Palestine Polytechnic University

College of Engineering

Title

Solar Power Shades for Dura Stadium

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الإهداء

وها نحن بفضل الله نصل إلى نهاية البداية ونقطف فرحة سنين كانت مليئة بالمثابرة والآن لا يسعنا أن نهدي نجاحنا هذا إلا لمن كانوا النور في أعيننا في كل تلك السنين الطوال.

إلى الذين قدموا ما عجزت ألسنتنا عن وصفه ... إلى أرواح الشهداء الذين رووا الأرض وخضبوها بدمائهم لنحيا بعزة وكرامة ... إلى أسرى الكرامة خلف قضبان السجان الظالمة ... إلى أرضي ووطني نهدي نجاحنا وثمرة علمنا لكم قبل أيا كان.

إلى من تعلمت منه الصمود والنجاح والصبر والمثابرة إلى من كسا العرق جبينه وغطى الشيب رأسه وهو يحفر لنا طريقا سهلاً من بين أكوام الحجارة والمعاناة وشدائد الحياة ... إليك يا أبي.

إلى التي سهرت الليالي تبتهل لنا العيش الكريم والنجاح إلى التي عانت صرخات المخاض لترى نور وجوهنا وتألقنا نجوماً في سماء هذا العالم ... إلى الغالية أمي.

إلى من شاركوني الضحكات وخبز الحياة إلى من عاهدتهم على أن نكون فخراً ونوراً وحياة لوالدينا إلى من تعاهدنا على أن تكون كتفاً بكتف في كل لحظات الحياة المرة قبل الحلوة إلى إخواني وأخواتي.

إلى من قاسمونا فتات الفرح ومشاق الطريق إلى من كانوا لنا سندا وعونا على السنين الثقال إلى إخوتي الذين لمن تلدهم أمي - إلى الأصدقاء والزملاء الأعزاء.

إلى من كانوا لنا آباء واخوة وأصدقاء وسهلوا لنا الطريق الشائك بالصعاب إلى الذين زرعوا فينا بذرة الإبداع - إلى أساتذتي.

الى كل من أخذ ويأخذ بأيدينا الى قمة النجاح الى أعزاءنا.

وما هذه إلا النهاية لبداية طريق سنصنعه من جديد لنجاح أعظم - نسأل الله التوفيق وطريق الصلاح.

Abstract

Using of renewable energy systems, especially solar energy, is one of the solutions for the production of sustainable and environmentally friendly electric power, this project aims at build a solar power system for Dura stadium and take advantage of the solar cells of this system as umbrellas for the seats of the masses, and after studying the consumption of the stadium where we took the consumption rate from 2013 to 2020 and this consumption amounts to 60,424 kwh/year , We noticed that consumption is not enough to cover the entire area of the stadium of 1118 m2 and so we relied on this area to build a system with a capacity of 152 kwp, and since there will be a surplus, there will be a contract between the municipality and the electricity company, and we are here in our turn to find out the fate of the surplus we had to know whether the area around the stadium receives this surplus or not?

When studying the full load of the area around the stadium of approximately 4 MW, the maximum value of the surplus from renewable energy sources is 25% of the full load and thus receive a surplus of 1m, and after the establishment of the final design of the project we calculated quantities where the cost of the project is 558699 ILS.

الملخص

يعد استخدام أنظمة الطاقة المتجددة ، وخاصة الطاقة الشمسية أحد الحلول لإنتاج الطاقة الكهربائية المستدامة والصديقة للبيئة، يهدف هذا المشروع إلى بناء نظام طاقة شمسية لملعب دورا والاستفادة من الخلايا الشمسية لهذا النظام كمظلات لمقاعد الجماهير ، وبعد دراسة استهلاك الملعب حيث أخذنا معدل الاستهلاك من سنة 2013 إلى 2020 ويبلغ هذا الاستهلاك 60424 كيلوواط ساعة في السنة ،لاحظنا ان الاستهلاك لايكفي لتغطية مساحة الملعب كامله البالغة 1118م^2 وبذلك اعتمدنا على هذه المساحة لبناء نظام تبلغ قدرته 152كيلو واط ،وبما أنه سيكون هناك فائض فيتوجب عمل تعاقد بين البلدية وشركة الكهرباء ، ونحن هنا بدورنا لمعرفة مصير الفائض توجب علينا معرفة هل المنطقة المحيطة بالملعب تستقبل هذا الفائض ام لا؟

عند دراسة الحمل الكامل للمنطقة المحيطة بالملعب البالغة تقريبا 4 ميجا واط ،يبلغ أقصى قيمة للفائض من مصادر الطاقة المتجددة 25% من الحمل الكامل وبذلك يتم استقبال فائض بما مقداره 1ميجا ،وبعد انشاء التصميم النهائي للمشروع قمنا بحساب كميات حيث تكون تكلفة المشروع ما مقداره 558699 شيكل.

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Chapter 1

Introduction

1.1 Overview

The idea of the project is to design a solar power system that provides power for Dura stadium, in addition to Take advantage of solar cells as shades. (overdoor umbrella).

1.2 Objectives

1- Design of solar power system capable of lighting a stadium and design a solar power shades for Dura stadium.

2- Support the grid (based on the system is Grid-Tied Solar System so the main grid will be supported.

1.3 Motivations:

Due to the electricity situation in our country , the extent of the difficulties that Facing us to generating energy, And the frequent interruption of electricity, has become important to utilization the solar power system to relieve pressure on the grid, and thus save energy. Therefore, it is necessary to exploit all places where energy can be saved and alternative energy used, hence the idea of exploiting stadiums by providing energy and generating it.

1.4 Software program.

- AutoCAD
- PV SYSTEM

1.5 Methodology

The current premaster plan has been developed by adopting the

following methodology:

- Collect data on solar power system and grid connected systems.
- Study projects related to solar power system.
- Study projects related to the stadiums' solar power system.
- Establish the background to start the project and how to work on it
- Project design contains two phases:

 - Project design calculations were done using some programs.
 - Project design using AutoCAD program.

1.6 Expected Results

It is expected that the 152 kw project built on an area of 1118 m^2 will be able to provide sufficient energy for the stadium, and the surplus will be a return for the stadium, so that the approximate cost of the project is expected to reach half a million.

Chapter 2

Literature Review

2.1 Introduction:

A Report Issued by the International power Agency Says that solar power has become the fastest source of power generation in the world, in which the growth of solar power surpasses all other types of sources. So, the need for solar power is booming. The global solar power market is expected to value 52.5 billion$, and it is expected that the market value of solar power will exceed 140 billion$ by 2023, and may reach 223.3 billion$ by 2026. Such as hotels, hospitals and homes . [1]

2.2 The Leading Countries in The Production of Solar power:

Izismile relayed a report of the International power Agency about the leading countries in the field of solar energy generation Globally, as follows:

Table 2.1: Leading Countries in The Production of Solar power[1]

number	The name of country	production quantity(MW)
1	Germany	38,250 MW
2	China	28,330 MW
3	Japan	23,409 MW
4	Italy	18622 MW
5	America	18317 MW
6	France	5678 MW
7	Spain	5376 MW
8	Victoria	4130 MW
9	Belgium	3,156 MW
10	South Korea	2398 MW

2.3 Countries Depend for Their power on Solar power:

1 - Cyprus:

Solar power is available in Cyprus more than most European countries, and the Mediterranean island aims to have the proportion of solar power generation of both types of solar cells and concentrated solar power systems reach 7% by 2020, making it one of the most participating countries in the renewable energy market, after Spain. It is equal to 8% with Germany, it is preceded by Greece with 5%, Portugal with 4%, and Malta with 1%.[1]

2- Japan:

Japan has witnessed a great development in benefiting from solar power since the late 1990s, as it became one of the five leading countries in the field, and ranked third in terms of "largest installations" after Germany and Italy, and it also maintained its second position among the largest solar power markets in the world for two consecutive years. 2013 and 2014, with capacities of6.9 and 9.6 GW, respectively. The total capacity reached (23.3 gigawatts), surpassing Italy(18.5 gigawatts), to become the third largest producer of solar power in the world after Germany (38.2 gigawatts) and China (28.2 gigawatts), as it produces sufficient power to cover 2.5% of the annual electricity demand in the country.[1]

3- Jeolla (South Korea):

In 2009, the capacity of the solar power plant in Sinan, South Jeolla Province, South Korea, reached 24 megawatts, making it the largest solar power plant in Asia. The German company Konergyi developed the plant at a cost of about 150 million$, and the station was built by Dongyang Corporation. For engineering installations.[1]

4 - Germany:

Germany was the world's top producer of solar power for seven years, starting in 2005, with a generation balance of 36 gigawatts in February, bringing the contribution of solar power that year to 6% of the total electricity production in the electric grid. However, this boom period was affected in 2012 by the decline in the national market for solar power in Germany as a result of amendments in the Renewable Energy Law (EEG), which provides for a reduction in the price of the energy unit, and restrictions on installations so that their capacity does not exceed 10 megawatts.[1]

2.4 power produced from solar power plants in Palestine:

The total capacity of operating and connected solar power stations and systems to grid in the West Bank and Gaza Strip is 80 megawatts (60 megawatts in the West Bank and 20 megawatts in Gaza), which is 2.3% of the final consumption of electricity, taking into account the difficulty of building high-capacity solar power stations due to Israeli reluctance.[2]

2.5 Main Photovoltaic executed projects in Palestine:

1-Tubas (West Bank): is a Palestinian city in the northeastern West Bank, located northeast of Nablus, west of the Jordan Valley ,as shown in figure 2.1.

<u>First Project :</u> The location of the project is as shown in figure 2.1, and part of the shape of pv system as shown in figure 2.2

-Year: 2012

- Capacity: 470 KW
- Donor: Czech Republic Development Cooperation
- Project value: 1.150.000USD
- Estimated production: 800.000 KWh/Year
- Reduced emission : 560 Tons Equivalent CO_2

<u>Second Project :</u> The location of the project is as shown in figure 2.1, and part of the shape of pv system as shown in figure 2.3

- Year: 2012- Capacity: 17 Grid connected stations for agricultural use (5Kwp /Each) + 5 stand alone projects (3Kwp/each) .
- Donor: Czech Republic Development Cooperation.[3]

Figure 2.1: Tubas project site

Figure 2.2 : first project

Figure 2.3 : second project

2-Jericho (West Bank): is a Palestinian city in the West Bank. It is located in the Jordan Valley, with the Jordan River to the east and Jerusalem to the west ,as shown in figure 2.4.

<u>The Project :</u> The location of the project is as shown in figure 2.4, and part of the shape of pv system as shown in figure 2.5, The shape of the design can be seen in figure 2.6.

- Year: 2010
- Capacity: 300 KW
- Donor: Government of Japan (JICA)
- Estimated production: 422.000 KWh/Year
- Reduced emission : 290.6 Tons Equivalent CO2[3]

Figure 2.4: Jericho project

Figure 2.5 : part of pv

Figure 2.6 :the design

3- Dead Sea (West Bank):is a salt lake bordered by Jordan to the east and the West Bank to the west.,as shown in figure 2.7.

The Project : The location of the project is as shown in figure 2.7, and part of the shape of pv system as shown in figure 2.8.

-Year: 2014

- Capacity: 710 KW
- Financed by: United Arab Emirates
- Total Cost: 993.800 USD.[3]

Figure 2.7: dead sea project site

Figure 2.8 : part of pv project

4- **Another Project :**The Palestinians are trying to implement the largest number of projects related to solar energy, In addition to the above, there are many other projects.
a- Hospitals: Multiple hospitals in west bank and Gaza strip: 5 hospitals .One of these hospitals is Al-Ahli Hospital in Hebron city (capacity of 225 KW). [3]

b- Universities: There are many universities that have installed a solar power system like:

-Palestine Polytechnic University :capacity of 230 KW

-Hebron University : capacity of 220 KW [3]

-Jenin University: capacity of70 KW[3]

-alistiqlal University : capacity of45KW[4]

c- Schools :A Multiple schools in west bank and Gaza strip (up to 100 PV systems). capacity of (5-15) KW.[3]

d-Also There are many projects for homes, factories and remote areas.

2.6 Solar power projects in stadiums:

There are many solar power projects that have been implemented on the stadiums in general, as we know that sport is a popular activity and many matches and sporting activities are held within one year, whether locally or internationally, for example the history of sports reached the World Cup semi-finals 1990 - England × West Germany. The demand for electricity has reached 2,800 megawatts, so using the stadiums to produce solar power will be beneficial and beautiful.[5]

There are many solar power stadiums in the world like:

1- The Brazilian National Stadium:

The Brazilian National Stadium, formerly known as the Garrincha Stadium, was built in 1974. Rebuilt in time for the 2014 FIFA World Cup in Brazil, the stadium was renamed in 2010 and it as shown in figure 2.9, and is now the second largest stadium in Brazil. The Brazilian National Stadium has the world's largest installed capacity of 2.5 MW of solar power.[6]

Figure 2.9 : The Brazilian National Stadium

2- Mineiro Stadium, Brazil:

The Mineiro Stadium was the main stadium for the 2014 FIFA World Cup and was the venue for the 2013 Confederations Cup and the 2016 Summer Olympics. In line with Brazil's 2014 "Green World Cup" campaign, the stadium installed a 1.4 megawatt rooftop photovoltaic system in 2013, providing 1.4 million kilowatt hours of green electricity annually.[6]

3- Vankdorf Stadium, Germany:

In 2007, the installation of solar energy equipment was completed, the total installed capacity of 1.3 megawatts, can produce 1 trillion kilowatt hours of electricity per year.[6]

4- Longteng Stadium In Taiwan:

The Dragon Stadium is an open stadium and the world's first stadium with an opening. Featuring a dragon theme, the 8,844 solar panels on the roof of the stadium make up the shimmering scales of a giant dragon as shown in figure 2.10. With a total installed capacity of 1 megawatt, it is the world's first sports stadium to be powered entirely by solar energy, with 85% of the power available to the surrounding area when idle.[6]

Figure 2.10 : Longteng Stadium In Taiwan

- In addition to the previous stadiums, there are still more like:

- Kaiserslautern Football Stadium, Germany.[6]

- Michigan Stadium.[7]

- 10 Best Solar Stadiums Around the World (2018 FIFA World Cup Edition) for football in Table 2.2.

