laods	quantity	Watt/unit	Nith time	Day time (h)	Total watt	Day energ	Nigth Ener con (kwh	DATA				prices
lampes in	24	36	0	7	864	6048	0	eff_inv =	0,9		CC	$645/Unit
lamp out	24	36	0	7	864	6048	0	pr =	0,8		PANEL	$56/Unit
lamp toil	24	36	0	4	864	3456	0	Ir =	6		Battery	$163/unit
lamp adm	24	36	0	3	864	2592	0	over_eff =	0,82			
lamp soin	24	36	0	7	864	6048	0	DOD =	0,75			
lamp cof	24	36	1	3	864	2592	864	Icc_max (A) =	70			
lamp	24	36	2	3	864	2592	1728	Icc_min(A) =	70		C. cntler :	7.24 KW
lamp	24	36	3	4	864	3456	2592	Vcc_max(V) =	430			99%
Enargy balance conputation								Vcc_min(V) =	72			
total power =	6912		Xo =	0,86363636	sg (kwh) =	13132,8		Isc_mod (A) =	10,16		panel (w):	340
Ed =	32832		Alpha d =	0,4	sp (kwh) =	5184		Voc_mod (V) =	41,34			
En =	5184		Alpha n =	1	st (kwh) =	18316,8		Vrated (V)=	34,12			
Ej' =	38016		X =	0,64	Ej (kwh) =	51148,8		Irated (A)=	9,83			
Modules sizing								conclusion				
PC (w) =	12900	N_s =	1,74165	N_p =	21,7846	Np_T =	37,9412	So we will have pv array with 6 Panels in series and 7 Strn				
battery sizing								total of 42 panels which gives 14.28 kw; 6 batteris in seri				
Cb (Ah) =	2544	Nb_s =	6,00	Nb_p =	10,18	Nb_t =	61,056	and 10 string total 60 batteri of 250Ah which stored 30kwh				
C_bat (Ah) =	250		Eff_bat =	0,8	6,88976	<N_s<	6,88976	With c controller of 7.2 kw; 70A; 72 Sysr vol (batr) 430V_P				
V_bat (V) =	12				2,1102	<N_p<	10,4015	Taking all environtal and technical paramiter in consiration				
V_sys (V) =	72							Total price here is $12800				

Source: https://www.enfsolar.com/pv/panel/2

4.2.4.2 Validation of the coponents

B) Epv = P pv,stc x PR x Ir

$U_{mpp,champ} = N_{p\text{-}s} \times V_{panel}$ = 6*34.12 = 204.72volt

$I_{mmp,champ} = N_{p\_p} \times I_{panel}$ = 7*9.83 = 68.81Ampere

P_{pv} =204.72*68.81 = 14.087KW

E_{pv} = 14.087*0.8*6 = 67620Wh = 67.62kwh

67.62 x 3 = 203kwh

Total energy supply for this metod: A +B = 78.88+203 = 282 kwh

$$\text{payback period} = \frac{\text{initial investment}}{\text{annual return}}$$

Initial investment = Total cost of system = ($12800 x 3) + 15500 + 2000+ 5% = $58500

≈ 8 0860 00DZD

annual return: as the school will be feed completely from the system, so there is no bill from the grid the annual return will be: energy supply/day x 365/year x energy cost in Algeria

The annual return = 282*365*4.17 ≈ 430400DZD

Payback period = $\frac{8086000}{430400}$ ≈ 19 year basing on Algerian (sonelgaz) energy price

4.2.4.3 Conclusion

The cost of system is very small than the previous methods and there is no excess in energy production thus, it is more accurate, therefore, more interested. However, we need 19 years to cover all the initial investment, this because of small energy price in Algeria and high cost of batteries, without the payback period will less than 10 years, and considering the international

4.2.5 Simulation: software designing

4.2.5.1 simulation using Bluesol

Photovoltaic system

Nominal power equal to 61,2 kWp

Project name:

THESIS

Located in

Sidi Bel Abess

Customer

Primary school at minicipality

designed by Pauwes

designer: Abdou Amadou Abdou Salami

mini-central pv system for primary shool

The weather information of the geographical location

Table 14 irradiance

Irradiances

Climate data and irradiance | Irradiance chart | Sun paths

Sidi Bel Abbes
Algeria

Latitude	35,19 °	Longitude	-0,63 °	Altitude	0,0 m
T Max	32,1 °C	T Min	7,8 °C	Time zone	1

Source of climatic data: NASA-SSE

Total annual irradiance

Direct	1222,75 kWh/m²
Diffuse	547,5 kWh/m²
Global	1770,25 kWh/m²

Monthly average irradiance on horizontal plane

Month	Global [kWh/m²]	Diffuse [kWh/m²]
January	2,72	0,87
February	3,64	1,11
March	4,74	1,48
April	5,94	1,8
May	6,55	2,11
June	7,08	2,15
July	6,92	2,08
August	6,26	1,87
September	5,25	1,55
October	3,94	1,23
November	2,8	0,97
December	2,4	0,81

Units of measurement

- (•) kWh/m² day
- ( ) kWh/m² month

After inserting the loads information, the software gives the following table

Table 15 computations database of the devices

Consumption database of electrical devices

User database | Program database

Description	Power [kW]	Devices	Unit	Daily consumption [kWh]	Annual consumption [kWh]
pc	0,17	15	kWh	1349,1	87691,5
Air condition	1,8	1	kWh	100,8	26308,8
DATA SHOW	2,7	2	kWh	111,24	29033,64
Printer	0,2	1	kWh	8,2	2140,2
Copie machine	0,7	1	kWh	39,7	10361,7
PUMP	0,44	2	kWh	31,32	11431,8
Lamps	0,36	100	kWh	277,2	101178
lampes	0,36	100	kWh	277,2	101178
Lampss	0,36	100	kWh	201,6	73584
Ligth	0,36	100	kWh	201,6	73584
ligths	0,36	100	kWh	201,6	73584
LIG	0,36	68	kWh	137,09	50037,85