Table 2.2:10 Best Solar Stadiums for football Around the World[8]

#	Name	Size (kWp)	Sport	Location	Country	Year	# panels(cells)
1	The Brazilian National Stadium	2,500	Football	Brasília, DF	Brazil	2013	9,600
2	Rio Tinto Stadium	2,020	Football	Sandy, Utah	USA	2015	6,500
3	Mineirao	1,420	Football	Belo Horizonte, Minas Gerais	Brazil	2014	6,000
4	Antalya Arena	1,400	Football	Antalya	Turkey	2015	5,600
5	Stade de Suisse	1,350	Football	Bern	Switzerland	2005	8,000
6	Allianz Riviera	1,342	Football	Nice	France	2013	4,000
7	Weser stadium	1,270	Football	Bremen	Germany	2011	200,000
8	Johan Cruijff Arena	1,128	Football	Amsterdam	The Netherlands	2014	4,200
9	Itaipava Arena Pernambuco	1,000	Football	São Lourenço da Mata, Pernambuco	Brazil	2014	3,650
10	Bentegodi-stadion	1,000	Football	Verona	Italy	2009	13,300

Chapter 3

Solar power-system

3.1Introduction

The sun produces an unbelievable amount of energy that reaches the earth. The amount of energy that is absorbed by the earth in one hour is more energy than mankind uses in one year. The total amount of solar energy reaching the earth in one year is huge - twice as much energy as ever existed from all sources of coal, oil, natural gas, and uranium combined. The sun strikes the surface of the earth at different angles ranging from 0 degrees (no sun) at the poles to 90 degrees at the equator during spring and fall. At the equator during noon time, the earth's surface gets the maximum amount of energy. As one moves away from the equator, the sun's rays have to travel longer through the atmosphere. Along the way some rays are reflected into space or scattered by clouds causing loss of energy as they go. On average, about 50% of the sun's energy makes it through the atmosphere and strikes the earth. The tilt in the earth's axis of rotation also causes variations in the amount of sunshine received. The north pole receives little sunshine in the winter months and likewise the south pole receives little in the summer months. So the amount of solar energy that reaches any given location varies by latitude, time of year, time of day, and local weather.[9]

Solar energy is a powerful source of energy that can be used to heat, cool, and light homes and businesses. A variety of technologies convert sunlight to usable energy for buildings. The most commonly used solar technologies for homes and businesses are solar photovoltaic's for electricity, passive solar design for space heating and cooling, and solar water heating.Businesses and industry use solar technologies to diversify their energy sources, improve efficiency, and save money. Energy developers and utilities use solar photovoltaic and concentrating solar power technologies to produce electricity on a massive scale to power cities and small towns.[10]

3.2 Solar Systems Grids :

There are three types of solar systems grids:

- Grid-Tied Solar Systems.
- Off-Grid Solar Systems.
- Hybrid Solar Systems.

3.2.1 Grid-Tied Solar Systems.

This type is generate power when the power grid is available and must connect to the power system to function, it can generate excess power that will be store for later use. Grid-tied, on-grid, utility-interactive, grid intertie and grid back feeding are all terms used to describe the same concept – a solar system that is connected to the utility power grids shown in figure 3.1.

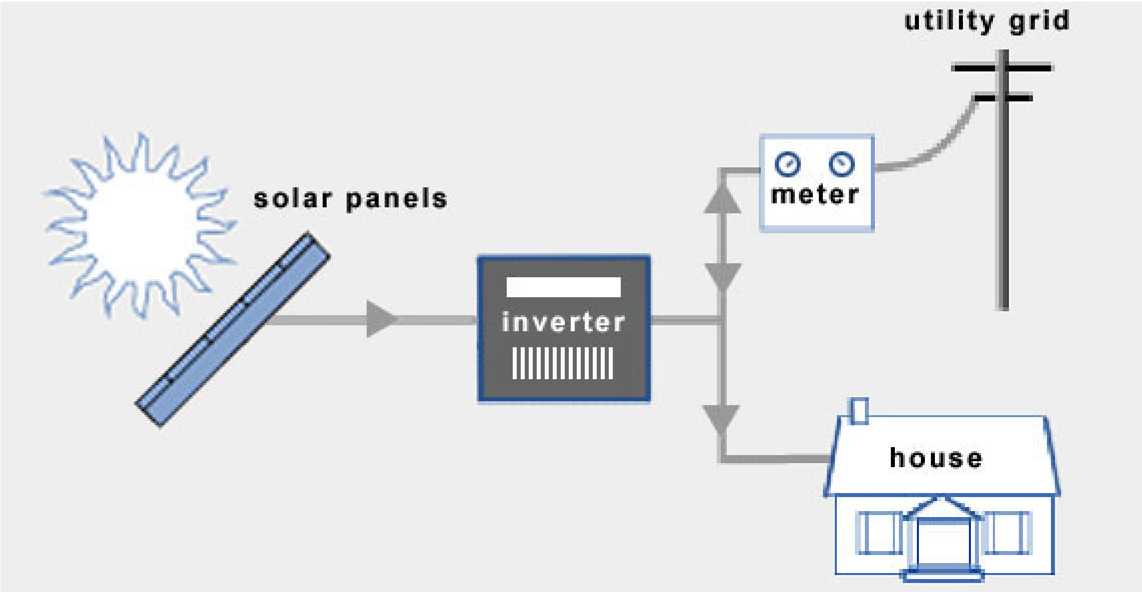


Figure 3.1 : Grid-Tied Solar Systems.[11]

a) <u>Advantages of Grid-Tied Systems:</u>

- <u>Save more money with net metering:</u>

  A grid-connection will allow you to save more money with solar panels through better efficiency rates, net metering, plus lower equipment and installation costs:

  Batteries, and other stand-alone equipment, are required for a fully functional off-grid solar system and add to costs as well as maintenance. Grid-tied solar systems are therefore generally cheaper and simpler to install.

  Your solar panels will often generate more electricity than what you are capable of consuming. With net metering, homeowners can put this excess electricity onto the utility grid instead of storing it themselves with batteries. Many utility companies are committed to buying electricity from homeowners at the same rate as they sell it themselves. [11]

- The utility grid is a virtual battery :

  Electricity has to be spent in real time. However, it can be temporarily stored as other forms of energy (e.g. chemical energy in batteries). Energy storage typically comes with significant losses. The electric power grid is in many ways also a battery, without the need for maintenance or replacements, and with much better efficiency rates. In other words, more electricity (and more money) goes to waste with conventional battery systems. Lead-acid batteries, which are commonly used with solar panels, are only 80-90% efficient at storing energy, and their performance degrades with time.

  Additional perks of being grid-tied include access to backup power from the utility grid (in case your solar system stop generating electricity for one reason or another). At the same time you help to mitigate the utility company`s peak load. As a result, the efficiency of our electrical system as a whole goes up. [11]

b) Equipment for Grid-Tied Solar Systems:

There are a few key differences between the equipment needed for grid-tied, off-grid and hybrid solar systems. Standard grid-tied solar systems rely on the following components:

- Grid-Tie Inverter (GTI) or Micro-Inverters.
- Power Meter.

- Grid-Tie Inverter (GTI)

What is the job of a solar inverter? They regulate the voltage and current received from your solar panels. Direct current (DC) from your solar panels is converted into alternating current (AC), which is the type of current that is utilized by the majority of electrical appliances.

In addition to this, grid-tie inverters, also known as grid-interactive or synchronous inverters, synchronize the phase and frequency of the current to fit the utility grid. The output voltage is also adjusted slightly higher than the grid voltage in order for excess electricity to flow outwards to the grid. [11]

- Micro-Inverters

Micro-inverters go on the back of each solar panel, as opposed to one central inverter that typically takes on the entire solar array. There has recently been a lot of debate on whether micro-inverters are better than central (string) inverters.

Micro-inverters are certainly more expensive, but in many cases yield higher efficiency rates. owners who are suspect to shading issues should definitely look into if micro-inverters are better in their situation. [11]

- Power Meter

Most owners will need to replace their current power meter with one that is compatible with net metering. This device, often called a net meter or a two-way meter, is capable of measuring power going in both directions, from the grid to your place and vice versa. [11]

3.2.2 Off-Grid Solar Systems.

It is a system that store solar power in batteries and use it when the power grid goes down , but this system have downside because cannot be expected to provide power for all
loads, the volume and cost of batteries and the sizing of this type of systems are more complex. The most benefit of this system there's no access to the power grid.Figure3.2 below describe off-grid system. [11]

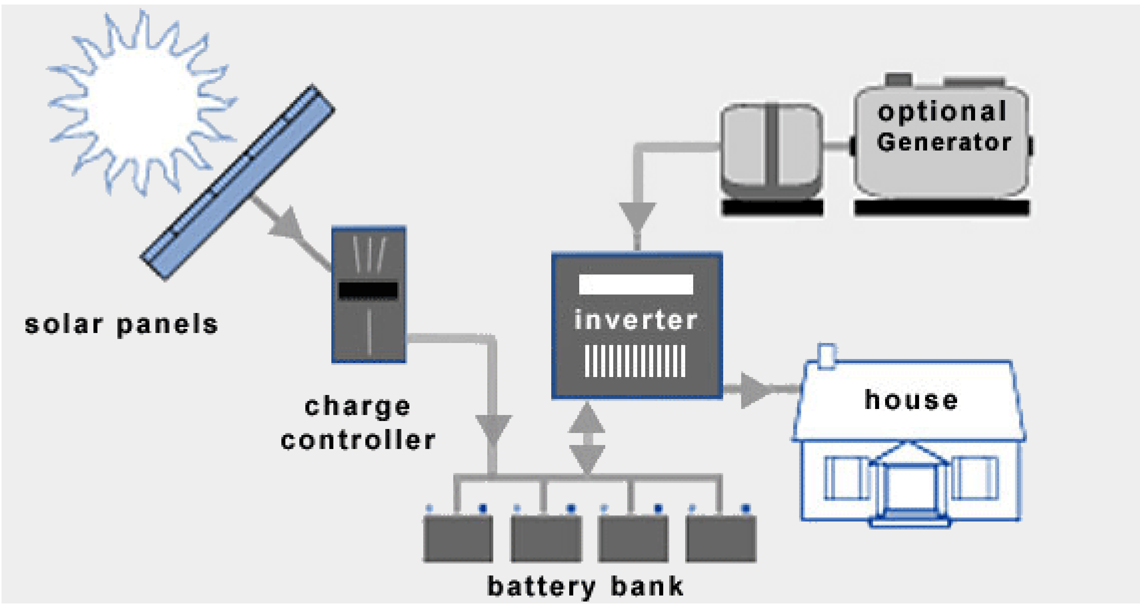


Figure3.2 :off-grid system[11]

a) Advantages of Off-Grid Systems:

- No access to the utility grid
  Off-grid solar systems can be cheaper than extending power lines in certain remote areas.

- Become energy self-sufficient
  Living off the grid and being self-sufficient feels good. For some people, this feeling is worth more than saving money. Energy self-sufficiency is also a form of security. Power failures on the utility grid do not affect off-grid solar systems.
  On the flip side, batteries can only store a certain amount of energy, and during cloudy times, being connected to the grid is actually where the security is. You should install a backup generator to be prepared for these kinds of situations. [11]

b) Equipment for Grid-Tied Solar Systems:

Typical off-grid solar systems require the following extra components:

- Solar Charge Controller. - Battery Bank. - Off-Grid Inverter.