Table 16 panel parameters

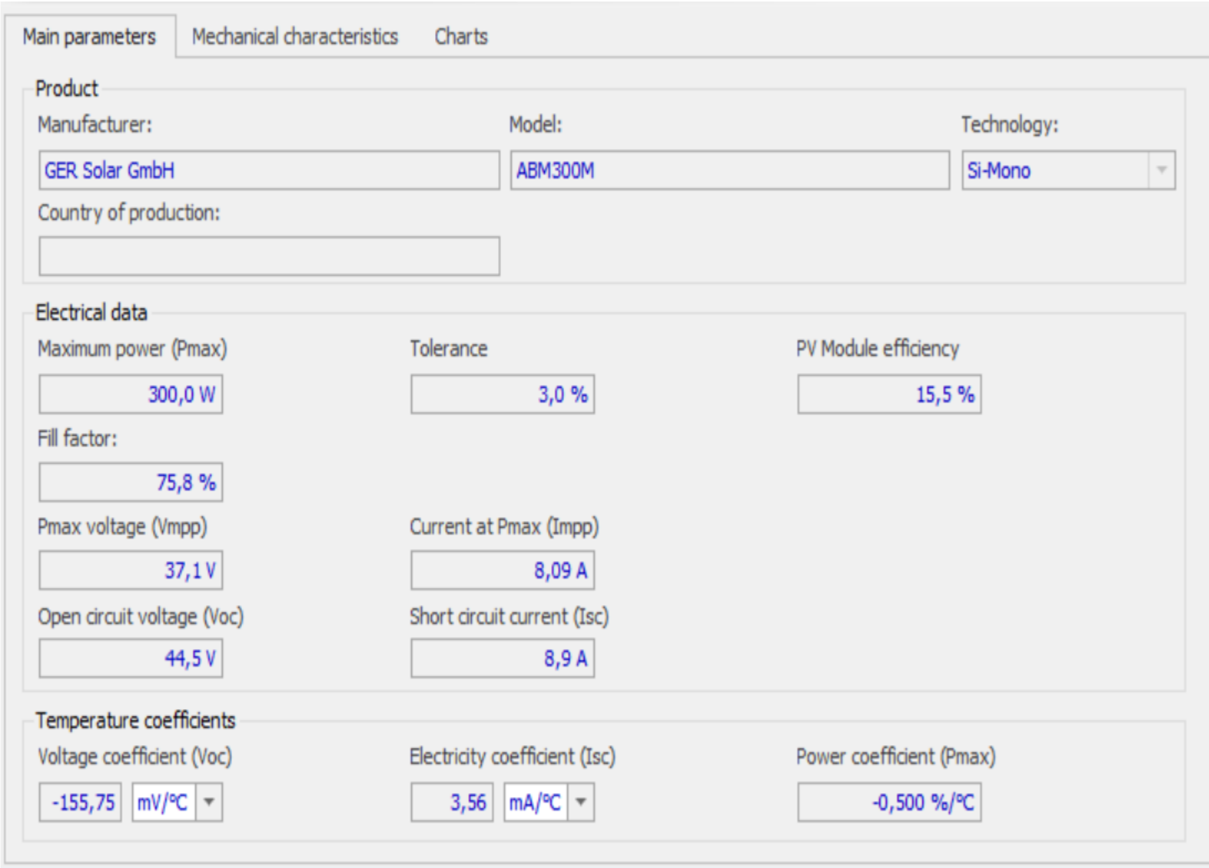


Table 17 battery parameters

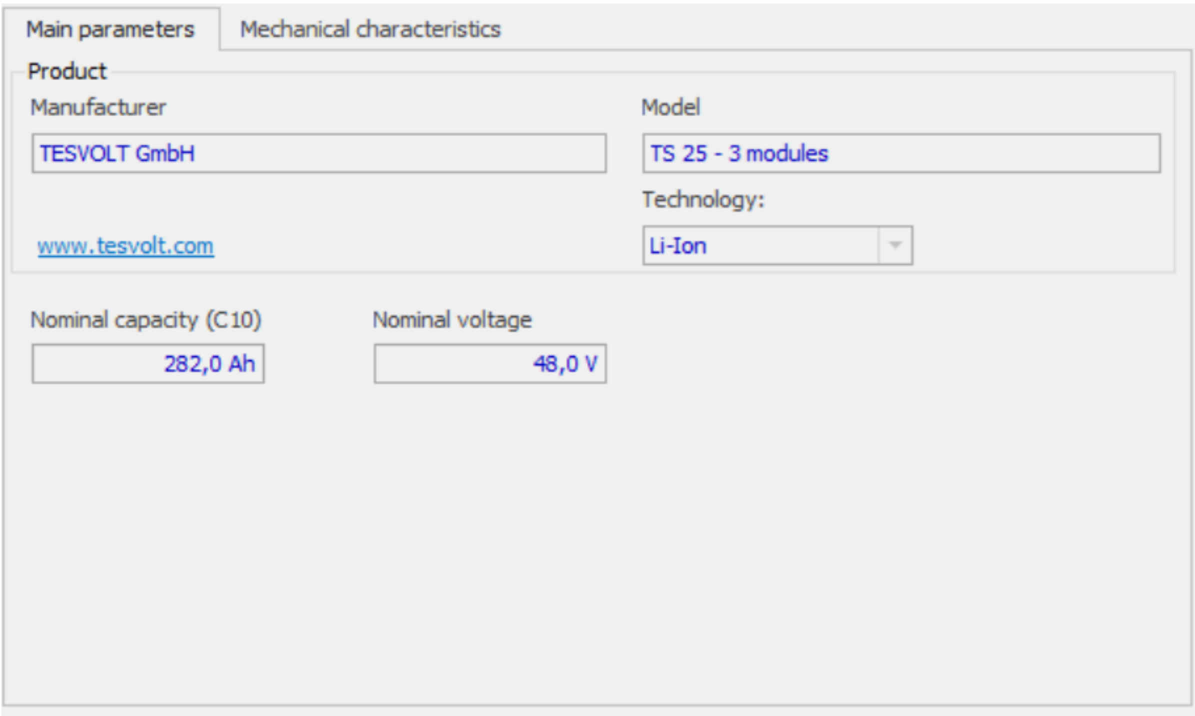
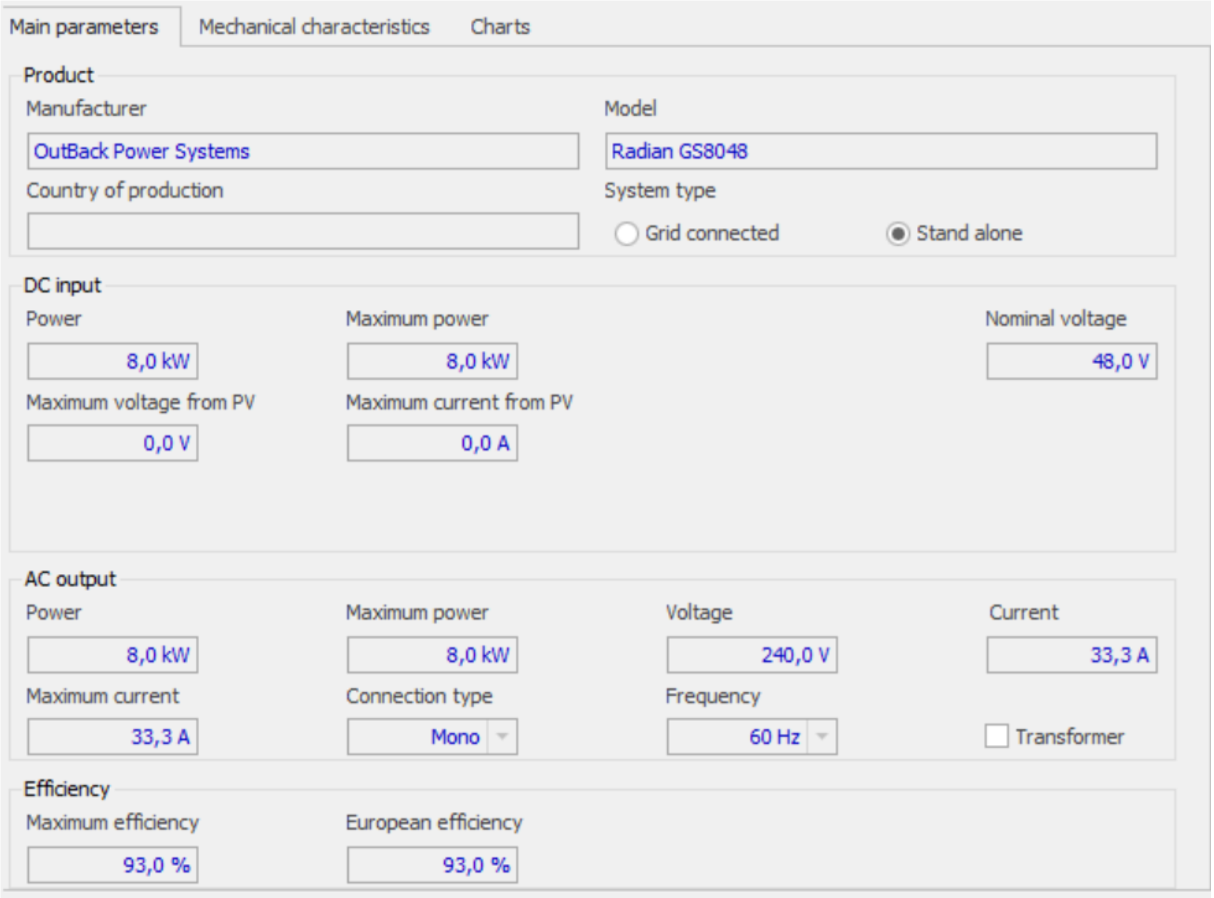


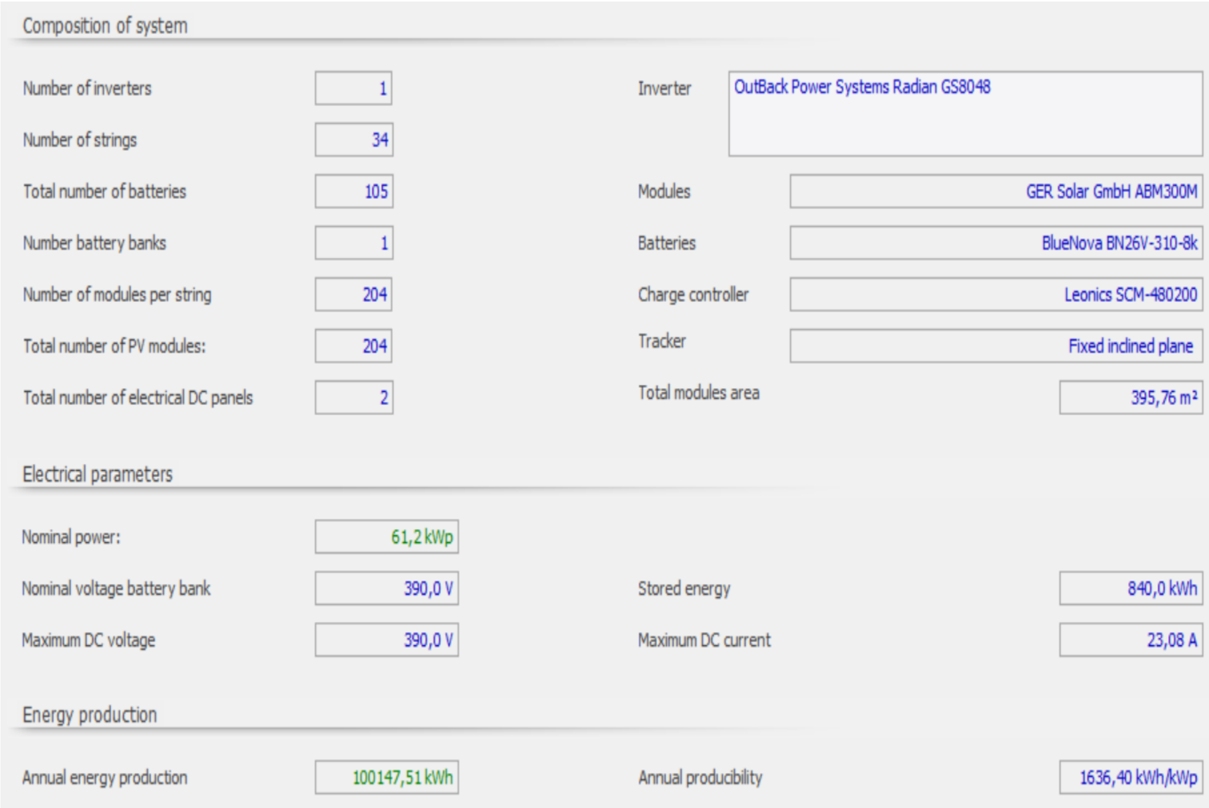
Table 18 inverter parameters



Code	Manufacturer	Model	Max. power [W]	Min. MPPT voltage [V]	Max. MPPT voltage [V]	Max. voltage from PV [V]	Input current [A]	Battery nominal voltage [V]	Output current [A]	MPPT
Leo-SCM480150	Leonics	SCM-480150	60600	192	408	552	150	480	150	✓
Leo-SCM480200	Leonics	SCM-480200	82600	192	408	552	200	480	200	✓
Leo-SCP2430	Leonics	SCP-2430	830	0	0	48	30	24	30	☐

The part of result, the system output

Table 19 composition of the system



Composition of system

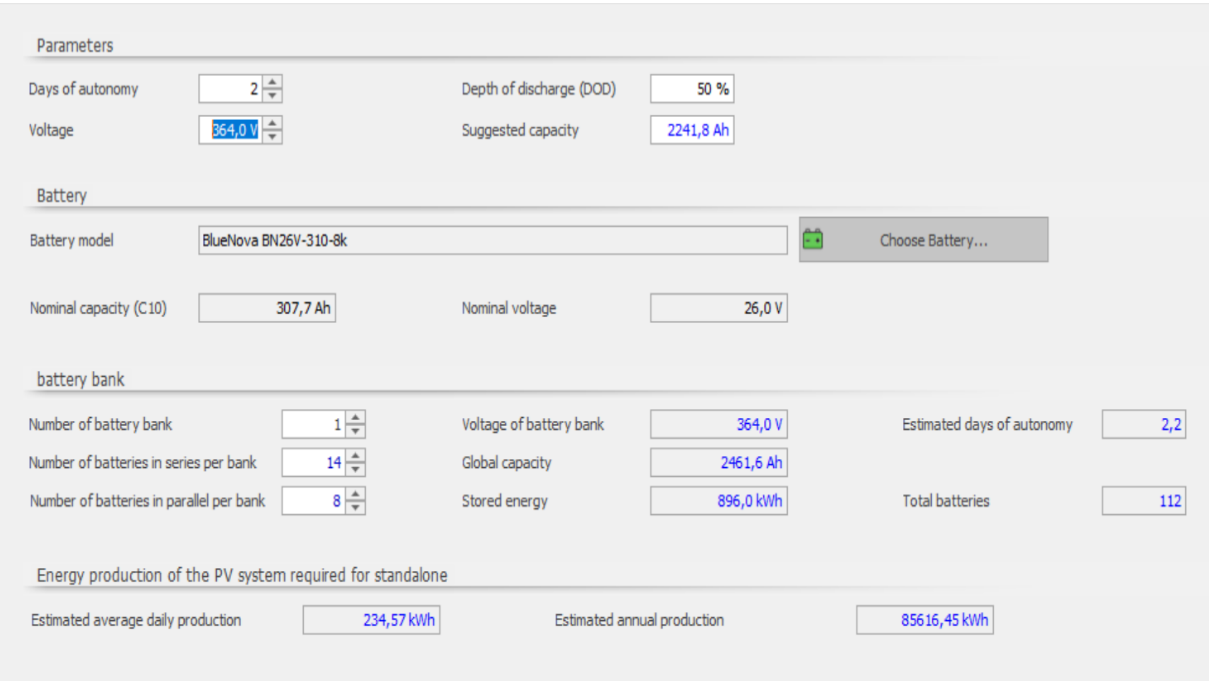
Number of inverters	1	Inverter	OutBack Power Systems Radian GS8048
Number of strings	34		
Total number of batteries	105	Modules	GER Solar GmbH ABM300M
Number battery banks	1	Batteries	BlueNova BN26V-310-8k
Number of modules per string	204	Charge controller	Leonics SCM-480200
Total number of PV modules:	204	Tracker	Fixed inclined plane
Total number of electrical DC panels	2	Total modules area	395,76 m²

Electrical parameters

Nominal power:	61,2 kWp		
Nominal voltage battery bank	390,0 V	Stored energy	840,0 kWh
Maximum DC voltage	390,0 V	Maximum DC current	23,08 A

Energy production

Annual energy production	100147,51 kWh	Annual producibility	1636,40 kWh/kWp



Parameters

Days of autonomy	2	Depth of discharge (DOD)	50 %
Voltage	364,0 V	Suggested capacity	2241,8 Ah

Battery

Battery model	BlueNova BN26V-310-8k	Choose Battery...	
Nominal capacity (C10)	307,7 Ah	Nominal voltage	26,0 V

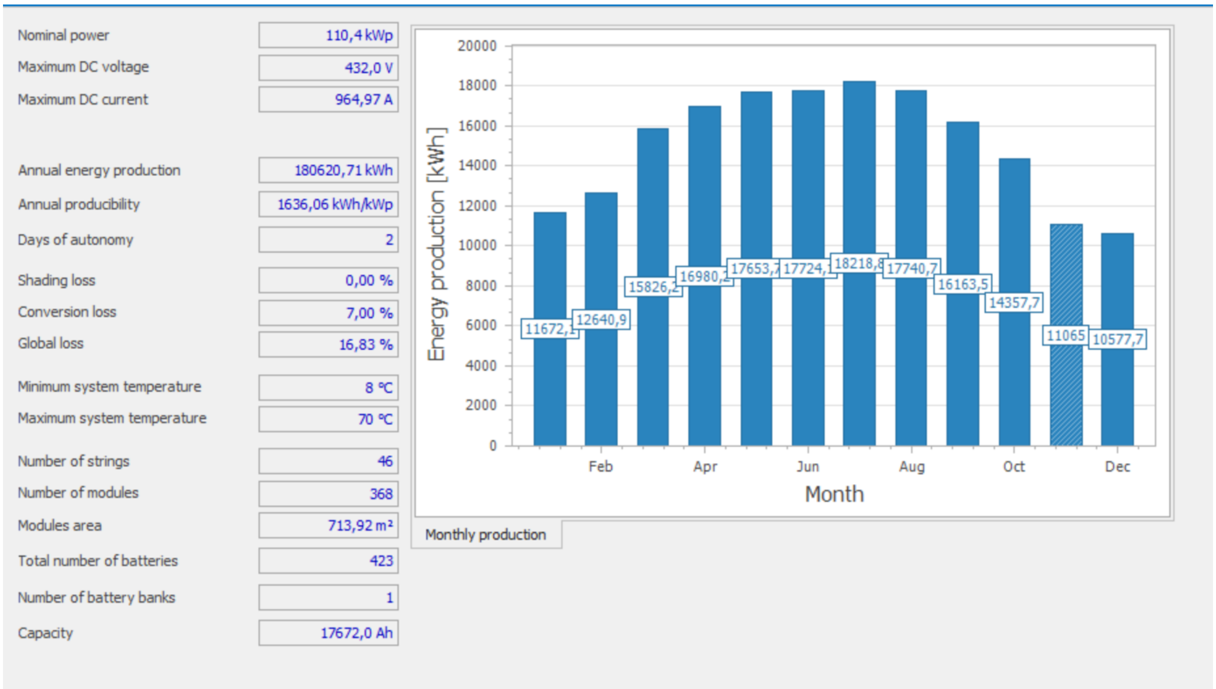
battery bank

Number of battery bank	1	Voltage of battery bank	364,0 V	Estimated days of autonomy	2,2
Number of batteries in series per bank	14	Global capacity	2461,6 Ah		
Number of batteries in parallel per bank	8	Stored energy	896,0 kWh	Total batteries	112

Energy production of the PV system required for standalone

Estimated average daily production	234,57 kWh	Estimated annual production	85616,45 kWh

Table 20 global system information



The first simulation with Bluesol software doesn't give exactly the same result as manual design but similar,

4.2.5.2 Simulation using pvsyst

Table 21 orientation angle

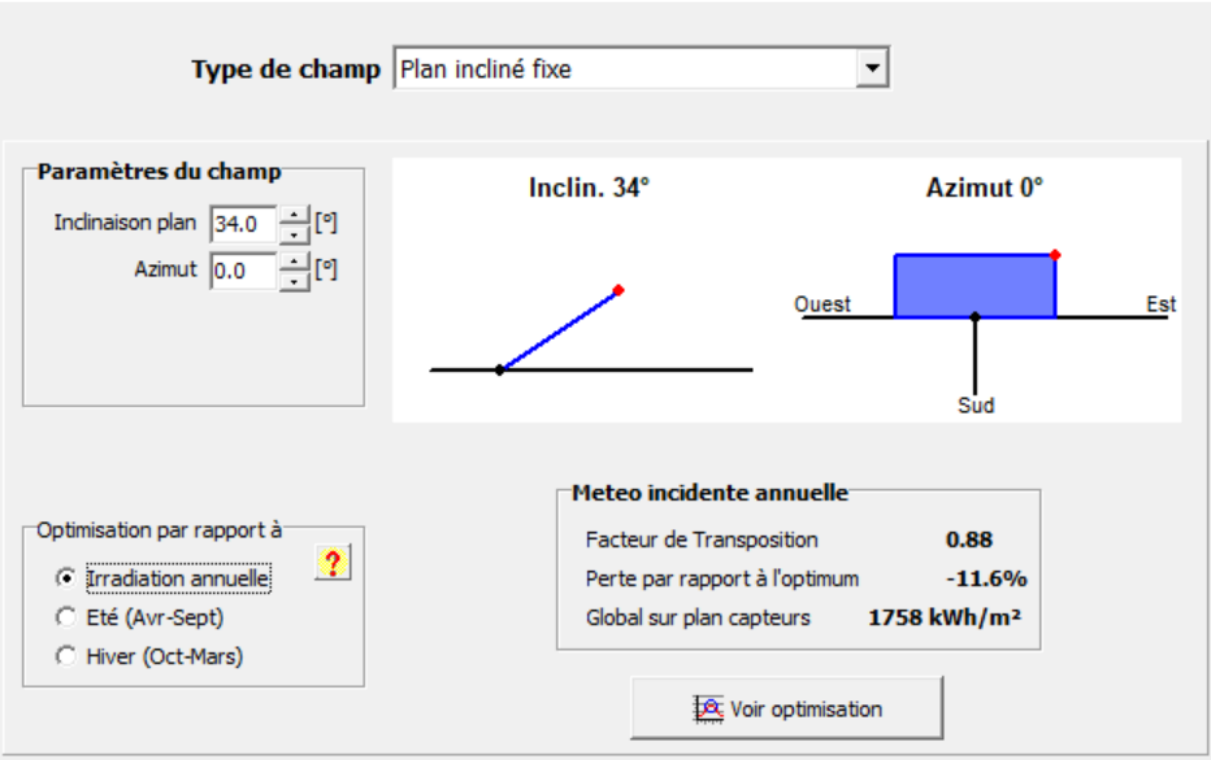


Table 22 devices

Definition of Daily Household consumptions, year

Consumptions | Hourly distribution

Daily consumptions

Number	Appliance	Power		Daily use		Hourly distrib	Daily energy
580	Lamps (LED or fluo)	36	W/lamp	9.0	h/day	OK	187920 Wh
2	HEATER	200	W/app.	7.0	h/day	OK	2800 Wh
1	PRNTER	450	W/app.	3.0	h/day	OK	1350 Wh
15	PC	0.15	kWh/day	6.0	h/day	OK	2186 Wh
2	Data show	270.0	W aver.	3.0	h/day	OK	1620 Wh
1	AIR CONDITION	1110	W/app.	5.0	h/day	OK	5550 Wh
3	Autres utilisations	440	W/app.	6.0	h/day	OK	7920 Wh
	Stand-by consumers	1	W tot	24 h/day		☑ 7 days/7	48 Wh