3.2.3 Hybrid Solar Systems.

Hybrid solar systems combines the best from grid-tied and off-grid solar systems. These systems can either be described as off-grid solar with utility backup power, or grid-tied solar with extra battery storage. Figure 3.3 below describe Hybrid solar systems. [11]

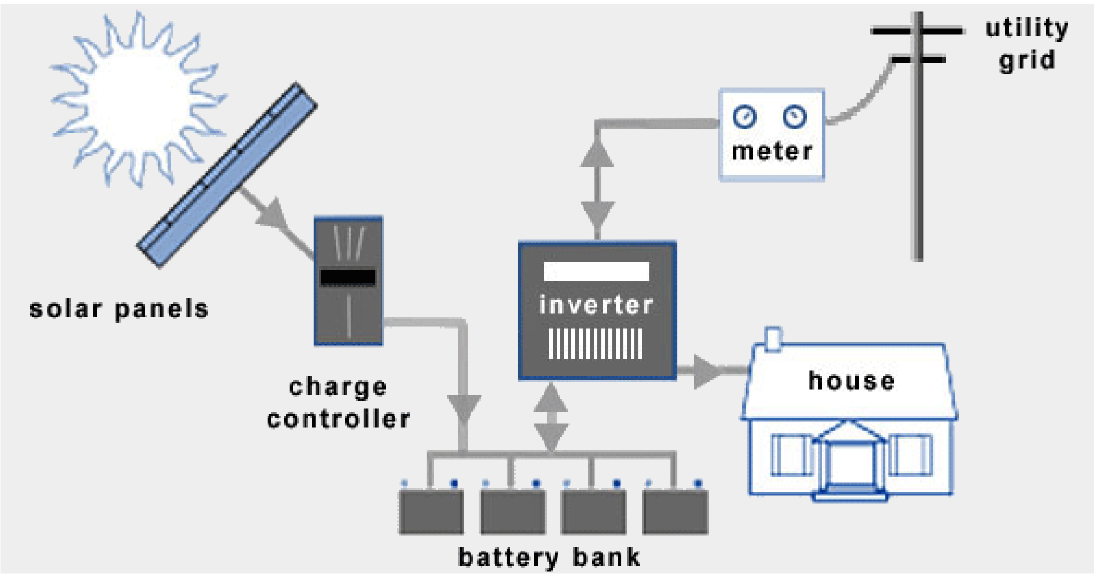


Figure 3.3: Hybrid solar systems. [11]

a) Advantages of Hybrid Solar Systems:

- Less expensive than off-gird solar systems:
  Hybrid solar systems are less expensive than off-grid solar systems. You don't really need a backup generator, and the capacity of your battery bank can be downsized. Off-peak electricity from the utility company is cheaper than diesel. [11]

- Smart solar holds a lot of promise
  The introduction of hybrid solar systems has opened up for many interesting innovations. New inverters let owners take advantage of changes in the utility electricity rates throughout the day.
  Solar panels happen to output the most electrical power at noon – not long before the price of electricity peaks. Your place can be programmed to consume power during off-peak hours (or from your solar panels).
  Consequently, you can temporarily store whatever excess electricity your solar panels in batteries, and put it on the utility grid when you are paid the most for every kWh. [11]

b) Equipment for Hybrid Solar Systems:

Typical hybrid solar systems are based on the following additional components:

- Charge Controller.
- Battery Bank.
- Battery-Based Grid-Tie Inverter.
- Power Meter.

- Battery-Based Grid-Tie Inverter

Hybrid solar systems utilize batter-based grid-tie inverters. These devices combine can draw electrical power to and from battery banks, as well as synchronize with the utility grid. [11]

3.2.4 Grid Systems Comparison.

To determine the grid system that will be connected to and advisable, a comparison must be made between these systems to find out the system that is suitable for the project.

1. Efficiency :

   - Grid tied system is an ON-grid system, this system is need simple calculations for sizing. These systems operate in parallel with the power grid so any fail in the PV system willnot affect the operation of electrical loads and any excess of energy is sent to the power grid.In this type of systems the power grid will work as a virtual battery.

   -Grid off system this system have downside because cannot be expected to provide power for all loads, the volume and cost of batteries and the sizing of this type of systems are more complex. The most benefit of this system there's no access to the power grid.Batteries are complicated, expensive and decrease overall system efficiency.

   - Hybrid solar systems run more efficiently than conventional generators that waste fuel under certain conditions. Hybrid solar systems operate efficiently in all types of conditions without wasting fuel. It depends on the grid in addition to batteries.

2. The Cost :

   - Grid tied system Its cost is not high because it does not need batteries or extra parts for the main parts to cause the high cost.

   - Grid off system(off-the-grid, standalone)To ensure access to electricity at all times, off-grid solar systems require battery storage and a backup generator (if you live off-the-grid). On top of this, a battery bank typically needs to be replaced after 10 years. Batteries are complicated, expensive.

- Hybrid Solar Systems:Less expensive than off-gird solar systemsBut it is more

expensive than theGrid tied system.

3- Maintenance: All systems need maintenance from time to time, but Grid off system and Hybrid Solar systems need focused maintenance and more complex because of the presence of batteries as they have a certain life.[11]

✓ Depends on the previous comparison and the goal of the project, the off Grid system well be excluded and the other two systems well be used , and here the cost plays its role, as the cost of batteries and their maintenance is very expensive , and to reduce this cost as much as possible, the on Grid will be the best choice.

3.3 PV-System

3.3.1 Photovoltaic power systems

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads ,the two principal classifications are grid-connected or utility-interactive systems and stand-alone systems, PV systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems.

Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid, the primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU), the PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized.

A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance, this allows the AC power produced by the PV system to either supply on-site electrical loads, or to backfeed the grid when the PV system output is greater than the on-site load demand, at night and during other periods when the electrical loads are greater than the PV system output, A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance, this allows the AC power produced by the PV system to either supply on-site electrical loads, or to backfeed the grid when the PV system output is greater than the on-site load demand, at night and during other periods when the electrical loads are greater than the PV system output, 4 the balance of power required by the loads is received from the electric utility This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for service or repair. [12]

3.3.2 Solar cells

When semiconductor materials are exposed to sunlight, electrons excite from the valence band to the conduction band creating charged particles called holes. By doping the silicon, i.e. adding tiny amounts of other materials like boron or phosphor to the crystalline structure, p- or n- type semiconductors are formed respectively. By bringing them together, a p-n junction serves for creating an electric field within the semiconductor, which is able to separate electrons and holes and which creates a direct current (DC) coming out from the solar cells through the contacts.

Sunlight impinges the solar cells. Some light is reflected at the surface and some light passes the solar cell unaffected. The rest is absorbed creating electron-hole pairs, which are separated by an electric field and brought to the contacts. Some electron hole pairs recombine before arriving at the contacts and heat the solar cell. Figure 3.4 illustrates this process.[13]

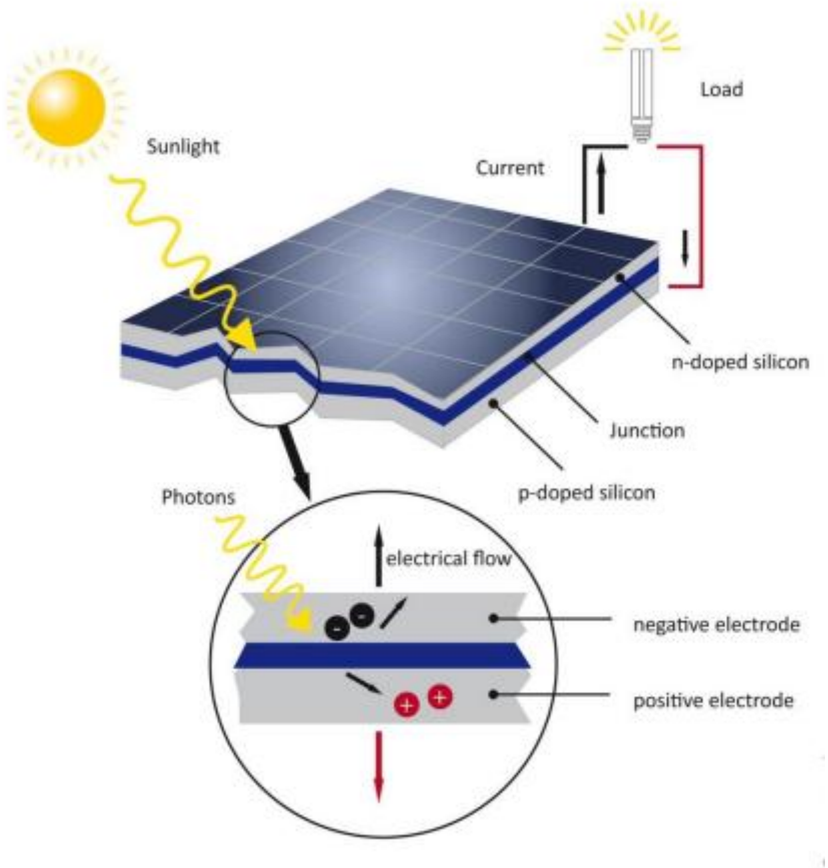


Figure 3.4: Crystalline solar cell working principle [13]

3.3.3 Solar Cell Types.

The PV market is clearly dominated by crystalline Si (cSi) based solar cells. Nearly 80% of the cells on the market are cSi based cells, either monocrystalline or multicrystalline. However, there are many other technologies available or being investigated.Figure 3.5 shows a schematic view of the different cell technologies available.

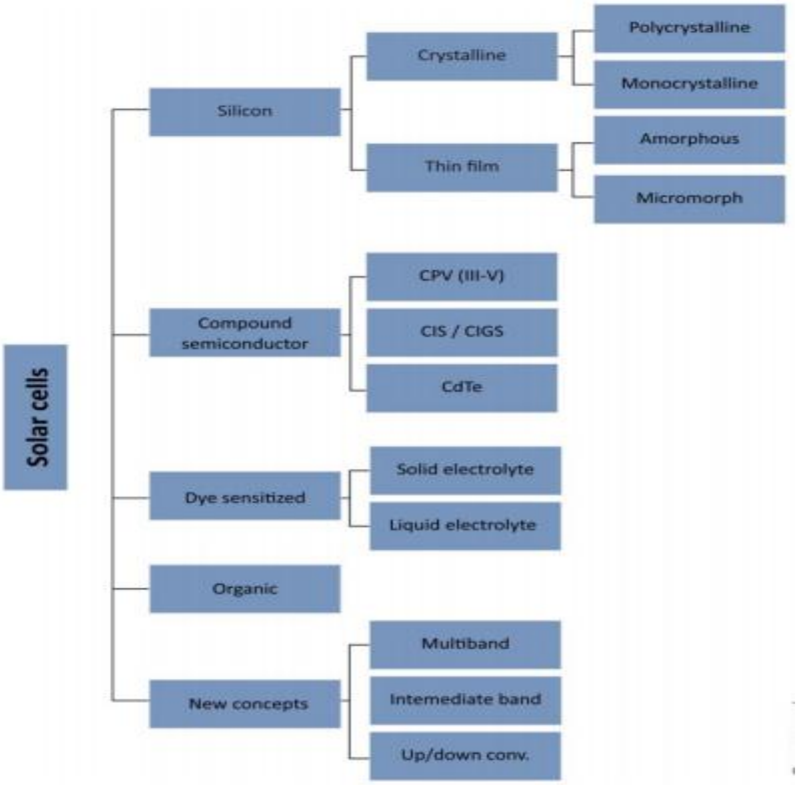


Figure 3.5: The Different Solar Cell Types [13]

Monocrystalline and polycrystalline cSi cells are wafer-based with thicknesses varying in the 150-250 μm range and sizes from 4 to 6. The wafers are gained from a silicon melt by different methods, condensed into blocks and then cut with a wire saw. Due to their high purity, a lot of energy is consumed during the manufacturing process and high temperature processes are necessary in order to remove defects. Monocrystalline solar cells are more efficient than polycrystalline cells. However, the manufacturing costs of polycrystalline cells are lower and thus their lower efficiency is compensated.

The electrical contacts on both front and back-sides are deposited by screen printing. Then metal strips connect the front side of a cell with the back side of the next cell in order to form a string of cells in series. Hence, a module consists of several strings of cells interconnected in series or parallel in order to obtain the desired current and voltage. Crystalline Si solar cells have a silicon nitride antireflection layer which gives them their characteristic blue color.[13]

3.3.4 Characteristics of Photovoltaic Module.

The I-V curve of a module strongly depends on the incoming irradiation. The output current of a solar cell directly relates to the incoming irradiation: The higher the irradiation, the more electron-hole pairs are produced and therefore the current increases. On the other hand, the voltage slightly varies with varying radiation.The performance of the solar cells varies with the temperature. As the cells get hot, current and voltage vary, hence diminishing the power output of the cell. For this reason, temperature coefficients of current, voltage, and output are given. With these parameters it is possible to simulate the real behavior of the module on the field.

The solar cells (and modules) are characterized by their electric characteristics. Solar cells behave similarly to diodes and therefore the electrical characteristics of a solar cell and a module are represented by using current-voltage curves (I-V curve). Figure 11 shows the I-V curve of a solar cell and gives the electrical behavior of different current-voltage ranges.[13]

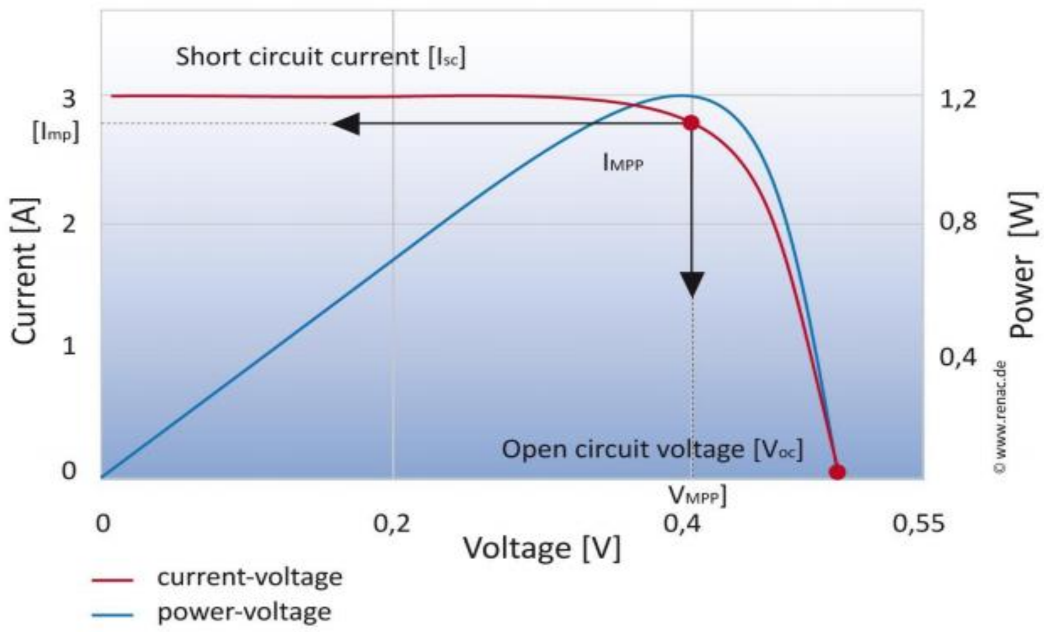


Figure 3.6: I-V and P-V Characteristics of Typical PV module.[13]

1- Isc represents the short circuit current, i.e. the value at which the current is at maximum and where the voltage is equal to zero.