Appliances info

Total daily energy **209394 Wh/day**

Total monthly energy **4487.0 kWh/month**

Consumption definition by

- (•) **Year**
- ( ) **Seasons**
- ( ) **Months**

Week-end or Weekly use

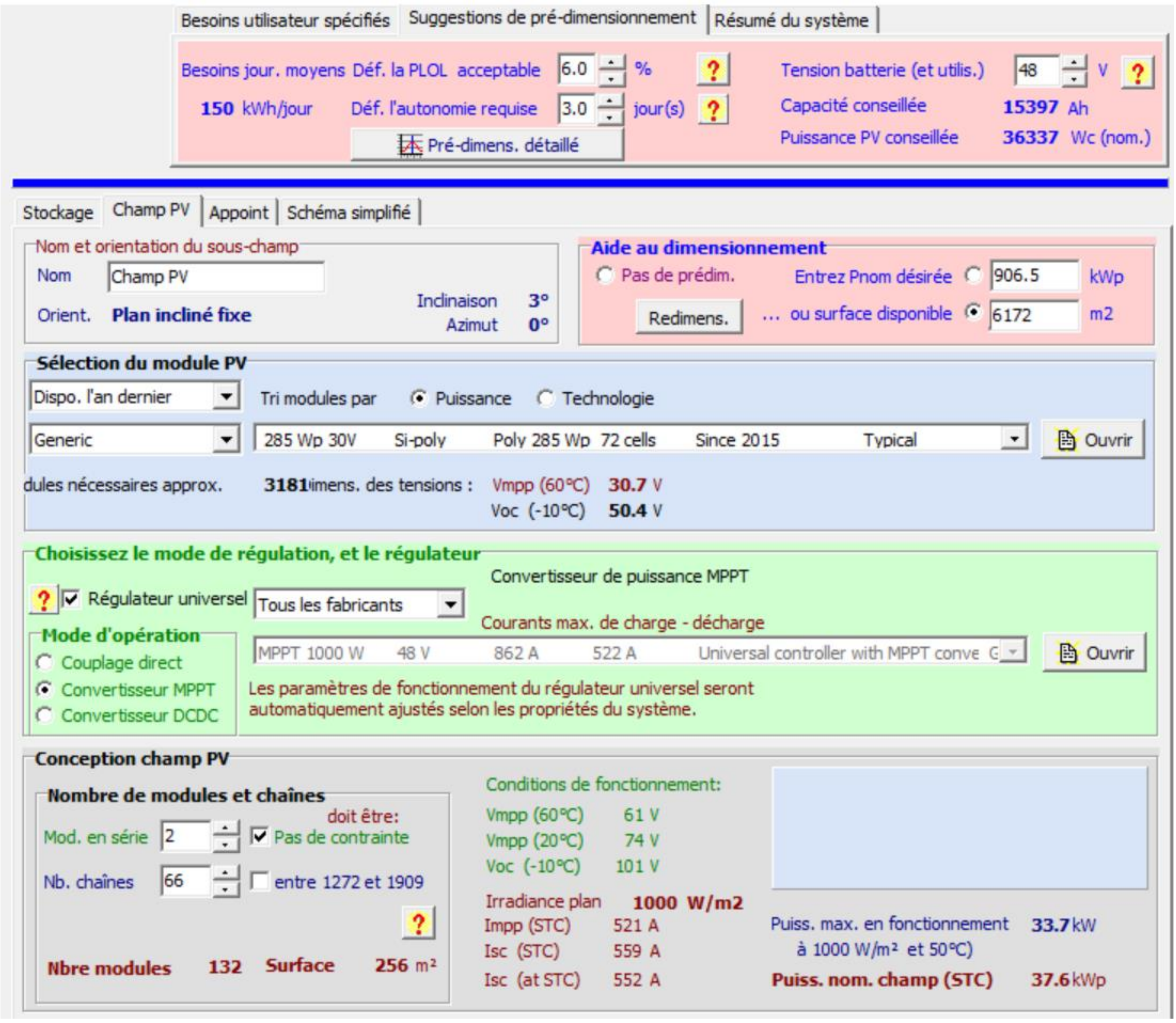
☑ Use only during

5 days in a week

Model

Load | Save

Table 23 pvsyst result



The battery

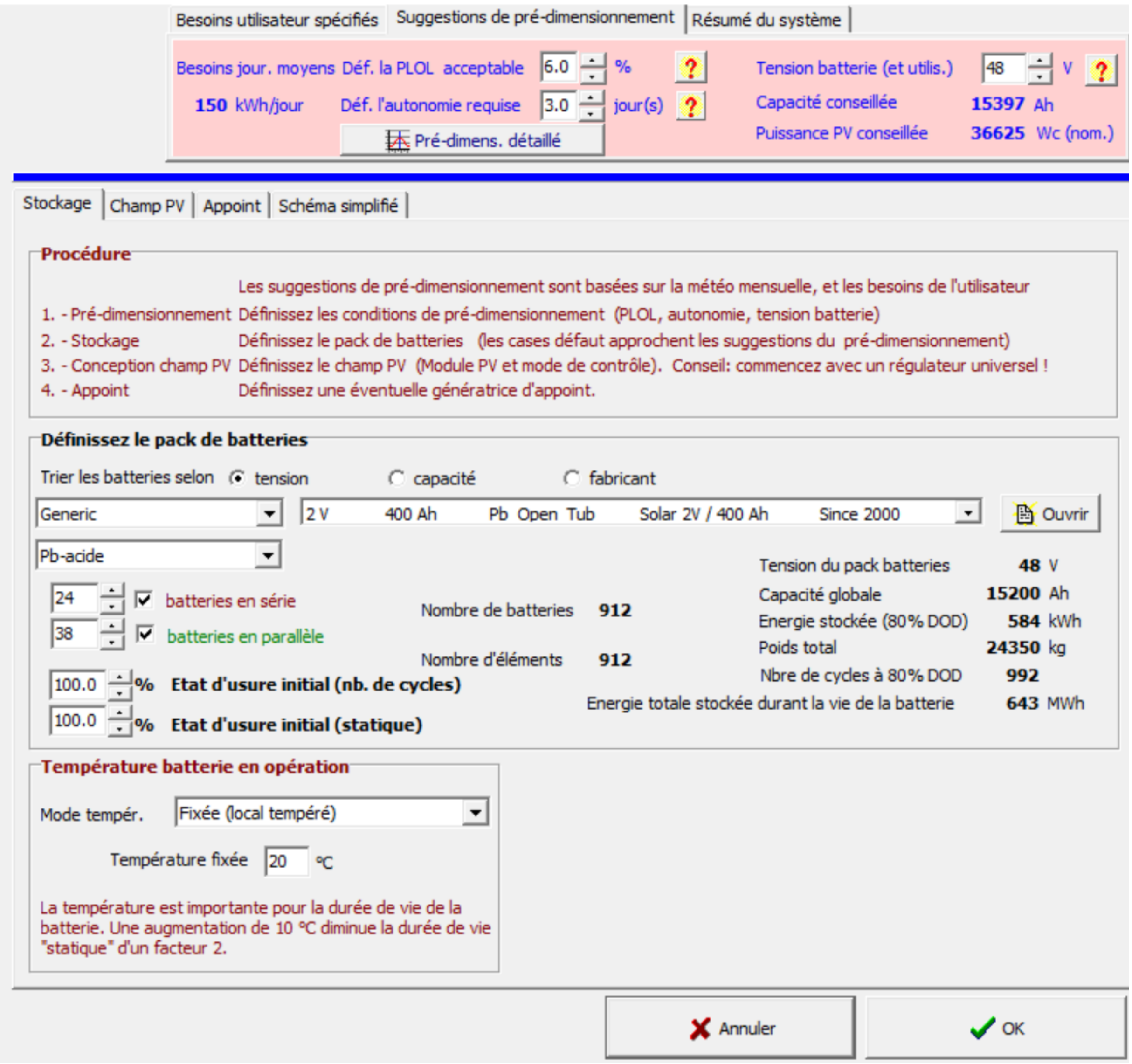


Figure 46 batteries park

Table 24 pv syst result

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Système isolé: Paramètres de simulation

Projet :	**memoir**			
Site géographique	**Sidi Bel Abess**		Pays	**Algeria**
Situation	Latitude	0.01° N	Longitude	0.00° E
Temps défini comme	Temps légal	Fus. horaire TU	Altitude	0 m
	Albédo	0.20		
Données météo:	**Sidi Bel Abess**	Meteonorm 7.2, Sat=100% - Synthétique		

Variante de simulation : Nouvelle variante de simulation

Date de la simulation 01/01/22 à 14h25

Paramètres de simulation	Type de système	**Système isolé avec batteries**		
Orientation plan capteurs	Inclinaison	3°	Azimut	0°
Modèles utilisés	Transposition	Perez	Diffus	Perez, Meteonorm
Besoins de l'utilisateur :	Consomm. domestique	Constants sur l'année		
	moyenne	150 kWh/Jour		

Caractéristiques du champ de capteurs

Module PV Si-poly	Modèle	**Poly 285 Wp 72 cells**		
Base de données PVsyst originale	Fabricant	Generic		
Nombre de modules PV	En série	2 modules	En parallèle	66 chaînes
Nombre total de modules PV	Nbre modules	132	Puissance unitaire	285 Wc
Puissance globale du champ	Nominale (STC)	**37.6 kWc**	Aux cond. de fonct.	33.7 kWc (50°C)
Caractéristiques de fonct. du champ (50°C)	U mpp	65 V	I mpp	521 A
Surface totale	Surface modules	**256 m²**	Surface cellule	231 m²

Paramètres du système	Type de système	**Système isolé**		
Batterie	Modèle	**Solar 2V / 400 Ah**		
	Fabricant	Generic		
Caractéristiques du banc de batteries	Nombre d'unités	24 en série x 38 en parallèle		
	Tension	48 V	Capacité nominale	15200 Ah
	Décharge: min. SOC	20.0 %	Energie stockée	583.7 kWh
	Température	Fixée (20°C)		
Régulateur	Modèle	Universal controller with MPPT converter		
	Technologie	MPPT converter	Coeff. de temp.	-5.0 mV/°C/elem.
Convertisseur	Efficacité maxi et EURO	97.0 / 95.0 %		
Seuils de régulation batterie	Seuils de commande selon	SOC calculation		
	Charge	SOC = 0.90 / 0.75	i.e. approx.	52.2 / 49.5 V
	Décharge	SOC = 0.20 / 0.45	i.e. approx.	46.5 / 48.3 V

Facteurs de perte du champ PV

Fact. de pertes thermiques	Uc (const)	20.0 W/m²K	Uv (vent)	0.0 W/m²K / m/s
Perte ohmique de câblage	Rés. globale champ	2.1 mOhm	Frac. pertes	1.5 % aux STC
Perte diode série	Chute de tension	0.7 V	Frac. pertes	1.0 % aux STC
Perte de qualité module			Frac. pertes	-0.8 %
Perte de "mismatch" modules			Frac. pertes	1.0 % au MPP
Perte de "mismatch" strings			Frac. pertes	0.10 %

Effet d'incidence (IAM): Fresnel, verre normal, n = 1.526

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.998	0.981	0.948	0.862	0.776	0.636	0.403	0.000

Figure 47 pvsyst sumulation result

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Système isolé: Besoins de l'utilisateur

Projet : **memoir**

Variante de simulation : **Nouvelle variante de simulation**

Principaux paramètres système	Type de système	**Système isolé avec batteries**		
Orientation plan capteurs	inclinaison	3°	azimut	0°
Modules PV	Modèle	Poly 285 Wp 72 cells	Pnom	285 Wc
Champ PV	Nombre de modules	132	Pnom total	**37.6 kWc**
Batterie	Modèle	Solar 2V / 400 Ah	Technologie	Pb-acide, ouverte, tubulair
Pack de batteries	Nombre d'unités	912	Tension / Capacité	**48 V / 15200 Ah**
Besoins de l'utilisateur	Consomm. domestique	Constants sur l'année	Global	54.7 MWh/an

Consomm. domestique, Constants sur l'année, moyenne = 150 kWh/jr

Valeurs annuelles

Utilisation 5 jours par semaine	Nombre	Puissance	Utilisation	Énergie
Lamps (LED or fluo)	580	36 W/lampe	9 h/jour	187920 Wh/jour
HEATER	2	200 W/app	7 h/jour	2800 Wh/jour
PRNTER	1	450 W/app	3 h/jour	1350 Wh/jour
PC	15		6 Wh/jour	2186 Wh/jour
Data show	2		3 Wh/jour	1620 Wh/jour
AIR CONDITION	1	1110 W tot	5 h/jour	5550 Wh/jour
Autres utilisations	3	440 W tot	6 h/jour	7920 Wh/jour
Consomm. de veille			24 h/jour, 7jours/7	48 Wh/jour
Energie journalière totale				209394 Wh/jour

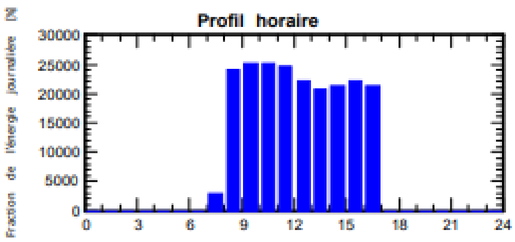


Figure 48 pv syst sumulation result1

PVSYST V6.81		01/01/22	**Page 3/5**

Système isolé: Résultats principaux

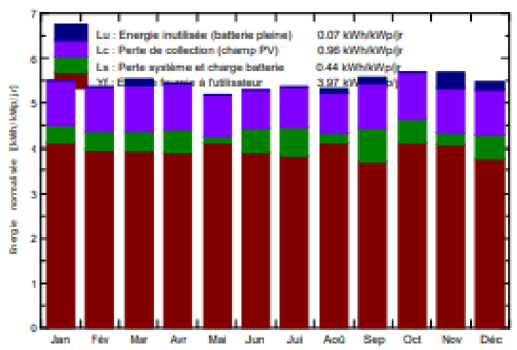
Projet : **memoir**

Variante de simulation : **Nouvelle variante de simulation**

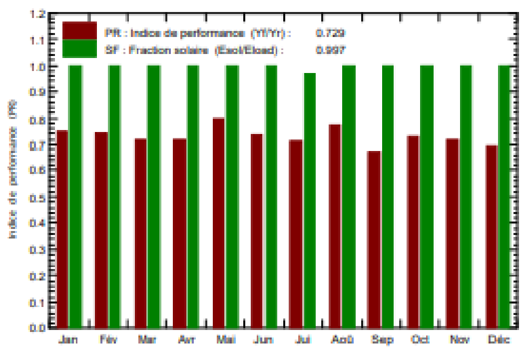
Principaux paramètres système	Type de système	**Système isolé avec batteries**		
Orientation plan capteurs	inclinaison	3°	azimut	0°
Modules PV	Modèle	Poly 285 Wp 72 cells	Pnom	285 Wc
Champ PV	Nombre de modules	132	Pnom total	**37.6 kWc**
Batterie	Modèle	Solar 2V / 400 Ah	Technologie	Pb-acide, ouverte, tubulai
Pack de batteries	Nombre d'unités	912	Tension / Capacité	**48 V / 15200 Ah**
Besoins de l'utilisateur	Consomm. domestique	Constants sur l'année	Global	54.7 MWh/an

Principaux résultats de la simulation				
Production du système	**Energie disponible**	**57861 kWh/an**	Productible	1538 kWh/kWc/an
	Energie utilisée	54505 kWh/an	En excès (inutilisée)	997 kWh/an
	Indice de performance (PR)	72.91 %	Fraction solaire (SF)	99.73 %
Besoins non satisfaits	Fraction du temps	0.5 %	Energie manquante	149 kWh/an
Vieillissement batterie (Etat d'usure (SOW))	SOW cyclage	98.0%	SOW statique	80.0%
	Durée de vie batterie	5.0 ans		

Productions normalisées (par kWp installé): Puissance nominale 37.6 kWc



Indice de performance (PR) et Fraction solaire (SF)



Nouvelle variante de simulation
Bilans et résultats principaux

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac
Janvier	167.9	164.6	4935	0.0	0.0	4816	4816	1.000
Février	148.6	144.4	4332	0.2	0.0	4188	4188	1.000
Mars	170.8	164.7	4934	133.1	0.0	4607	4607	1.000
Avril	163.7	156.2	4685	0.2	0.0	4397	4397	1.000
Mai	163.4	154.2	4674	0.0	0.0	4816	4816	1.000
Juin	162.6	152.8	4694	0.0	0.0	4397	4397	1.000
Juillet	169.2	159.6	4900	0.0	149.3	4458	4607	0.968
Août	167.3	159.0	4875	144.8	0.0	4816	4816	1.000
Septembre	167.2	160.8	4866	158.7	0.0	4188	4188	1.000
Octobre	174.6	169.4	5104	0.0	0.0	4816	4816	1.000
Novembre	167.0	163.5	4954	365.6	0.0	4607	4607	1.000
Décembre	165.6	163.0	4908	194.7	0.0	4398	4398	1.000
Année	1988.0	1912.3	57861	997.3	149.3	54505	54654	0.997

Légendes:	GlobHor	Irradiation globale horizontale	E_Miss	Energie manquante
	GlobEff	Global "effectif", corr. pour IAM et ombrages	E_User	Energie fournie à l'utilisateur
	E_Avail	Energie solaire disponible	E_Load	Besoin d'énergie de l'utilisateur
	EUnused	Énergie inutilisée (batterie pleine)	SolFrac	Fraction solaire (Eutile / Ebesoin)

Figure 49PV SYST SIMULATION OUTPUT

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Système isolé: Graphiques spéciaux