2- Voc represents the open circuit voltage, i.e. the value at which voltage is at its maximum and where the current is equal to zero.

3- The green line represents the resulting power curve (power = current x voltage).

4- The maximum power point (MPP) is the current and voltage value at which the power output of the solar cell is at its maximum.

5- The maximum of the green line will give the current value of the MPP (Impp) and from here the voltage value of the MPP (Vmpp) can be found by using the I-V curve.[13]

3.3.5 PV - Inverter

The inverter is responsible for the conversion of DC into AC and for the regulation of voltage and frequency. There are mainly two types of inverters: Single- and three-phase inverters. Single-phase inverters deliver AC to one phase of a power transmission line, whereas three-phase inverters deliver AC to all three phases of a power transmission line. Small systems, typically below 5 kWp, commonly use single phase inverters because one line is enough to absorb the power delivered by a PV system. Larger systems commonly use three-phase inverters (the electricity deliveredby the PV system is split into three parts, each being delivered to one of the three phases), which give more freedom with regard to system sizing.

It is also possible to connect multiple single phase inverters to form a three-phase system. In this case, the power difference between phases shall not exceed 5 kW as defined by the grid utility. Because the maximum output power is wanted, the Maximum Power Point has to be known. However the MPP of the PV array is continuously changing due to changes in the irradiation, which is why inverters do need electronic power devices that are able to follow the changes in current and voltage. Inverters therefore commonly incorporate Maximum Power Point Trackers (MPPT) in order to guarantee that the inverter adjusts to the MPP. The response velocity to changes in the irradiation, accuracy, and efficiency of the MPPTs determines the efficiency of the inverter.[13]

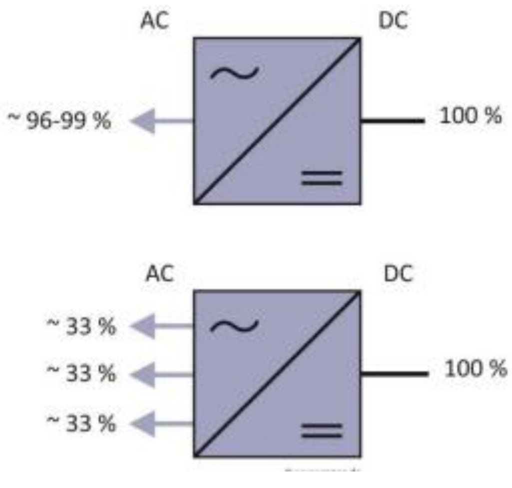


Figure 3.7: Principle Scheme of Single- and Three-Phase Inverters.[13]

Some inverters additionally incorporate transformers. They serve for matching the voltage of the grid and the galvanic separation in case of thin-film based systems. Transformers typically have an efficiency of 90-95 % and furthermore they cause additional costs. Therefore, inverters without transformers are being intensively studied and some companies do offer already transformer less inverters with the same features as inverters which incorporate transformers. However, grid utilities in some countries still do not accept transformer less inverters.

The efficiency of an inverter is defined as follows:

$$\eta = \frac{P\ out\ AC}{P\ IN\ DC} \quad \text{...} 3.1$$

Equation 3.1 comprises the losses caused by the transformer (if available), MPPT, and all other losses caused by current conversion.

Inverters can also be categorized depending on their working principle. The grid-controlled inverters use the grid voltage for determining the switch-on and -off pulses for the internal electronic devices. As a consequence of this technique, the quality of the out coming frequency signal is low and does not present a complete sinusoidal shape. By incorporating power electronics, the quality of the signal can be improved. Self-commutated inverters do have a more complex internal structure that allows for a better sinusoidal signal formation. They are commonly used for stand-alone systems, but also for grid-connected systems.

Regarding system sizing, there are many parameters that have to be taken into account. The nominal power, the MPPT range, the maximum input voltage, the maximum DC current are parameters that are commonly used for system design. Furthermore, one has to bear in mind that the thin-film based modules require transformers in order to separate the modules from the grid galvanically.

The inverters can be classified according to their connection to the modules. There are mainly three different types of inverters: Module inverters, string inverters, and central inverters. Each connection concept presents advantages and disadvantages. The selection of one of these concepts depends on many parameters and it has to be optimized during sizing. Figure 3.7 introduces schematically the different inverter configurations.

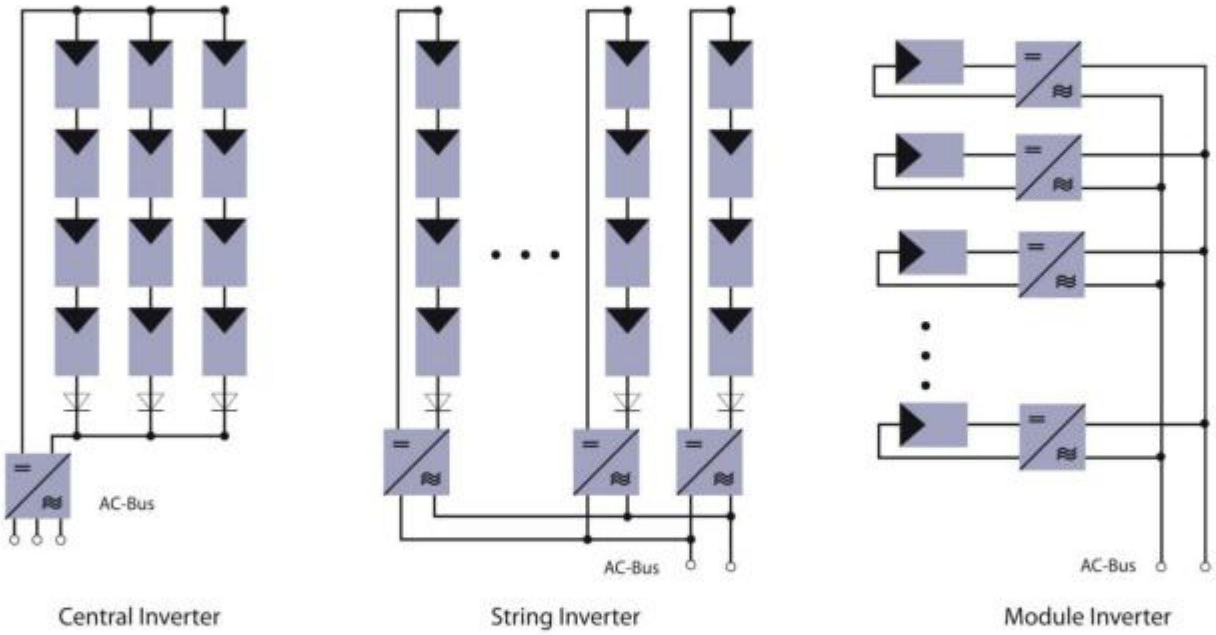


Figure 3.8: Different inverter configurations.[13]

1- Module inverters are small inverters located at the back side of the modules. The advantage of module inverters consists in quickly transforming the current from DC to AC, hence avoiding DC cables and losses. Since there is only one PV module per inverter, the MPPT works very accurately. However, nowadays the installation costs are much higher than for external inverters.

2- String inverters are commonly used in small and medium sized installations, like household or small ground mounted installations. Since they are easy to install, many installers prefer to install them also for large field installations. Central inverters manage a few module strings and typically have one MPPT. String inverters are prepared for both indoor and outdoor installation. Their size varies depending on the rated power but they are usually smaller than 50 x 50 x 30 cm. Generally, string inverters are rated from less than 1 kWp up to 12-20 kWp. The advantage of this concept consists in their close location to the PV array so that the DC wiring is reduced, hence reducing losses and wiring costs. Additionally, in case of failure, the system continuesworking and only a small part of the system does not work. This effect does not happen with central inverters, where the entire system is stopped if an inverter failure occurs.

3- Central inverters connect many module strings. They usually have more than one MPPT in order to optimize the power output of each string and always convert directly into a three-phase system. The rated power of a central inverter varies from 25-50 kWp up to 2.5-5 MWp.

3.3.6 Power Losses of PV

Due to low energy yield of the PV systems, it is essential to transmit the produced energy to the consumers with minimum losses as possible. Therefore, it necessary to minimize these losses by eliminating the factors that cause the losses occurred in PV systems, factors that may cause losses in PV systems are environmental factors such as shade, dust, snow, rain, temperature and such losses due to system components such as cables, inverters and batteries. PV systems should be installed taking into account the losses and the produced energy should be consumed in local areas where it was produced as much as possible. Figure 3.8 shows some losses occurred in a PV system. The power loss can vary between 10% to 70% depending on different reasons which effect the PV system performance .About 25% of the produced energy by the PV system is lost due to some system losses as shown in the a Figure 3.8.[14]

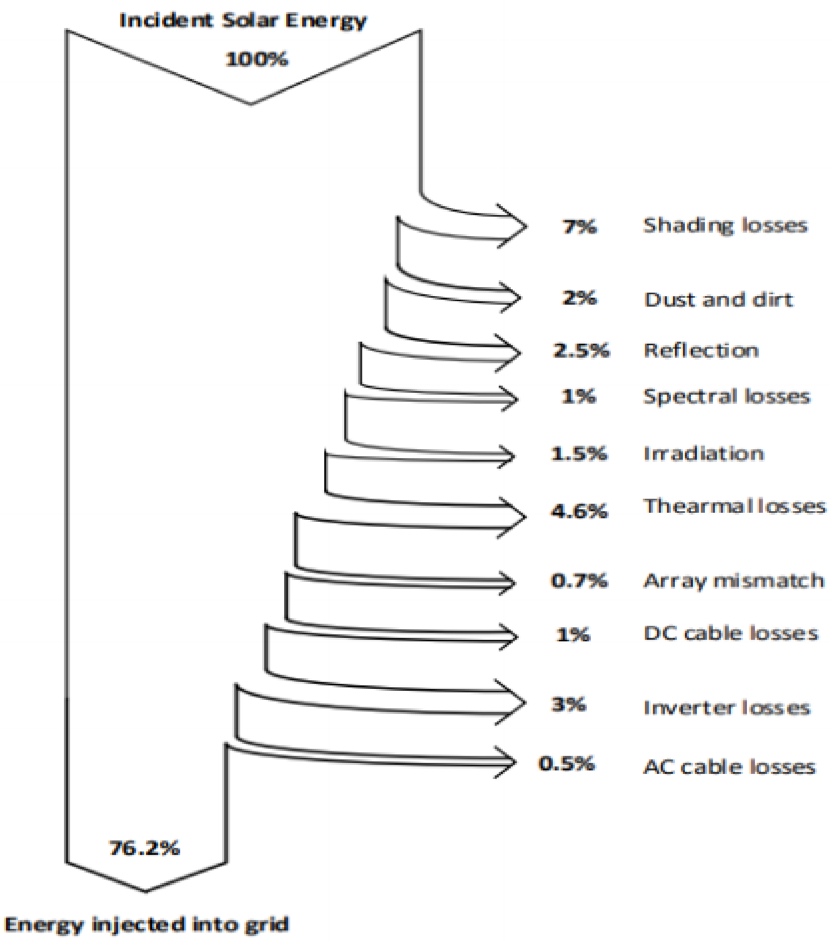


Figure 3.9: PV System Losses[14]

- **Shading Losses**: Shadowing of PV modules must be avoided if possible. It is often underestimated and leads to strong decrease in the output yield of the PV array. If a solar cell within a module is shaded, it will generate less current than neighboring solar cells. The solar cell becomes reverse biased, receives current from other solar cells, and dissipates power in form of heat. If the module does not have bypass diodes mounted, this effect might lead to irreversible damages of the solar cell and module.

  There are several types of shading. They are listed here:

  1. Direct shadowing: This particular case of shadowing causes strong losses in the output yield of the PV system. In this case, a shadowing object is placed close to modules and shades the PV array constantly. The closer the shadowing object is to the array, the darker the shadow is and the less diffuse light reaches the module surface, the more problematic the situation gets.

  2. Temporary shadowing: This is caused by natural conditions, like snow, leaves, soiling, etc. This effect is especially important in ground mounted systems in rural areas, where the PV arrays come much easier in contact with dust. The tilt angle of the array shall exceed 10° in order to allow self-cleaning and water evacuation after raining. In snowy regions, the lower part of the module is commonly covered a long period of time. Therefore, a horizontal arrangement of the modules is recommendable in order to minimize losses. In this case, the snow will cover only one string of the modules and the bypass diodes will avoid high shadowing losses.

  3. Self-shading: A bad system design might cause shading on modules caused by other modules that have been placed ahead. As a rule of thumb, the modules located in a row must be separated from each other approximately 4-6 times the height of the tilted module. Generally that depends strongly on the latitude where the system is installed. It has to be calculated for each project separately .Under these conditions, mutual shading is avoided. Figure 3.9 shows schematically the minimum separation between module rows.