Projet : **memoir**

Variante de simulation : **Nouvelle variante de simulation**

Principaux paramètres système	Type de système	**Système isolé avec batteries**		
Orientation plan capteurs	inclinaison	3°	azimut	0°
Modules PV	Modèle	Poly 285 Wp 72 cells	Pnom	285 Wc
Champ PV	Nombre de modules	132	Pnom total	**37.6 kWc**
Batterie	Modèle	Solar 2V / 400 Ah	Technologie	Pb-acide, ouverte, tubulair
Pack de batteries	Nombre d'unités	912	Tension / Capacité	**48 V / 15200 Ah**
Besoins de l'utilisateur	Consomm. domestique	Constants sur l'année	Global	54.7 MWh/an

Diagramme d'entrée/sortie journalier

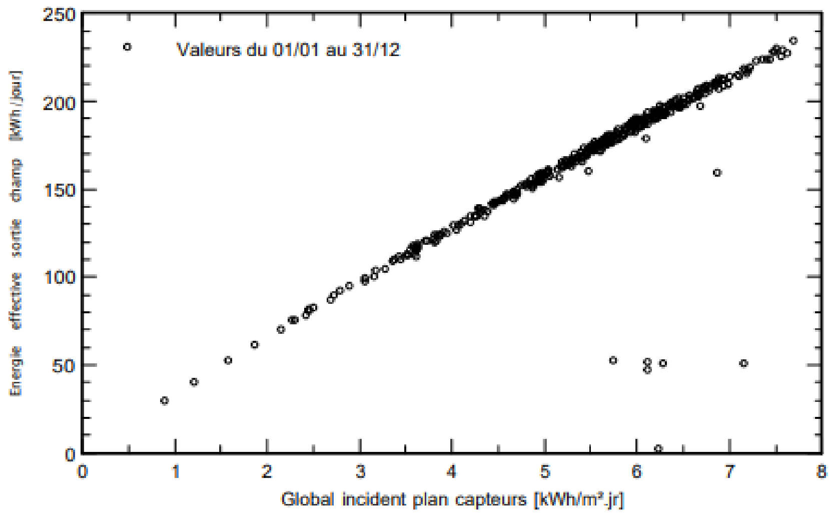


Figure 50 PV SYST RESUL

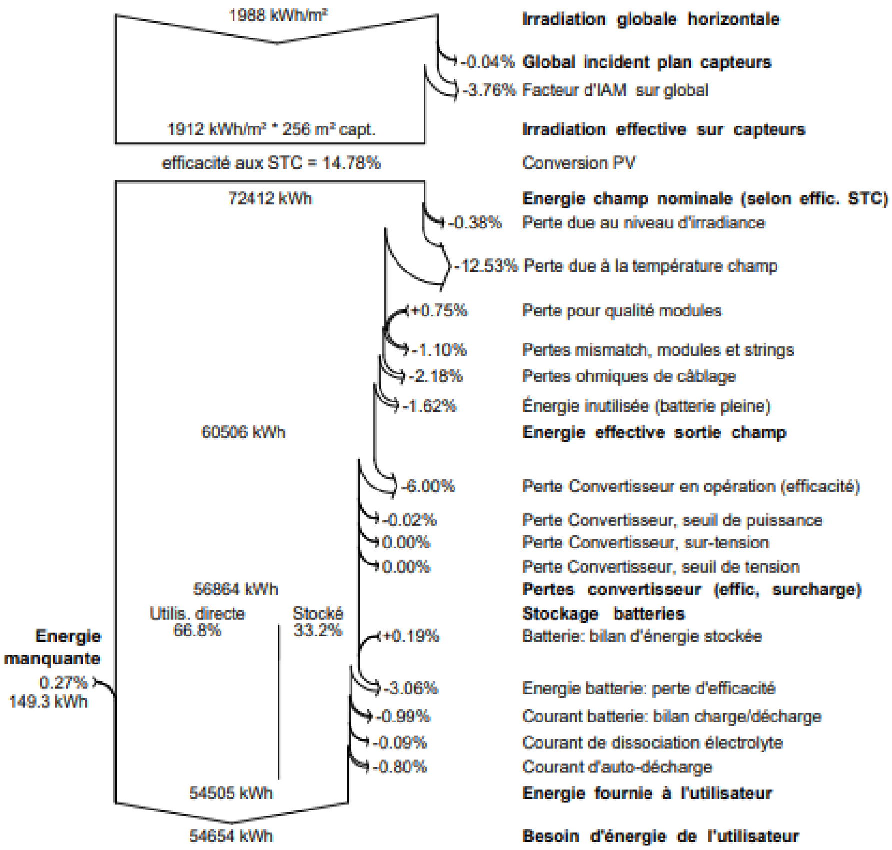
Système isolé: Diagramme des pertes

Projet : **memoir**

Variante de simulation : **Nouvelle variante de simulation**

Principaux paramètres système	Type de système	**Système isolé avec batteries**		
Orientation plan capteurs	inclinaison	3°	azimut	0°
Modules PV	Modèle	Poly 285 Wp 72 cells	Pnom	285 Wc
Champ PV	Nombre de modules	132	Pnom total	**37.6 kWc**
Batterie	Modèle	Solar 2V / 400 Ah	Technologie	Pb-acide, ouverte, tubulai
Pack de batteries	Nombre d'unités	912	Tension / Capacité	**48 V / 15200 Ah**
Besoins de l'utilisateur	Consomm. domestique	Constants sur l'année	Global	54.7 MWh/an

Diagramme des pertes sur l'année entière



4.2.3 System configuration

When it comes on installation, geographical coordinates of the site are highly recommended to be determine, such as latitude, longitude, temperature, location angle of declination etc, especially for optimization we need to very rigorous on angle of beam radiation.

Installing electrical materials might to be based on its technical data sheet that the manufacturer has provide, therefore reading the technical data sheet is much more necessary.

In general, it is recommended to orient to panels towards the equator to maximize the yield of the field regardless of the season, so the orientation might be south for the northern sites of the hemisphere, and north for the southern sites.

4.2.3.1 Panels configuration

Inclinaision angle can be determined basically by the latitude of the site like how show the figure below:

Latitude ϕ	Inclinaison β
$\phi < 10°$	$\beta = 10°$
$10° < \phi < 30°$	$\beta = \phi$
$30° < \phi < 40°$	$\beta = \phi + 10°$
$\phi > 40°$	$\beta = \phi + 15°$

Figure 51 Latitude & inclinaison

4.2.4 Modules mounting

4.2.4.1 Panels mounting

Operating temperature and temperature coefficient have been taking in account on panels sizing, it is now important to take in account the quality and the behavior of mounting material,

Saline corrosion affects all metals like aluminum; therefore, it is advisable to use materials that comply with CIS 61701, stainless materials for pv modules supports if available.

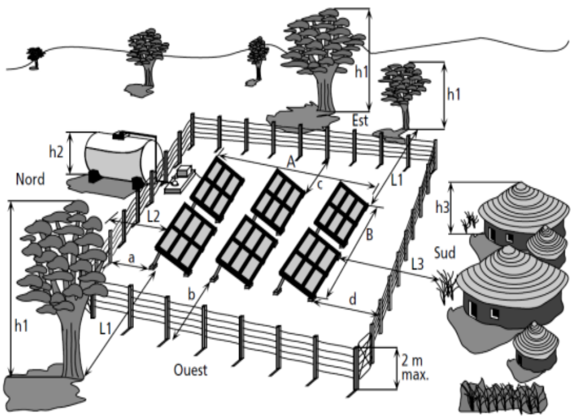
Structural members should be either:

corrosion resistant aluminum, 6061 or 6063 o hot dip galvanized steel per ASTM A 123 o coated or painted steel (only in low corrosive environments such as deserts) o stainless steel (particularly for corrosive marine environments)

is generally applied for big solar field energy generation like for the field up to 5 Mw, in this case it is best option because of its accessibility during the installation process and during routine cleaning, maintenance and repairs, there is also cooling possibility for ground mount by optimum airflow that panels allow which enhance the yield of field.

Grounding all the materials of the field include support is mandatory especially if the resistance between the metal structures and the earth connection is less than 22 KΩ

Distance estimation between the field and obstacle to limit the shadows. (Roussey, 2021)



Distance des obstacles à l'ouest ou à l'est :

$L1 \geq 2\,h1$

Distances des obstacles au nord et au sud

Latitude	Nord	Sud
0 à 10°	$L_2 \geq 0{,}4\,h_2$ ou ≥ 2 m	$L_3 \geq 0{,}7\,h_3$
10 à 20°	$L_2 \geq 0{,}25\,h_2$ ou ≥ 2 m	$L_3 \geq 1{,}0\,h_3$
20 à 30°	$L_2 \geq 2$ m	$L_3 \geq 1{,}4\,h_3$
30 à 40°	$L_2 \geq 2$ m	$L_3 \geq 2{,}0\,h_3$
40 à 45°	$L_2 \geq 2$ m	$L_3 \geq 3{,}3\,h_3$

Figure 52 distances obstacles

For house or small size solar energy generation is more recommended to use rooftop because of extra cost of ground installation.

4.2.4.2 Inverter installation & Charge controller

As any electrical product, there is need to focus technical data sheet to ensure a good installation of the product, for good safety of the installation, technical room might be provided and organized convenable to technical data sheet by ensuring ventilation, space between the components etc.

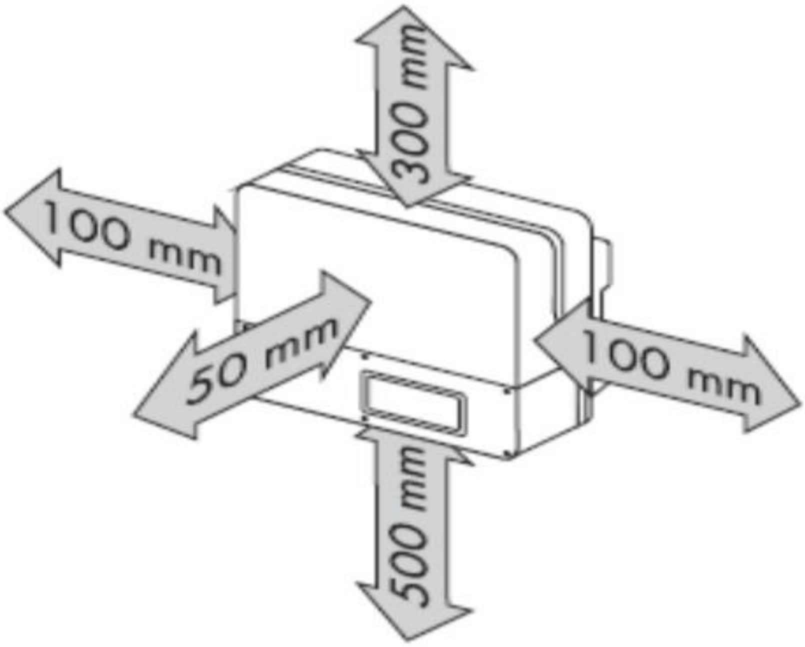


Figure 53 inverter installation

When it's come to paralyze two or three inverter or charge controller (as inverter and charge controller sometime are in one), power scheme and communication scheme must be correctly fixed like how show the figure below:

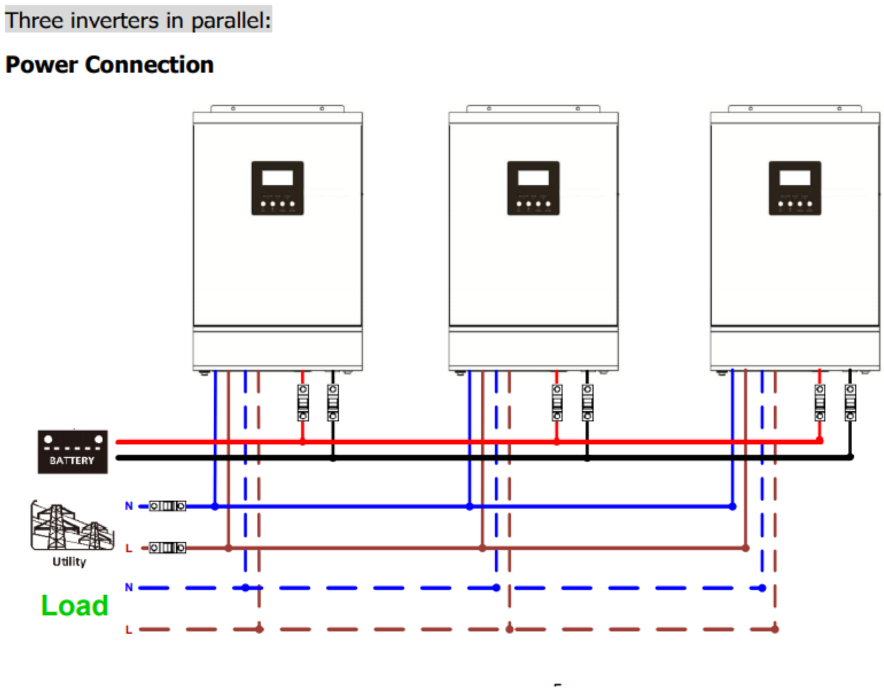


Figure 54 three inverters communicated in parallel

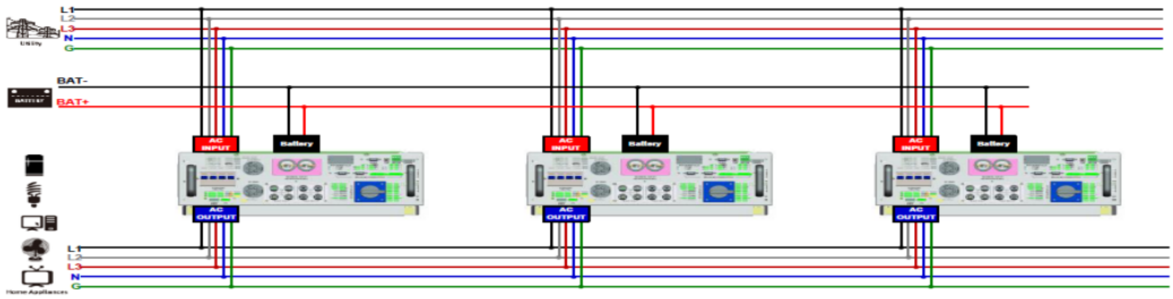


Figure 55 power scheme connection

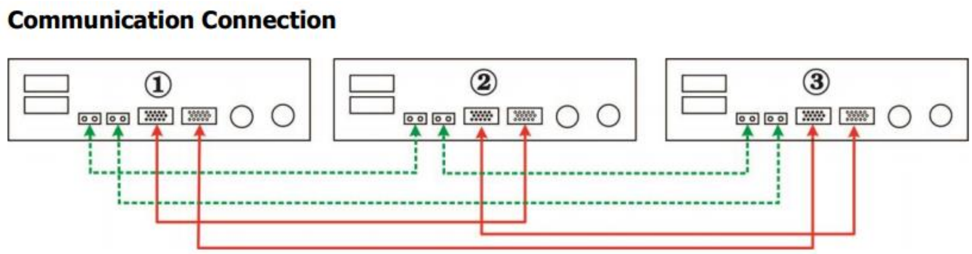


Figure 56 communication scheme connection

For more safety of the system, it is recommended to use distributor box for connection with the grid.

4.2.4.3 Batteries installation:

It is crucial important to sure that batteries are charged before use them at first time, any major discharge affect the batteries life,

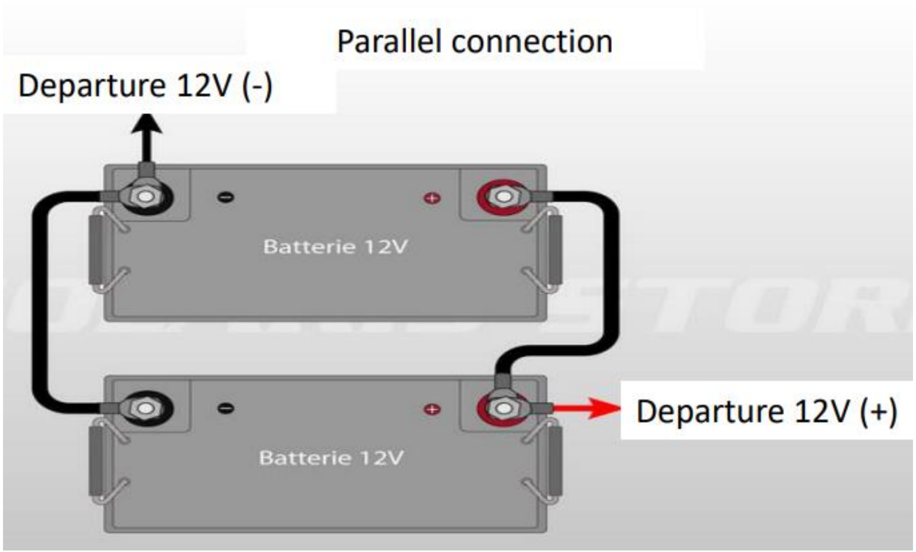


Figure 57 batteries parallel connection

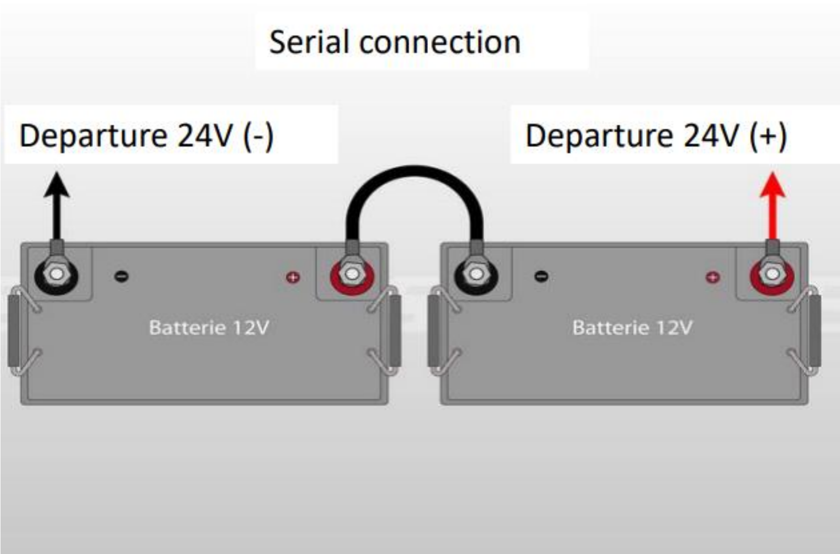


Figure 58 batteries serial connection

4.2.5 Mount of the system

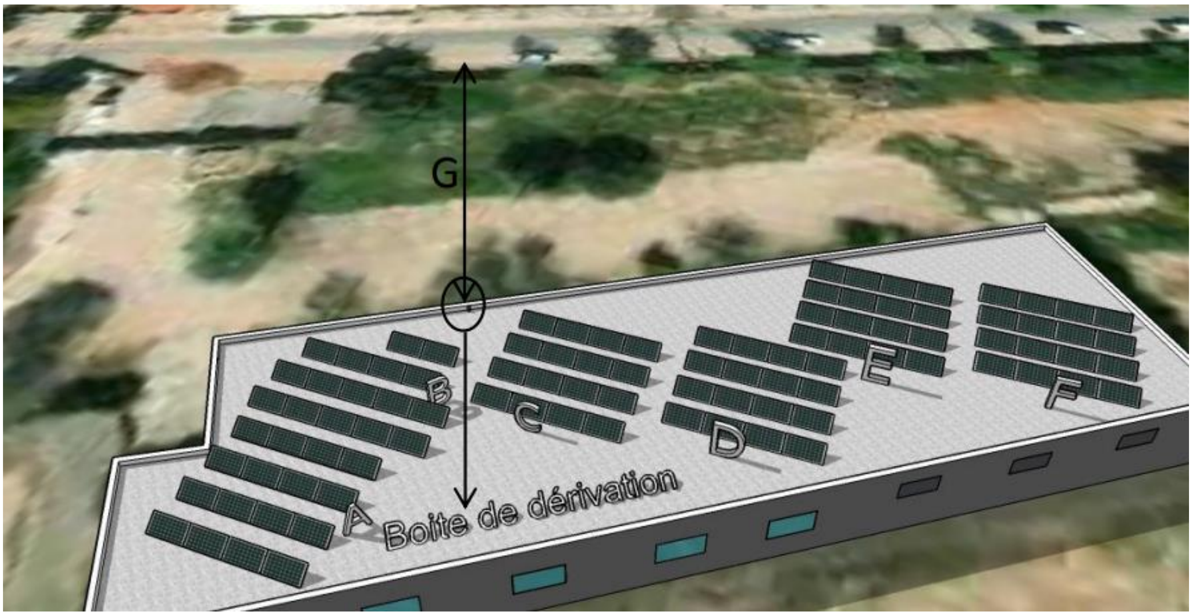


Figure 59 panels mounting

4.2.4.4 Cost of system estimation

After studying the installation of the PV system and determining the components of the system that will be used in the installation, it is important to estimate the total cost of the system.

Chapter V

5.1 Conclusion

Photovoltaic solar energy effectively contributes to energy policies renewables that act to fight against environmental pollution and preserve fossil resources. The solar photovoltaic system is a system that aims to produce electricity by exploiting the sun's rays thanks to photovoltaic modules, and the inverter that converts direct current into alternating current we can operate
devices and cables that connect the various components of the photovoltaic system.

The thesis objective is to study the installation and the determination of the size of a mini solar power plant for a primary school at the municipality of Sidi Bel Abbes. In chapter one we gave an overview on the topic background and relative problem, after we proceed in chapter two on literature of review by giving the generalities regarding the topic and last study relative, our details base on different recent technologies on renewable energy especially photovoltaic systems and their operating principle with a mention of their main components and their different types. After data collection and methodology in chapter three we simulate the performance of the site with solargis software and it shows a good performance ratio with it is considered pr = 0.8, we started chapter four by designing the system which we used manual and design and simulation with software.

Three manual methods have done, but the two first methods are very expensive less accurate because of excess energy production and we noted that designing a semi-central for primary school it is very important to satisfy the needs of customer and it is so important also to save some bill of energy consumption this is part of global objective of CES-MED project; to achieve this aim, we propose to decentralize the system and reduce the installation cost by reducing some unnecessary component like inverter for lighting and use some appliances with direct current. This have been done on third method which is most interested.

The first method is classical with smoothing on batteries backup and all DC output of array is converted to AC before use, consequently this make the project very cost because there is need of charge Controller high value, also inverter of high KVA;

The second method, we used the watthours simple method without smoothing, but more accurate, and less expensive;

The third method is classical method with smoothing, but as lighting a big part of energy required and is possible to use direct current for lighting to reduce the system.

After All the analysis, it shows that the third is more recommendable for viability of the system, economically most effective because it reduces $240 OOO from the first method.

For this thesis we have used PVsyst and Bluesol to simulate the system, and the software have given the result approximatively to the manual design with high performance, a depth finance analysis of the system has done by using SOLARGIS software and it shows a good performance ratio. The software confirms the manual designing, and we specific materials to install the system by the manual design, according to the result the highly feasible.

The whole cost of the system seems to be high due to batteries high prices, moreover the amount of stored energy is very high for smoothing to cover all the irregularity of the weather because the most interested period of study in Algeria is during winter so, there need to satisfy the needs even during worst weather, to reduce the cost and increase the effectiveness of system, we adopter the third method.

5.2 Recommendation

Photovoltaic energy effectively contributes to fight against environmental pollution and preserve, it is very recommendable for government to put all the strategies, policies and institutions related to renewables energy in other to succeed this huge transition.

On technical side using photovoltaic energy, it is crucial important to recommend to use as much as possible the appliances that consume direct current to increase the efficiency of system.

Separate inductive loads from classic loads, like putting each type in separate phase, it can help to reduce the size of inverter, thus the global cost of the system and reduce also the mechanic intervention.

Avoid using charge controller or inverter with high electrical value; size the system with the available equipment in the market.

Use fuses for each equipment also for each line for system security

References

A. Boudghene Stambouli, Z. Khiat, S. F. (2012). *Feature | Renewable energy development in Algeria | Algerian Network for Academics Scientists & Researchers*. http://www.new.anasr.org/2013/08/16/feature-renewable-energy-development-in-algeria/

Clima-med. (2012). *Convention des maires Méditerranée – Clima-Med*. https://www.climamed.eu/fr/the-covenant-of-mayors/mediterranean/

Dejene Nage, G. (2018). Estimation of Monthly Average Daily Solar Radiation from Meteorological Parameters: Sunshine Hours and Measured Temperature in Tepi, Ethiopia. *International Journal of Energy and Environmental Science*, *3*(1), 19. https://doi.org/10.11648/j.ijees.20180301.12

Deli, K., Houdji, E. T., Djongyang, N., & Njomo, D. (2017). Operation and maintenance of back-up photovoltaic systems: An analysis based on a field study in Cameroon. *Http://Dx.Doi.Org/10.1080/20421338.2017.1341731*, *9*(4), 437–448. https://doi.org/10.1080/20421338.2017.1341731

Freesunpower. (n.d.). *Advanced Tutorials: Solar Radiation for Solar Energy Systems*. Retrieved October 25, 2021, from http://www.freesunpower.com/radiation.php

Iftikhar, H. (2012). Solar PV System Design By. *Transnational Journal of Science and Technology*, *8000*(4), 13.

Klass, D. L. (1984). RENEWABLE ENERGY. *CHEMTECH*, *14*(10), 610–615. https://doi.org/10.1017/9781108676397.006

Kumar, P., Chandra, K. A., Patel, S., Pal, N., Kumar, M., & Sharma, H. (2020). Operational Challenges towards Deployment of Renewable Energy. *Renewable Energy - Resources, Challenges and Applications*. https://doi.org/10.5772/INTECHOPEN.92041

M.R. KOLHE B.E (Elect), M. B. A., KHOT, D. P. G., & Statistics, P. D. of. (2015). ALTERNATIVE ENERGY : A SPECIAL REFERENCE TO SOLAR ENERGY. *Alternative Energy*, *6*(9), 29–43.

Photovoltaic Solar Energy[1] |authorSTREAM. (n.d.). Retrieved October 31, 2021, from http://www.authorstream.com/Presentation/mukunthu-638585-photovoltaic-solar-energy-1/

Point, R. A. (2021). *Report on Solar Energy System - Assignment Point*. https://www.assignmentpoint.com/business/report-on-solar-energy-system.html

Power, E. (2021). *Pure Sine Wave Inverters | Inverter.com.au*. https://inverter.com.au/pure-sine-wave-inverter/1

Ristinen, R. A., & Kraushaar, J. J. (2006). *Energy and the environment*. 365.

Roussey, B. (2021). *Ground Mount vs. Rooftop Solar Panels | Cleanenergyauthority.com*. Clean Energy. https://www.cleanenergyauthority.com/solar-energy-resources/ground-mount-vs-rooftop-solar-panels-031221

Sa, solar flex. (2007). *1. Components. The first component needed is one or more Solar Panels. They supply the electricity and charge the batteries. - PDF Free Download*. http://docplayer.net/13273050-1-components-the-first-component-needed-is-one-or-more-solar-panels-they-supply-the-electricity-and-charge-the-batteries.html

Sherwani, A. F., Usmani, J. A., & Varun. (2010). Life cycle assessment of solar PV based electricity generation systems: A review. *Renewable and Sustainable Energy Reviews*, *14*(1), 540–544. https://doi.org/10.1016/j.rser.2009.08.003

Wenham et al. (2007). *Applied Photovotaics*.

William. (2021). *Top Solar Panel Manufacturers Worldwide: 15 Best Companies*. Phoenixsun. https://thephoenixsun.com/top-solar-panel-manufacturers/

Yatimi, H., & Aroudam, E. (2016). Evaluation of the Characteristics of the PV Module Considering Effects of Real Climatic Conditions. *Renewable Energy in the Service of Mankind Vol II*, 457–467. https://doi.org/10.1007/978-3-319-18215-5_40

Zafar, S. (2020). *Renewable Energy in Algeria | EcoMENA*. 20 OCTOBER 2020. https://www.ecomena.org/renewables-algeria/

“Algérie Commune de Sidi Bel-Abbès plan d’action en faveur de l’énergie durable.” 2015.

S. Paul and Md. K. A. Khan, “Design, fabrication and performance analysis of solar inverter,” in 2013 IEEE Energytech, Cleveland, OH, USA, Jul. 2013, pp. 1–5. doi: 10.1109/EnergyTech.2013.6645306.

W. T. Rhodes et al., Eds., “Solar Cells and Solar Modules,” in Photovoltaic Solar Energy Generation, vol. 112, Berlin/Heidelberg: Springer-Verlag, 2005, pp. 85–94. doi: 10.1007/3-540-26628-3_6.

Paul Breeze, Power Generation Technologies, Newnes 2019.

A. Boudghene Stambouli, Z. Khiat, S. F. (2012). *Feature | Renewable energy development in Algeria | Algerian Network for Academics Scientists & Researchers*. http://www.new.anasr.org/2013/08/16/feature-renewable-energy-development-in-algeria/

Clima-med. (2012). *Convention des maires Méditerranée – Clima-Med*. https://www.climamed.eu/fr/the-covenant-of-mayors/mediterranean/

Dejene Nage, G. (2018). Estimation of Monthly Average Daily Solar Radiation from Meteorological Parameters: Sunshine Hours and Measured Temperature in Tepi, Ethiopia. *International Journal of Energy and Environmental Science*, *3*(1), 19. https://doi.org/10.11648/j.ijees.20180301.12

Deli, K., Houdji, E. T., Djongyang, N., & Njomo, D. (2017). Operation and maintenance of back-up photovoltaic systems: An analysis based on a field study in Cameroon. *Http://Dx.Doi.Org/10.1080/20421338.2017.1341731*, *9*(4), 437–448. https://doi.org/10.1080/20421338.2017.1341731

Freesunpower. (n.d.). *Advanced Tutorials: Solar Radiation for Solar Energy Systems*. Retrieved October 25, 2021, from http://www.freesunpower.com/radiation.php

Iftikhar, H. (2012). Solar PV System Design By. *Transnational Journal of Science and Technology*, *8000*(4), 13.

Klass, D. L. (1984). RENEWABLE ENERGY. *CHEMTECH*, *14*(10), 610–615. https://doi.org/10.1017/9781108676397.006

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Photovoltaic Solar Energy[1] |authorSTREAM. (n.d.). Retrieved October 31, 2021, from http://www.authorstream.com/Presentation/mukunthu-638585-photovoltaic-solar-energy-1/

Point, R. A. (2021). *Report on Solar Energy System - Assignment Point*. https://www.assignmentpoint.com/business/report-on-solar-energy-system.html

Power, E. (2021). *Pure Sine Wave Inverters | Inverter.com.au*. https://inverter.com.au/pure-sine-wave-inverter/1

Ristinen, R. A., & Kraushaar, J. J. (2006). *Energy and the environment*. 365.

Roussey, B. (2021). *Ground Mount vs. Rooftop Solar Panels | Cleanenergyauthority.com*. Clean Energy. https://www.cleanenergyauthority.com/solar-energy-resources/ground-mount-vs-rooftop-solar-panels-031221

Sa, solar flex. (2007). *1. Components. The first component needed is one or more Solar Panels. They supply the electricity and charge the batteries. - PDF Free Download*. http://docplayer.net/13273050-1-components-the-first-component-needed-is-one-or-more-solar-panels-they-supply-the-electricity-and-charge-the-batteries.html

Sherwani, A. F., Usmani, J. A., & Varun. (2010). Life cycle assessment of solar PV based electricity generation systems: A review. *Renewable and Sustainable Energy Reviews*, *14*(1), 540–544. https://doi.org/10.1016/j.rser.2009.08.003

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William. (2021). *Top Solar Panel Manufacturers Worldwide: 15 Best Companies*. Phoenixsun. https://thephoenixsun.com/top-solar-panel-manufacturers/

Yatimi, H., & Aroudam, E. (2016). Evaluation of the Characteristics of the PV Module Considering Effects of Real Climatic Conditions. *Renewable Energy in the Service of Mankind Vol II*, 457–467. https://doi.org/10.1007/978-3-319-18215-5_40

Zafar, S. (2020). *Renewable Energy in Algeria | EcoMENA*. 20 OCTOBER 2020. https://www.ecomena.org/renewables-algeria/

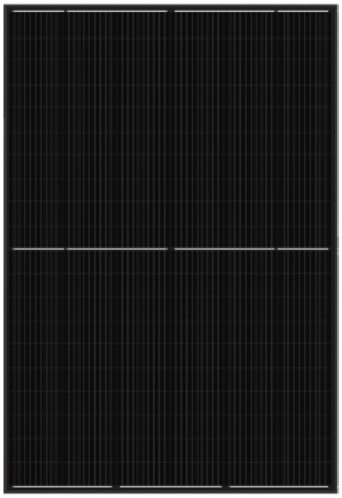
Index

A

MONOCRYSTALLINE 120 CELLS

CSM360-380 WATT

Full Black/Black Frame



The advantages:

9BB PERC solar Cell

More busbars,the less of broken and cracking,as the narrowed cell bus bar width,the light receiving area and power are increased too

1500V System Voltage

1500V system voltage design compatible to 1000V/1500V and Reduce BOS cost greatly.

Low-Light Performance

Excellent performance in low-light environments (e.g. early morning, dusk, and cloud, etc.)

Positive Tolerance

Guaranteed Positive Tolerance up tp 5W

Withstand challenging environmental conditions

2400 Pa negative load

5400 Pa positive load

2400/5400 is the measured load,and the safety factor is 1.5 times

PID-Resistant

Anti-PID-Technology

Salt-resistant & Ammonia-Resistant

Passed salt mist & ammonia corrosion,

blowing sand and hail testing

100% electroluminescence inspection

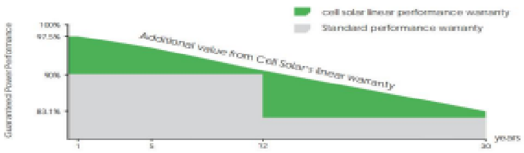
15 years manufacturer's warranty

- ISO9001:2015 Quality Standards
- ISO14001:2015 Environmental Standards
- OHSAS18001 Occupational Health & Safety Standards
- IEC61215,IEC61730 certified products
- UL1703 cedified products

IEC TÜV SÜD TÜV Rheinland CE PV CYCLE

LINEAR PERFORMANCE WARRANTY

15 Year Product Warranty • 30 Year Linear Power



CELLSOLAR
Email:sales@cellsolarenergy.com www.cellsolar-energy.com

MONOCRYSTALLINE 120 CELLS

Model--CSM360-380	CSM360-120	CSM370-120	CSM375-120	CSM380-120
Nominal output Pmpp	360Wp	370Wp	375Wp	380Wp
Nominal voltage Vmpp	33.52V	33.92V	34.12V	34.32V
Nominal current Impp	10.76A	10.92A	11.01A	11.09A
Short circuit current Isc	11.29A	11.46A	11.54A	11.60A
Open circuit voltage Voc	40.60V	41.03V	41.20V	41.40V
Module efficiency	19.76%	20.31%	20.59%	20.86%

Electrical characteristics (at Standard Test Conditions (STC) STC:Irradiance 1000W/m , Cell temperature 25℃ , AM1.5

MECHANICAL DATA

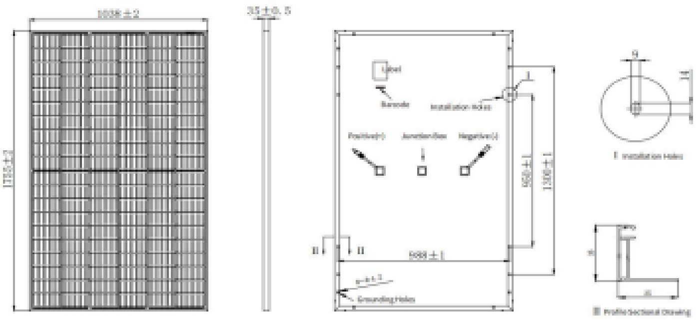
Solar Cells	9BB Monocrystalline PERC SOLAR CELL
Cell Orientation	120 cells (6×20)
Module Dimensions	1755×1038×35mm
Weight	19.68 kg
Glass	3.2 mm (0.13 inches),High Transmission,AR Coated Heat Strengthened Glass
Encapsulant Material	EVA (Ethylene-Vinyl-Acetate)
Backsheet	White Composite film /Black
Frame	35 mm(1.38 inches)Anodized Aluminium Alloy
J-Box	IP 68 rated
Cables	Photovoltaic Technology Cable 4.0mm2 (0.006 inches^2), 900mm/1200mm(Customized Available)
Connector	MC4 /TS4 Compatible with MC4

TEMPERATURE RATINGS

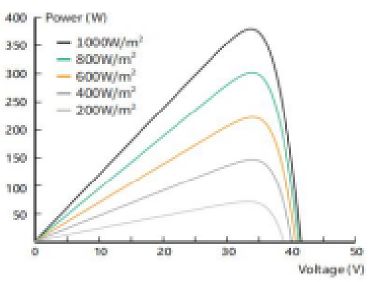
NMOT(Nominal Moudule Operating Temperature)	41°C (±3°C)
Temperature Coefficient of PMAX	-0.37%/°C
Temperature Coefficient of VOC	-0.29%/°C
Temperature Coefficient of ISC	0.05%/°C

MAXIMUM RATINGS

Operational Temperature	-40~+85°C
Maximum System Voltage	1500V DC(IEC)
	1500V DC(DL)
Max Series Fuse Rating	20A



Power-Voltage Curve(380W)



B

CSBATTERY

Durable Battery *Choose* CSBattery

SX12 SX6 SX2 Solar Battery

Specially Designed For Solar Applications

Deep cycle Gel Solar Battery

SX series designed for true-deep cycle solar applications, with features like thick, pure virgin lead plates (99.996%), heavy-duty over-the-partition welds, super-C additive and a proprietary gel formulation designed for years of cycling long service life.