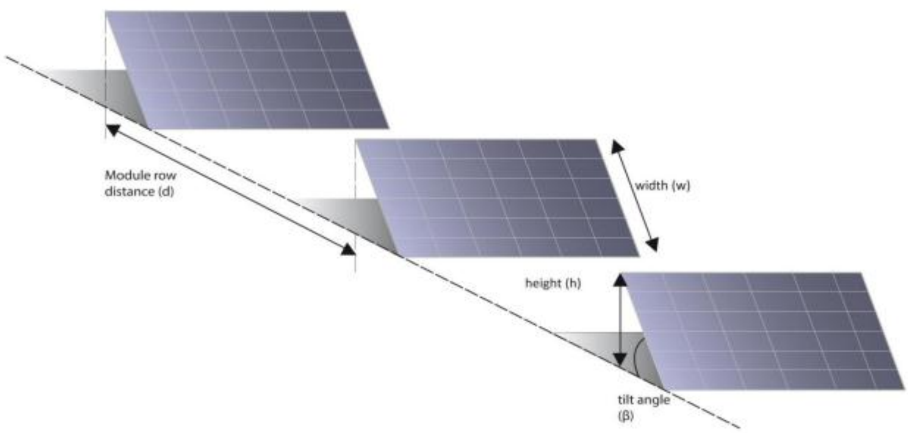


Figure 3.10: Separation between module rows in order to avoid mutual shading [13]

For PV arrays consisting of multiple rows of PV modules and array structure, the shading derate factor should be changed to account for losses occurring when one row shades an adjacent row. Spacing between rows is a compromise between optimizing the use of space and self-shading losses. The plant designer decides what will be the separation between module rows. An expression that can be used is the following:

d= L . $[\frac{\sin(\beta-\gamma)}{\tan(\alpha+\gamma)} + \cos(\beta - \gamma)]$ 3.2

Being d the separation between module rows (in m), L the height of the PV-array (in m), β the ground inclination (º) and α the solar elevation (º) at the worstγmodule inclination (in º), irradiation day. The obtained separation d between module rows guarantees that at noon on the worst irradiation day, that is to say, the day where the sun at noon has the lowest elevation, there will not be any self-shading between rows. Furthermore the quotient L/D is equivalent to the Ground Cover Ratio (GCR), defined as the ratio of the PV array area to the total ground area. This metric can be used to predict yields per land-area. Ground coverage ratio values depend on the geographical location, type of system (fixed, 1-axis or 2-axis tracking) and the shading derate factor. They vary typically between 60% and 20% percent (for solar plants with 2-axis tracking systems).

- **<u>Temperature losses</u>**

Temperature affects negatively the performance of PV modules. To determine the variation of P_{mpp} at different temperatures the following expression issued

P_{mpp} (T) = P_{mpp} (STC)* (1+ΔT x T_k) 3.3

being P_{mpp} (STC) the rated power of the module at Standard Test Conditions (STC, 25°C ambient temperature and radiation on the module 1000W/m2), P_{mpp} (T) the module power at another conditions and T_k the corresponding temperature coefficient. The temperature T which must be plugged into the expression is not the ambient temperature, but the module temperature. The temperature of the module cells can be estimated by using the expression:

T_{cell} = T_{amb}+ (NOCT-20)*G/800..3.4

where NOCT is the Nominal Operating Cell Temperature expressed in °C (usually given by the module manufacturer in the module data sheets and G the irradiance in W/m2 . If NOCT is not given, 48°C is recommended as a reasonable value which describes well most of the commonly used PV modules.

3.4 Solar Radiation.

Solar Radiationduring a day/month/year The position of the sun in relation to one's position is given by the zenith angle (γ_s) and the azimuth (α_s). The zenith angle is the angle between the local vertical and the line that connects the observer with the sun. The sun´s azimuth is the deviation of the sun´s position with respect to the south. The azimuth of the PV module with respect to the south is noted as (α) and the inclination is defined as (β).

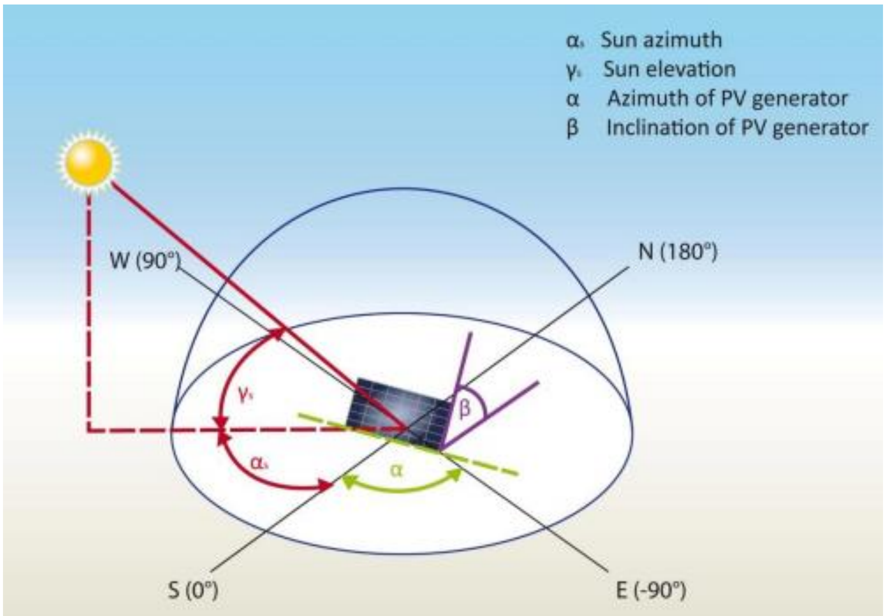


Figure 3.11 : Angle explanation

The zenith and the azimuth depend on the local time of the day (t), the day of the year (d), and the latitude of the observer (λ). The hour angle (h) is given in degrees and defined as follows:

$h = \frac{360}{24}$ (t - 12)..3.5

Each day is defined by the declination angle (δ), which represents the latitude of the sun. The declination angle is given in degrees and defined as follows:

$\delta = 23.44 \cdot \sin[360 \cdot (\frac{d-80}{365.25})]$..3.6

The zenith and the azimuth angles are given by the following equations:

$\cos \gamma_s = \sin\delta \cdot \sin\lambda + \cos\delta \cdot \cos\lambda \cdot \cos(h)$ 3.7

$\tan \alpha_s = \frac{\sin(h)}{\sin\lambda \cos(h) - \cos\lambda \tan\delta}$ 3.8

3.4.1 Orientation of Modules and its Influence on the Output .

The orientation and inclination of the PV modules determine the amount of irradiation that the surface receives to a very great extent. They influence the amount of energy finally produced and it is obviously very important to take them into account. If the modules are not mounted on a tracking system that follows the position of the sun in order to get a high radiation income, the modules must be oriented facing south in the northern hemisphere and facing north in the southern hemisphere. This guarantees the maximum irradiation level for an array throughout the year. In regions close to the equator, the orientation is not important but a minimum of 10º inclination is necessary in order to evacuate water in case of rain. Figure 5: Different orientations and inclinations and the amount of solar radiation received on each surface in comparison to an optimum of 30° and facing south

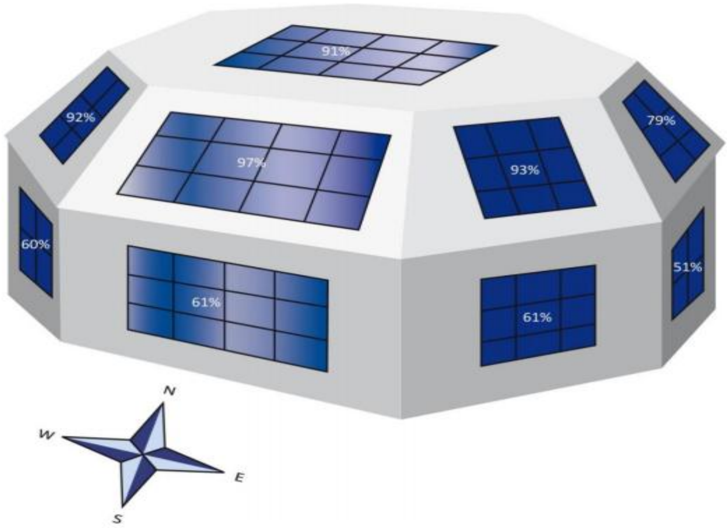


Figure 3.12 : Different Orientations and Inclinations and the Amount of Solar Radiation

3.4.2 Solar Radiation in Palestine

Palestine is among the countries in the so-called solar belt (the area confined between latitudes 40 degrees north and 40 degrees south) in more than 300 sunny days a year with average daily brightness of about 6 hours, increasing in summer and less in winter, as the average solar radiation per day Up to 5.4 kilowatts per square meter, which is equivalent to an annual production of 1950 kilowatt hours of energy, which enabled Palestine to be one of the best areas to exploit solar energy, and the possibility of investment economically feasible [15]

3.5 Solar System Calculations:

1- AC Power

$P_{ac=}\frac{E}{G*365}=\frac{KWh/year}{G*365}=$ 3.9

2- DC Power

$P_{dc(STC)}=\frac{P_{ac}}{efficency}=$ 3.10

3- Area

$A=\frac{p_{dc(sTc)}}{\left(\frac{1kw}{m2}\right)*\text{efficincy pv}}=$ 3.11

The amount of solar energy depends on its capacity and size In the solar system.

4- Number of Panels

Number of panels$=\frac{\text{capacity of project}}{\text{capacity of module}}$ = ...3.12

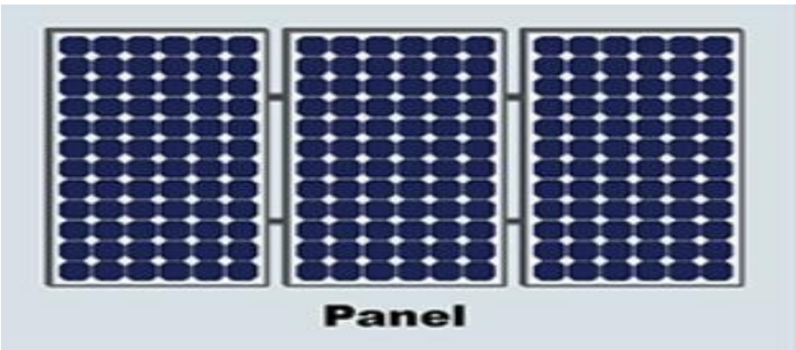


Figure 3.13 : Photovoltaic Panels

The total energy consumed during a year is calculated by knowing the consumption during the year divided by the kilowatt hour price.
the price of 1kwh in palestine=0.2$

5- Total energy consumed during a year

Total energy consumed during a year $=\frac{\text{Consumption within a year}}{\text{the price of 1kwh}} = \frac{C}{\$}$................................3.13

The capacity of solar PV projects the energy during a year divided by the production capacity, which equals (1500 to 1700) kilowatt hours per year.

6- The capacity of solar PV project

The capacity of solar PV project$=\frac{\text{Energy during a year kwh}}{\text{1700 peak shine hours}} = \frac{E}{1700}$..3.14

Calculate the size of the solar cells and count the number of panels

7-The size of the solar system in kilowatts

$P_{PV}=\frac{EL}{\eta V \quad \eta R \quad PSH}$ Sf 3.15

P_{PV}: The size of the solar system in kilowatts.

E_L: Energy consumed per day in kilowatt hours.

S_f: Lost substitution factor .

η_V: Transformer efficiency.

η_R: Regulator efficiency.

PSH: The number of hours of radiation per day.

To obtain a large voltage and electric current, one group of cells is connected in series to increase the voltage, and then another group is connected in parallel with the previous group to increase the current. By repeating this process for a large group of solar cells, we can obtain the appropriate voltage and current.

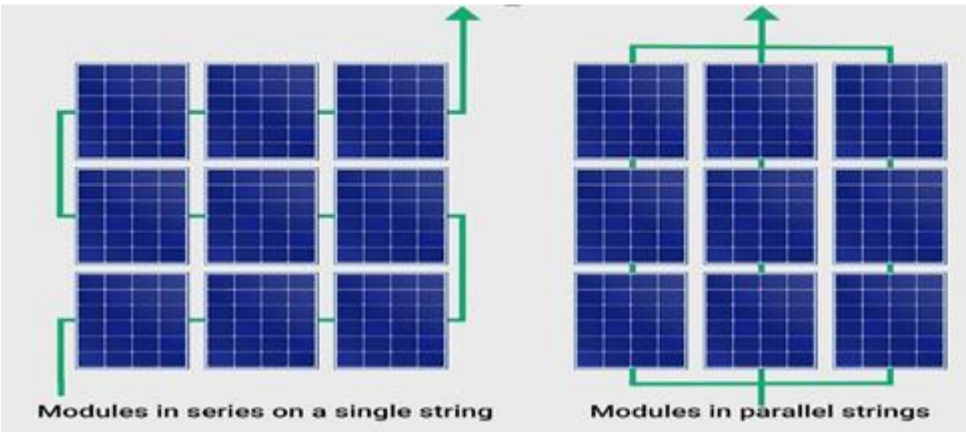


Figure 3.14: Modules in series and parallel

8- Number of panels in a series

Number of panels in a row=$\frac{\text{Inverter voltage}}{\text{Cell voltage}}$ = ...3.16

9-Number of panels in parallel

Number of panels in parallel=$\frac{\text{total number of panels}}{\text{Number of panel in a row}}$ = ...3.17

*$\tan\theta=\frac{h}{y}$

The Separation Distance between The Rows of Solar Panels.

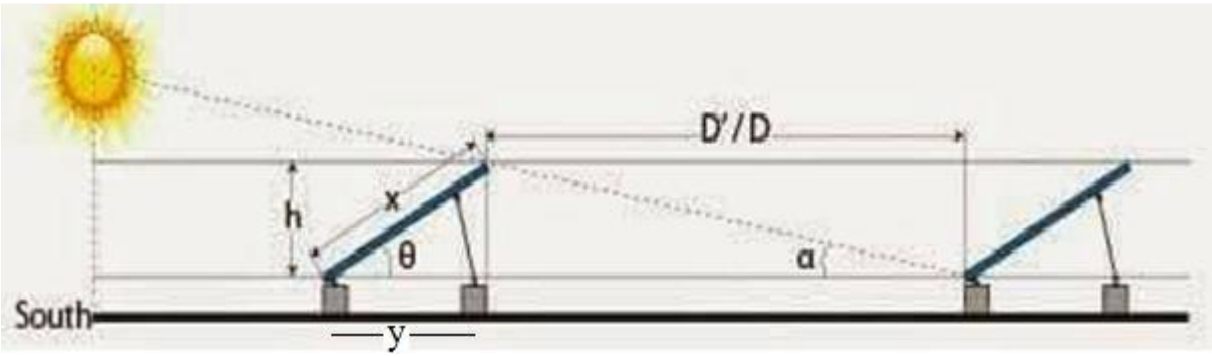


Figure 3.15 : The Separation Distance between The Rows of Solar Panels

10- Solar panel height

$h = x * \sin(\theta)$..3.18

h: Solar panel height
x: Solar panel length
θ:The angle of inclination is approximately 27 degrees

11- Oblique shadow distance.

$D' = \frac{h}{\tan\alpha}$ = ...3.19

D' :Oblique shadow distance.
α:minimum solar altitude angle.

12- $D = D' * \cos(180 - \Psi)$ 3.20

Ψ:suns azimuth angle.

The following equation can be used to make approximate calculations:

$D = a.[\sin\beta \cdot \tan(23.5 + Lat) + \cos\beta]$ 3.21

a : Module length.
β :Module angle.
Lat : Latitude in the workplace and in our country is 32 degrees.

How to make the project Design ?

1-Finding the total consumption of the place, or depending on the space of the place where the solar system is to be built, and thus choosing the most appropriate solution to work on it.

2- Choose Solar Panels:

We choose the type of solar panels, its size in watts, and the number of panels needed, Based on the quality of the solar panels, the materials used in the manufacture of the panels, their energy efficiency and the temperature coefficient are taken into consideration.

3- Choose Inverter:

We choose an inverter based on its capacity and energy efficiency, which determine the quality of the inverter in converting DC to AC.

4- Choose Fuses , CBs:

Electrical protection devices are divided into: MCB , MCCB , FUSES , ELCB , ACB .

- MCB (MINIATURE CIRCUIT BREAKER):

They are used in low voltage circuits with rated current from 10 to 125 ampere

- MCCB (MOLDED CASE CIRCUIT BREAKER):

Bigger in size,Take hold of the installation,It is used in the main feeding circuits
The rated current has a higher range of 16A to 1600A .

- FUSES:

The highest permissible value for electric current to pass through the fuse without burning or cutting the fuse wire, and this value called breaking capacity ranges between 50 and 400 amperes or more depending on the type of turquoise and its uses.

- ELCB(EARTH LEAKAGE CIRCUIT BREAKER):

This circuit breaker is used to cut off the electrical current in the event of a small electrical current leakage into the ground

.

- ACB (AIR CIRCUIT BREAKER):

is an electrical device used to provide Overcurrent and short-circuit protection for electric circuits over 800 Amps to 10K Amps. These are usually used in low voltage applications below 450V.

10- Choose CB

I CB≥ 1.25*IL 3.18

Safety Factor 25%.

Fuse current:

Fuse currnt ≥ KT Ks Is.c 3.19

KT =safety factor to reflect temp & irradiation.

Ks = short circuit safety coefficient to avoid immediately interruption

5- Choose the suitable DC & AC cable:

rated voltage of the DC cable=1.5 phase voltage of the AC cable.

Voltage drop in cables=0.02*Voltage at the ends of a group of cells.

6- Choose the right meter, is it single phase, three phase:

Single phase ,and the amount of 220 volts.
Three-phase and the amount is 380_400 volts.

Chapter 4

Steel Structure

4.1 Introduction :

Structural steel is one of the materials which used for any kind steel construction, it is formed with a specific shape. These steel materials are of certain standards of chemical composition and proper strength. The steel materials are also defined as hot rolled products, having cross sections like angles, channels and beam. All across the world, there is an increasing demand for steel structures.

There is a big advantage of steel over the concrete in terms of its ability to bear better tension as well as the compression which resulted in lighter construction. The steel authority of particular country takes care of the availability of structural steel for construction projects.

There are various structures which come under the edges of steel structures. These structures may be used for the industrial, residential, office and commercial purposes. The purpose of bridge is for roadways and railway lines. The structures like towers are used for different purposes such as power transmission, nodal towers for mobile network, radar, telephone relay towers, etc.[16]

Common shapes include the I-beam, HSS, Channels, Angles and Plate(pv panel).[17]

Figure 4.1 : shapes

Main structural types

- Frame structures: Beams and columns.
- Grids structures: latticed structure or dome.
- Prestressed structures.
- Truss structures: Bar or truss members , Truss bridge: truss members.
- Arch structure.
- Arch bridge.
- Beam bridge , Suspension bridge .
- Cable-stayed bridge.

4.2 Effects on the Steel Structure:

A structure must be designed and constructed so as to safely resist the applied load. The applied load consists of dead loads, live loads, and environmental loads. Dead load includes the self-weight of the structure and permanent fittings and equipment. Live load includes the weight of the structure's occupants and contents. Environmental loads include the effects of snow, wind, earthquake, rain, and flood. Additional loads may also be imposed by the self-straining forces caused by temperature changes, shrinkage, or settlement.[18]

"Dead loads" comprise the weight of the structure itself as well as things like mechanical equipment, ceiling and floor finishes, cladding, facades, and parapets. The dead load is essentially the amount of consistent weight that a building must support at all times.

Calculation or Determination of dead loads on a structure:Dead loads are calculated by estimating the quantity of each material and then multiplying it with the unit weight of that specific material.[19]

"Live Loads "Refers to loads that do, or can, change over time, such as people walking around a building (occupancy) or movable objects such as furniture. Live loads are variable as they depend on usage and capacity. However, design codes can provide equivalent loads for various structures.[20]

Calculation or Determination of dead loads on a structure :Live loads are considered and added to the total load acting on a member at the time of designing of the building.

As the dead load is individually calculated to each and every member of the building whereas for live load it is calculated on the basis of expected sudden loads on the building in future. Suppose the structure is made for cinema halls or stadiums there might be an overcrowd during releases and matches.[19]

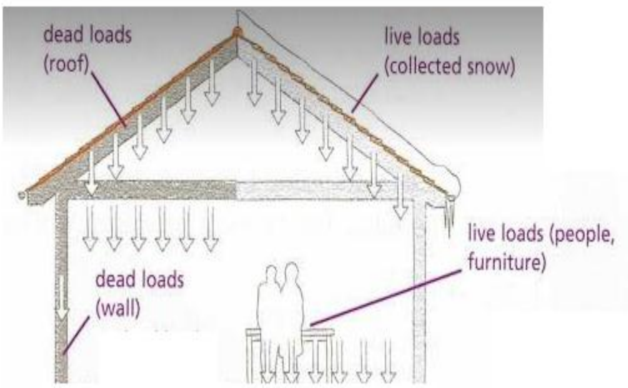


Figure 4.2: live & dead loads

1- Wind Loads : When wind strikes an enclosed building the wind flows around the sides and over the roof and either a pressure or a suction is produced on the external surfaces of the building. As shown in Figure 3, the windward wall that is perpendicular to the wind direction experiences an inward, positive pressure. As wind flows round the corners of the windward wall, the turbulence produced separates the air flow from the walls and causes an outward, negative pressure or suction on the side walls and the leeward wall. As wind flows over a high-sloping gable roof, a positive pressure is produced on the windward side of the ridge and suction on the leeward side of the ridge.

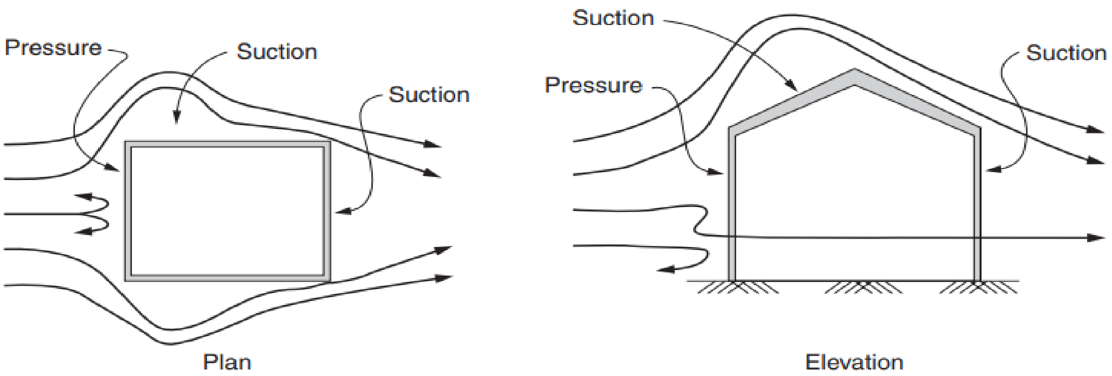


Figure 4.3: Wind pressure.[17]

2- Snow loads:

This type of loads is considered only on the structure which receives snowfall during monsoon. Snow loads are calculated by the projections made by snow at different parts of the structure, The amount of snow load depends on the height of building, size & shape of the roof, the location of building whether it's on the slope or not, the frequency of snow etc.[18]

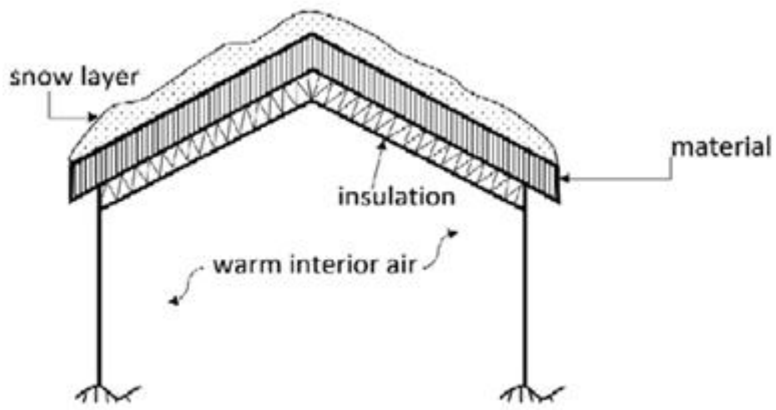


Figure4. 4: Snow load

3- Earthquake loads:

These type of loads causes movement of the foundation of structures. Earthquake forces are internal forces that developed on the structure because of ground movements.

Three mutually perpendicular forces act on the structure during an earthquake, two horizontal forces which act in opposite direction and one vertical force due to the weight of the structure. As vertical force doesn't affect much during earthquake whereas two opposite horizontal forces results in movement of the building during an earthquake. These two horizontal direction forces are considered in the design.

Due to inertia, additional forces on the structure develop on the superstructure. The impact of an earthquake on structure depends on the stiffness of structure, soil media, location and height of the structure. Accordingly, the earth has been divided into several zones depending on the magnitude of an earthquake.[19]

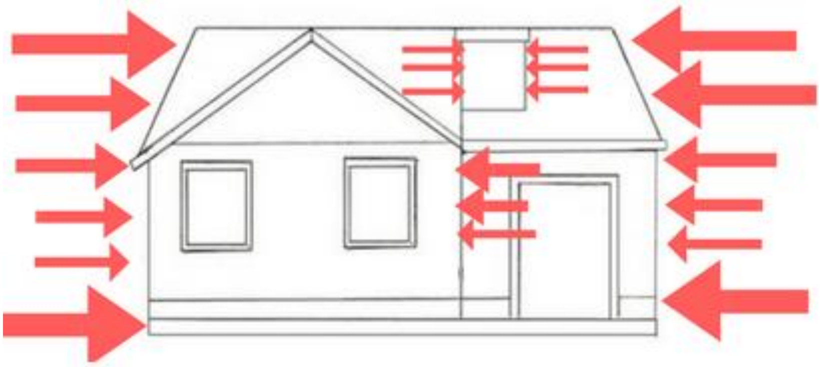


Figure 4.5 : Earthquake loads

In order to compute the seismic forces acting on a structure is deduced by computing one of the below-mentioned methods.

1. Response spectrum method

2. Seismic coefficient method.

4- Rain Load:

Each portion of a roof shall be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow.[21]

4.3 Steel Structure Calculation

1- Calculation or Determination of <u>wind loads</u> on a structure:
Wind loads are considered in design if the height of the building is more than 15m. The intensity of wind load depends upon the velocity of wind, size, and height of the building.

To calculate the design wind pressure or a total load of wind on a building the following expression is used

$P_z = 0.6\ V_z^2$ 4.1

Where Pz Is in N/m2 at height Z and Vz is in m/sec.

Up to the height of 30m, the wind pressure is considered to act uniformly. Above 30m the wind pressure may increases.