SX is well-suited to all deep-cycle off-grid solar power system, from commercial to personal, solar sites.

SX can provide the best and reliable service under extreme conditions such as high temperature and frequent power outages for Solar project.

SX is the highly reliable, safe, and maintenance-free option.

ISO 9001 IEC 60896 UL CE

Complied Standards

IEC60896-21/22	BS6290part4
JISC8704	GB/T19638
IEC61427	CE/ISO

General features

- Able to operate at -40~60℃
- DOD 50% 1500 times Cycles
- Integrated design to ensure the best uniformity and reliability
- Long life and high stability under hightemp. environment (no cooling needed)
- Use super-C additives: Deep discharge recovery capability

Technical Specifications

Nominal Voltage		12V/6V/2V
Design Floating Life @25℃		20 Years
Nominal Capacity @25℃(20 hour rate@1.8V)		100%C (Ah)
Capacity @25℃	10hour rate (1.8V)	90%C (Ah)
	5 hour rate (1.8V)	80%C(Ah)
	1 hour rate (1.75V)	58%C(Ah)
Internal Resistance	Full Charged Battery@25℃	≤0.02*C(mΩ)
Ambient Temperature	Discharge	-25℃~60℃
	Charge	-25℃~60℃
	Storage	-25℃~45℃
Max.Discharge Current@25℃		6C (5s)
Capacity affected by Temperature (10 hour)	40℃	108%
	25℃	100%
	0℃	90%
	-15℃	70%
Self-Discharge@25℃per Month		3%
Charge (Constant Voltage) @25℃	Standby Use	Initial Charging Current Less than C*0.25A Voltage 2.25-2.3V
	Cycle Use	Initial Charging Current Less than C*0.25A Voltage 2.37-2.4V

SM6 6V Solar Battery Items specifications

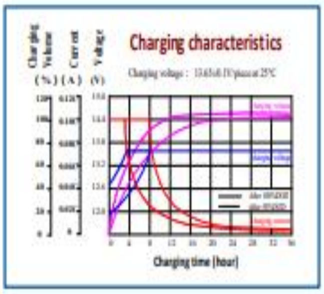
Model	Nominal Voltage (V)	Capacity (Ah)	Dimension (mm)				Net Weight	Gross Weight	Terminal
			Length	Width	Height	Total Height	kgs	kgs	
SX6-200	6	200	306	168	220	222	30	30.1	M8
SX6-210	6	210	260	180	247	249	29.5	29.6	M8
SX6-220	6	220	306	168	220	222	31.5	31.6	M8
SX6-225	6	225	243	187	275	275	30.5	30.6	M8
SX6-250	6	250	260	180	265	272	34.5	34.6	M8
SX6-310	6	310	295	178	346	366	46	46.2	M8
SX6-330	6	330	295	178	354	360	46.6	46.8	M8
SX6-380	6	380	295	178	404	410	55.3	55.8	M8
SX6-420	6	420	295	178	404	410	56.8	57.3	M8
SX8-170	8	170	260	182	266	271	34.3	34.8	M8
SX8-200	8	170	260	182	295	300	38.3	38.8	M8

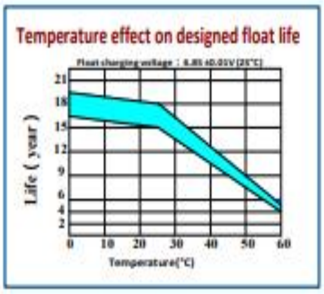
Address: Floor 3, Building Evolution, Xingdong industry Park, NO.61, Liuxian 2nd Road, Baoan, Shenzhen, China.
Phone: +86-755-29123661// **Email:** Sales@csbattery.cn
Website: https://www.csbattery.cn

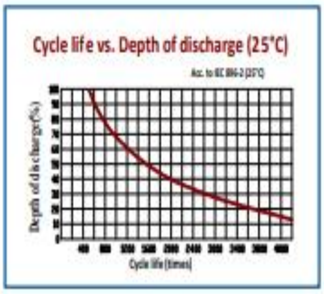
SM2 2V Solar Battery Items specifications

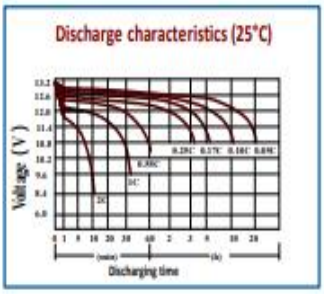
Model	Nominal Voltage (V)	Capacity (Ah)	Dimension (mm)				Net Weight	Gross Weight	Terminal
			Length	Width	Height	Total Height	kgs	kgs	
SX2-200	2	200/10HR	170	106	330	367	13.2	13.4	M8
SX2-300	2	300/10HR	171	151	330	365	18.7	18.9	M8
SX2-400	2	400/10HR	211	176	329	367	26.3	26.5	M8
SX2-500	2	500/10HR	241	172	330	364	31.2	31.4	M8
SX2-600	2	600/10HR	301	175	331	366	37.9	38.2	M8
SX2-800	2	800/10HR	410	176	330	365	51.8	52.1	M8
SX2-1000	2	1000/10HR	475	175	328	365	62.5	62.8	M8
SX2-1200	2	1200/10HR	472	172	338	355	69	69.3	M8
SX2-1500	2	1500/10HR	401	351	342	378	97	97.5	M8
SX2-2000	2	2000/10HR	491	351	343	383	130.5	131	M8
SX2-2500	2	2500/10HR	712	353	341	382	180.5	181	M8
SX2-3000	2	3000/10HR	712	353	341	382	190.5	191	M8

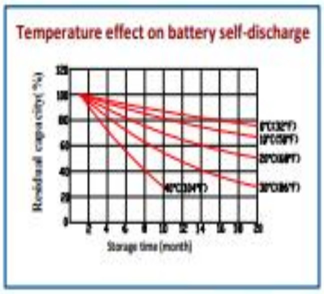
Performance Characteristics

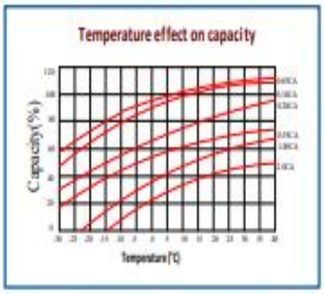












Address: Floor 3, Building Evolution, Xingdong industry Park, NO.61, Liuxian 2nd Road, Baoan, Shenzhen, China.
Phone: +86-755-29123661// **Email:** Sales@csbattery.cn
Website: https://www.csbattery.cn

C

UX series solar inverters

autarco

The Autarco UX series inverters offer the best and most reliable performance in its class. The inverter is a key element in a solar PV power plant and these inverters provide the reliable basis for Autarco's unique kWh guarantee.

- 10 Insured 10-year product warranty
- Compact, lightweight
- Max efficiency of 99%
- High speed MPPT algorithm
- Cloud-based digital O&M

Quality certificates

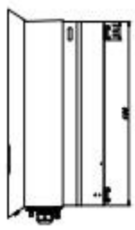
- EN50438, VDE0126-1-1, G59/3, NB/T32004, AS4777, IEC61727
- IEC62109-1-2, AS3100, EN61000-6-1, EN62109
- VDE4105, CE, Solarif

General characteristics

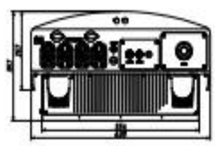
Dimensions (W x H x D)	630 x 700 x 357mm
Mounting	Wall bracket
Max. site altitude	4000m
IP protection class	IP65 according IEC 60529
Isolation type	Transformerless
Cooling principle	Convection with smart fan-cooling
Noise level, typical	< 30dBA, <50dBA with cooling fan
LED indicators	3
LCD display	20 x 2 characters
Communication interfaces	1xRS485, 2xRJ45, 2xTerminal
Optional interfaces	RS232, RJ45, GPRS
DC switch	Integrated (optionally excluded)

Front

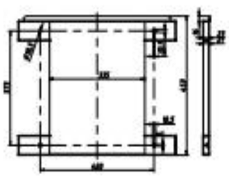
Side



Bottom



Bracket



Input characteristics

	S2.UX40000(S)	S2.UX50000(S)	S2.UX60000(S)	S2.UX70000(S)-HV
Max. PV input power (W)	48000	60000	72000	84000
Max. DC voltage (V)	1100	1100	1100	1100
MPP tracker voltage range (V)	200-1000	200-1000	200-1000	200-1000
Start-up DC voltage (V)	200	200	200	200
Number of MPP trackers	4	4	4	4
Max. DC current per MPPT (A)	22	28.5	28.5	28.5
Number of DC connections per MPPT	2	3	3	3
DC connection type	MC4	MC4	MC4	MC4
Turn on power (W)	10	10	10	10

Output characteristics

AC connection	380 / 400 VAC	380 / 400 VAC	380 / 400 VAC	540 VAC
Power connection	3-phase	3-phase	3-phase	3-phase
Rated AC power (W)	40000	50000	60000	70000
Max. AC power (W)	44000	55000	66000	77000
Grid voltage range (V)	According to VDE 0126-1-1, G59/3, AS4777, NB/T32004			
Grid frequency range (Hz)	According to VDE 0126-1-1, G59/3, AS4777, NB/T32004			
Rated AC current (A)	58.0	72.2	86.6	84.2
Max. AC current (A)	66.9	83.3	100.0	92.6
Power factor	0.8...1...0.8	0.8...1...0.8	0.8...1...0.8	0.8...1...0.8
Harmonic distortion (%)	< 2	< 2	< 3	< 3
Cooling principle	Convection	Cooling fan	Cooling fan	Cooling fan
DC injection current (mA)	< 50	< 50	< 50	< 50
Weight (kg)	61	63	63	63

Efficiency

Max. effiency	98.8% - 99.00%
Euro efficieny	98.4% - 98.50%
MPPT efficieny	>99.90%

Other characteristics

Operating temperature range	-25°C to +60°C
Relative humidity range	0% to 100%

Protection

DC overvoltage protection	Integrated
DC reverse polarity protection	Integrated
Short circuit protection	Integrated
Grid monitoring	Integrated
Residual current detection	Integrated
Insulation resistance monitoring	Integrated
Temperature protection	Integrated
Islanding protection	Integrated

The specifications contained in this datasheet may deviate slightly from our actual products due to on-going product improvement and are subject to change at any time without prior notice.