In order to calculate the V_z the following expression is used

$V_z = k_1\ k_2\ k_3\ V_b$ 4.2

Where

k1 = Risk coefficient.

k2 = Coefficient based on terrain, height and structure size.

k3 = Topography factor.[17]

2- Calculation or Determination of <u>Snow loads</u> on a structure:
The minimum snow load on any area above ground or roof area which is subjected to snow accumulation is obtained by the expression

$S= \mu S_0$ 4.3

Where

S = Design snow load

μ = Shape coefficient

S_0 = Ground snow load

3- Calculation or Determination of Rain loads on a structure:

The rain load on the roof, in lb/ft2 , is given by

$R = 5.2(d_s + d_h)$ 4.5

Where

d_s = depth of water up to the inlet of the overflow drain when the primary system is blocked in inches .

d_h = additional depth of water, or hydraulic head, above the inlet of the overflow drain at its design flow, in inches.

5.2 = lb/ft2 per inch of water. [18]

- In addition to manual calculations, many programs can be used to calculate steel structures like : Sap , Etab , Robot and Cad.

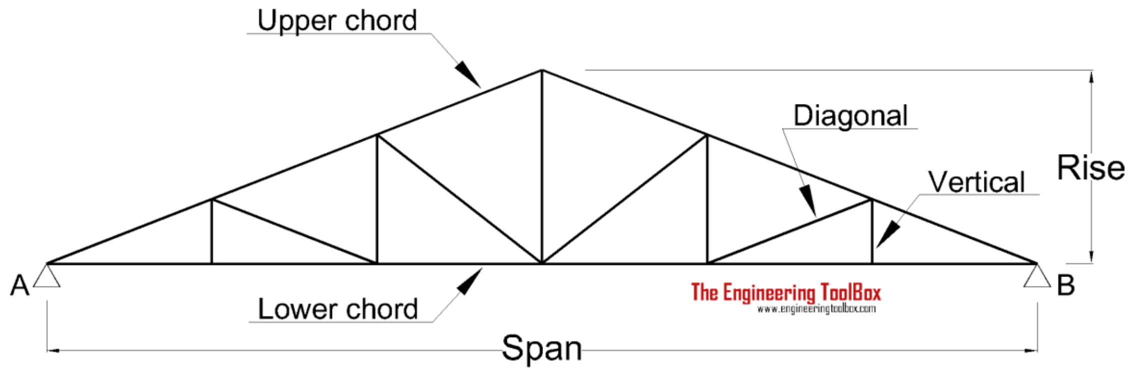
Enterprise Resource Planning (SAP) system, is the ERP software developed by the German company.

ETAP is considered one of the most important programs for studying and analyzing the transient or dynamic performance of electrical power systems under different operating conditions under the Microsoft Windows operating system and providing the highest level of performance for analyzing large networks that require intensive accounts with on-line monitoring of control applications on these networks.

A robot program, which is a well-known structural analysis program, which analyzes concrete or metal structures, obtaining results and presenting them in a simple form, and one of its advantages is the possibility of choosing the design code, ease of handling and accuracy of results.

CAD software was introduced for the steel detailers to design buildings or structures in a 2D format that helped them make projects more accessible, faster and cost-effective with output that was not achieved before. Manual drafting methods were time-consuming and incurred a cost in the rework of structures if not found precise and well-detailed.

❖ Double Howe Truss



$\sum$ MA = 0..4.6

$\sum$Fy = 0+..4.7

Chapter 5

Data of Case Study

5.1 The Geographical Location of The Stadium.

Dura International Stadium is an association football stadium, in the city of Dura in the Hebron Governorate district of the West Bank.

Figure 5.1 : The geographical location for the stadium.[22]

5.2 About Stadium.

Dura stadium is one of the most important sports facilities on the national level in terms of size and design. Its capacity is 18,000, and the surface is artificial turf. The cost of the renovations is over 7 million USD. The International Dura Stadium was inaugurated on June 12, 2011 in an international meeting that brought together Italian and Palestinian Olympic athletes. In November 2019 the world's largest keffiyeh, measuring 3,000 square meters [23]

5.2.1 Description of Dura stadium.

Country: Palestine
City: Dura - Palestine
Sports: Soccer
Status: Active
VIP seats: 200
Public seats: 18,000
Year built: 2011
Lighting level: 1000 lux
Surface type: Artifical
Width: 60 M
Length: 90 M[24]
Stadium photo: As figure 5.2

Figure 5.2 : Dura Stadium.

5.3 Dura Stadium consumption.

The stadium consumes a large amount of power monthly and annually, and the following tables are the amount of consumption during 2013 to 2020 according to the Electricity Station.

- **The amount power the stadium consumed (2013-2020).**

  During the period from 2013 to 2020, the method of calculating the stadium consumption differed from the previous one, as the device used to measure energy consumption became programmed with a factor of 120. [25]

Table 5.1: Consumption (KWh) for Dura stadium at 2020. [25]

Number #	Date	Month	Consumption (KWh)
1	20/1/2020	January	474
2	20/2/2020	February	474
3	29/3/2020	March	1194
4	20/4/2020	April	1194
5	20/5/2020	May	1445
6	20/6/2020	June	9
7	20/7/2020	July	200
8	20/8/2020	August	1964
9	20/9/2020	September	2958
10	20/10/2020	October	6674
11	20/11/2020	November	7412
12	20/12/2020	December	1074

- The highest monthly consumption rate was 7412KWh

- Amount of annual consumption for 2020 was25072KWh/year

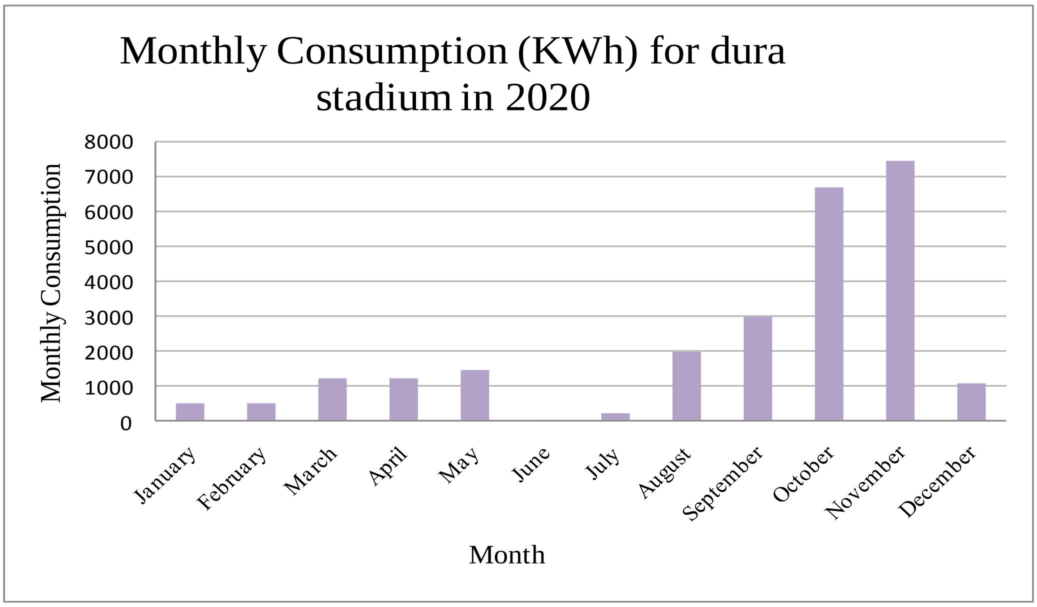


Figure 5.3 : Monthly Consumption in 2020.

Table 5.2 : Consumption (KWh) for Dura stadium in 2019.[25]

Number #	Date	Month	Consumption (KWh)
1	20/1/2019	January	2729
2	20/2/2019	February	3128
3	20/3/2019	March	4030
4	20/4/2019	April	650
5	20/5/2019	May	1044
6	20/6/2019	June	681
7	20/7/2019	July	2417
8	20/8/2019	August	4137
9	20/9/2019	September	1677
10	20/10/2019	October	6470
11	20/11/2019	November	5000
12	20/12/2019	December	2009

- The highest monthly consumption rate was 6470 KWh

- Amount of annual consumption for 2019was33972KWh/year

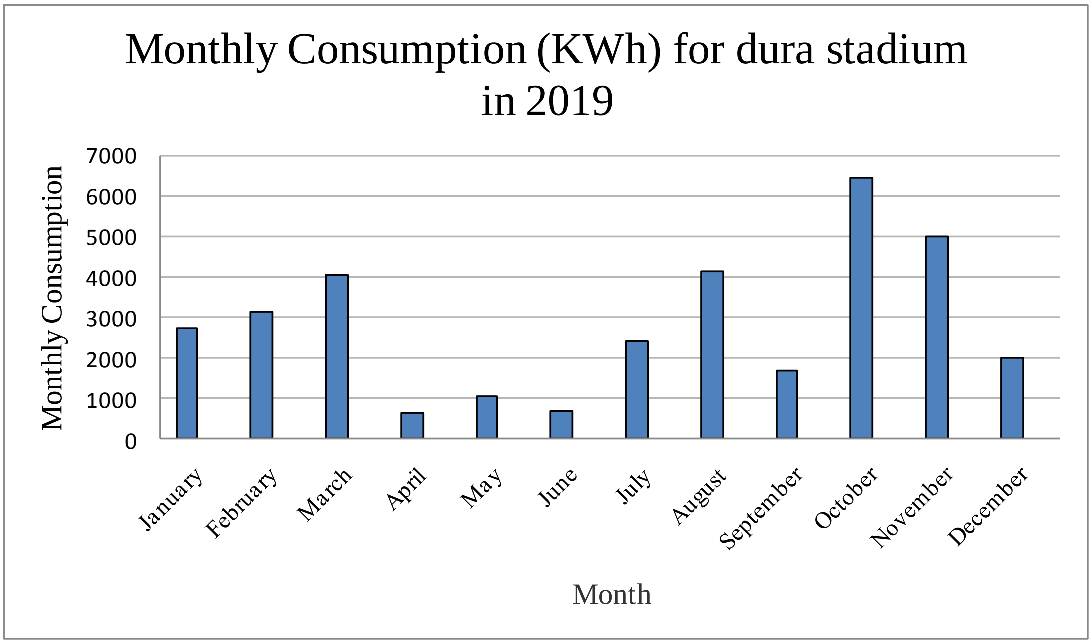


Figure 5.4 : Monthly Consumption in 2019**.**

Table 5.3: Consumption (KWh) for Dura Stadium in 2018.

Number #	Date	Month	Consumption (KWh)
1	20/1/2018	January	255
2	20/2/2018	February	5376
3	20/3/2018	March	5872
4	20/4/2018	April	2100
5	20/5/2018	May	3301
6	20/6/2018	June	1803
7	20/7/2018	July	4349
8	20/8/2018	August	3570
9	20/9/2018	September	4131
10	20/10/2018	October	5938
11	20/11/2018	November	2848
12	20/12/2018	December	2610

- The highest monthly consumption rate was 5938 KWh

- Amount of annual consumption for 2018 was42153KWh/year

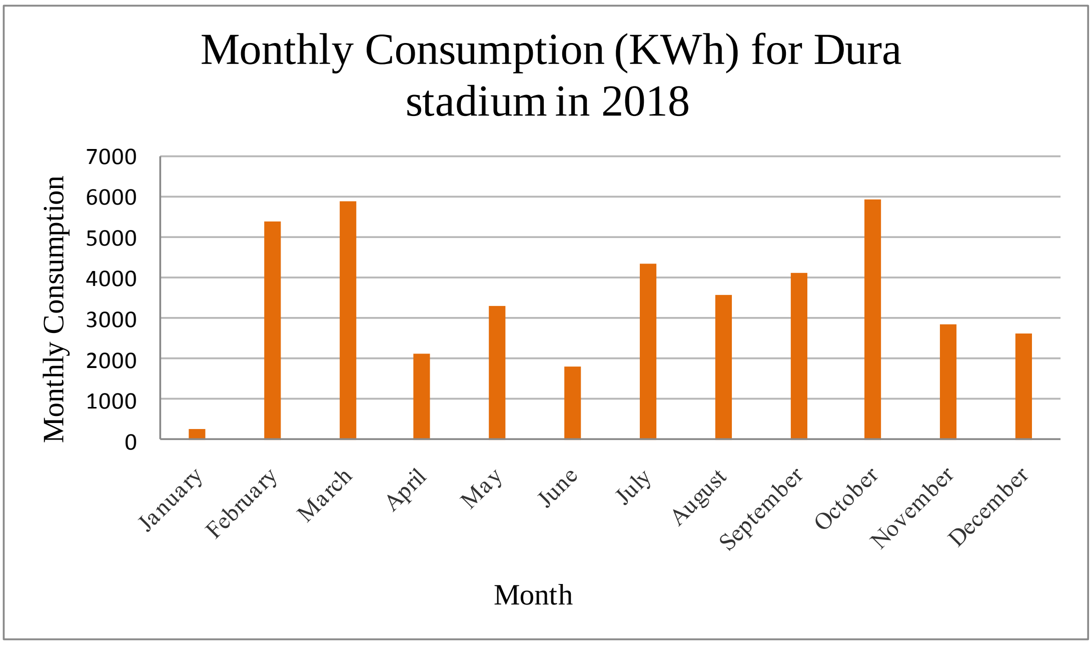


Figure 5.5 : Monthly Consumption in 2018.

Table 5.4 : Consumption (KWh) for Dura stadium in 2013 .

Number #	Date	Month	Consumption (KWh)
1	20/1/2013	January	7920
2	20/2/2013	February	7920
3	20/3/2013	March	7440
4	20/4/2013	April	4080
5	20/5/2013	May	2040
6	20/6/2013	June	1680
7	20/7/2013	July	8520
8	20/8/2013	August	4800
9	20/9/2013	September	8160
10	20/10/2013	October	8280
11	20/11/2013	November	4920
12	20/12/2013	December	7800

Table 5.5 : Consumption (KWh) for Dura stadium in 2014**.**

Number #	Date	Month	Consumption (KWh)
1	20/1/2014	January	10680
2	20/2/2014	February	9600
3	20/3/2014	March	5280
4	20/4/2014	April	6120
5	20/5/2014	May	3720
6	20/6/2014	June	6000
7	20/7/2014	July	6960
8	20/8/2014	August	13440
9	20/9/2014	September	8280
10	20/10/2014	October	9600
11	20/11/2014	November	8520
12	20/12/2014	December	4320

Table 5.6: Consumption (KWh) for Dura stadium in 2015.

Number #	Date	Month	Consumption (KWh)
1	20/1/2015	January	8640
2	20/2/2015	February	8160
3	20/3/2015	March	5160
4	20/4/2015	April	5400
5	20/5/2015	May	4800
6	20/6/2015	June	9120
7	20/7/2015	July	15120
8	20/8/2015	August	9000
9	20/9/2015	September	11400
10	20/10/2015	October	6720
11	20/11/2015	November	6840
12	20/12/2015	December	9600

Table 5.7: Consumption (KWh) for Dura stadium in 2016.

Number #	Date	Month	Consumption (KWh)
1	20/1/2016	January	11040
2	20/2/2016	February	7560
3	20/3/2016	March	5160
4	20/4/2016	April	3120
5	20/5/2016	May	3960
6	20/6/2016	June	3120
7	20/7/2016	July	5760
8	20/8/2016	August	7320
9	20/9/2016	September	5880
10	20/10/2016	October	4080
11	20/11/2016	November	5160
12	20/12/2016	December	3720

Table 5.8: Consumption (KWh) for Dura stadium in 2017.

Number #	Date	Month	Consumption (KWh)
1	20/1/2017	January	3720
2	20/2/2017	February	3480
3	20/3/2017	March	3240
4	20/4/2017	April	3840
5	20/5/2017	May	3960
6	20/6/2017	June	4320
7	20/7/2017	July	5400
8	20/8/2017	August	6240
9	20/9/2017	September	3360
10	20/10/2017	October	4800
11	20/11/2017	November	3600
12	20/12/2017	December	4320

Table 5.9 : Average Consumption (KWh) for a Dura stadium 2013 to 2018.

Number #	Month	total Consumption for month in(KWh) from (2013 to 2018)	Average Consumption in(KWh)
1	January	42255	7042.5
2	February	42096	7016
3	March	33411	5358.6666675
4	April	35563	4110
5	May	33583	3630.166667
6	June	42644	4340.5
7	July	61967	7684.833333
8	August	65356	7395
9	September	65206	6868.5
10	October	65737	6569.666667
11	November	67235	5314.666667
12	December	70803	5395

- The highest monthly consumption rate was 7684.833333KWh

- Amount of Annual Consumption for Average was70105.5KWh/year

Figure 5.6 : Average Consumption from 2013 to 2018

Table 5.10 : Average Consumption (KWh) for a Dura Stadium 2013 to 2020.

Number #	Month	total Consumption for month in(KWh) from (2013 to 2020)	Average Consumption in(KWh)
1	January	45458	5682.25
2	February	45698	5712.25
3	March	37376	4672
4	April	26504	3313
5	May	24270	3033.75
6	June	26733	3341.625
7	July	48726	6090.75
8	August	50471	6308.875
9	September	45846	5730.75
10	October	52562	6570.25
11	November	44300	5537.5
12	December	35453	4431.625

- The highest monthly consumption rate was 6570.25KWh

- Amount of Annual Consumption for Average was60424KWh/year

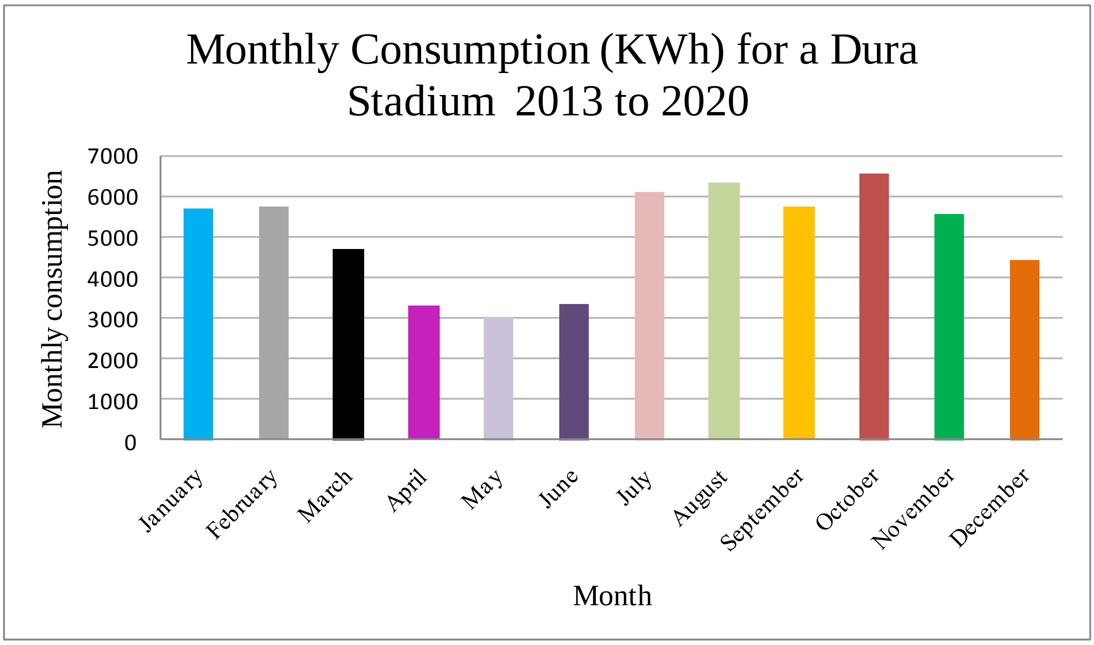


Figure 5.7 : Average Consumption from 2013 to 2020.

Table 5.11 : Average Consumption (KWh) for a Dura Stadium 2018 to 2020.

Number #	Month	total Consumption for month in(KWh)	Consumption in(KWh)
1	January	3458	1152.666667
2	February	8978	2992.666667
3	March	11096	3698.666667
4	April	3944	1314.666667
5	May	5790	1930
6	June	2493	831
7	July	6966	2322
8	August	9671	3223.666667
9	September	8766	2922
10	October	19082	6360.666667
11	November	15260	5086.666667
12	December	5693	1897.666667

- The highest monthly consumption rate was 6360.666667KWh

- Amount of Annual Consumption for Average was33732.33333 KWh/year

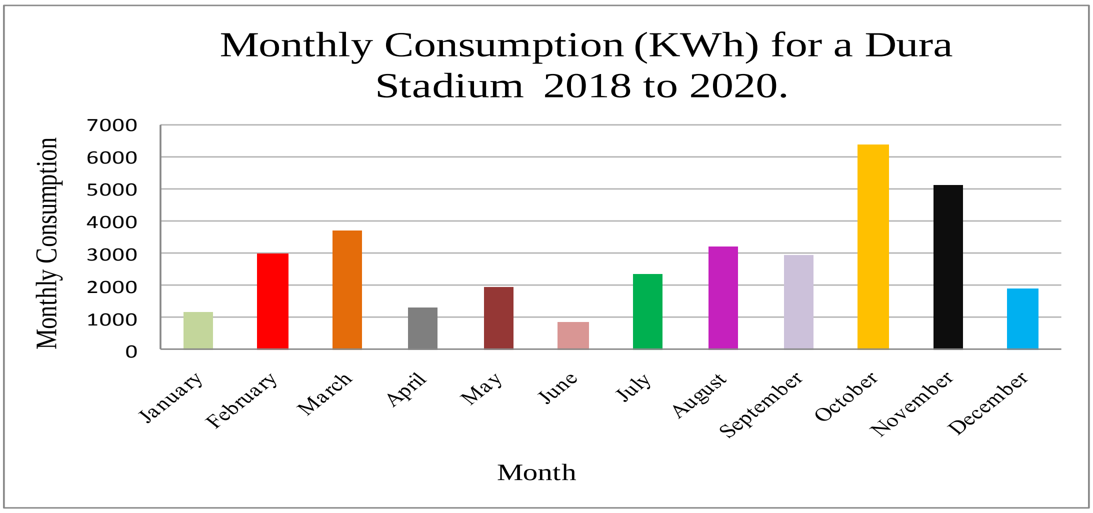


Figure 5.8 : Average Consumption from 2018 to 2020.

Table 5.12 : Summary of annual consumption at all year .

For a year	The Highest Monthly Consumption	Annual Consumption
2020	7412 KWh	25072KWh/year
2019	6470 KWh	33972 KWh/year
2018	5938 KWh	42153KWh/year
Average from 2013-2018	7684.833333KWh	70105.5KWh/year
Average from 2018-2020	6360.666667KWh	33732.33333KWh/year
Average from 2013-2020	6570.25KWh	60424KWh/year

The Highest Value — The Second Value — The Third Value

The Fourth Value — The Fifth Value — The Lowest Value

By Looking at The Table, The Highest Consumption was at Average from 2013-2018.

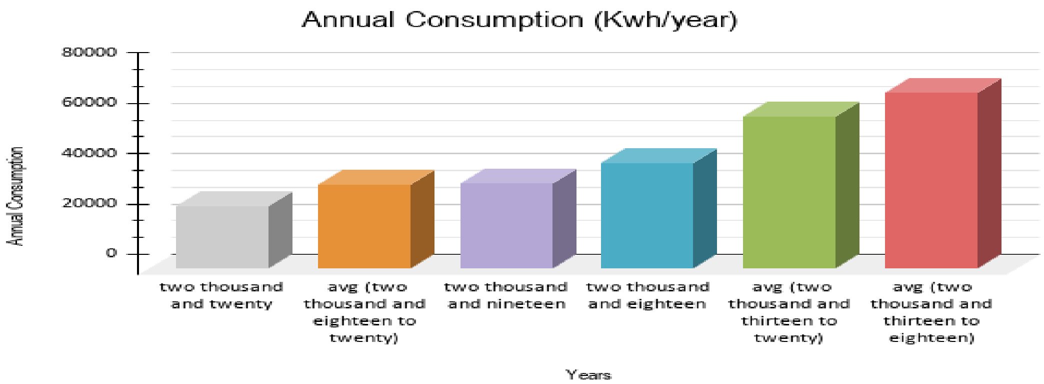


Figure 5.9 : Annual Consumption

5.4 Calculations based on the consumption of the stadium

The capacity of solar PV project= $\frac{\text{energy during a year kwh}}{\text{1700 peak shine hours}} = \frac{\text{60424KWh}}{\text{1700 peak shine hours}}$ = 35.5Kwp

- Take safety factor 1.25
- 35.5* 1.25 = 44.375KWac
- type of solar panel choose **JKM535M-7TL4-TVsolar panels 535 wp**
- Number of panels= $\frac{\text{capacity of project}}{\text{capacity of module}} = \frac{44375}{535}$ = 82.9=84 panels

Based on these methods, will be choose the highest number of solar cell 84 panels .

Panel length = 2.23 m

Panel width = 1.134m

number of panels = 84 panel / 535 WP

Title : Roof Layout .

South direction : ↓

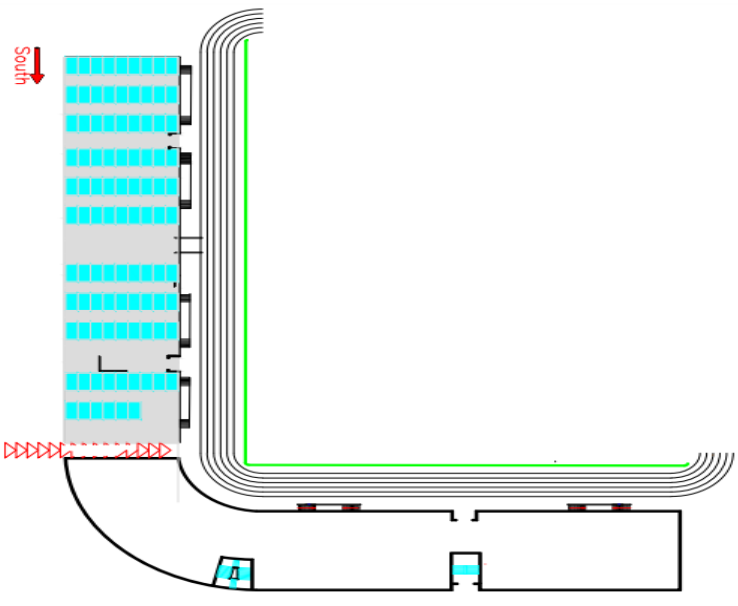


Figure 5.10 : Roof Layout

5.5 Conclusion:

When looking at the number of solar cells produced depending on the consumption of the stadium, we note that they did not cover the entire area of the stadium, and this will not be useful in two respects ,In terms of the shape of the shades ,On the other hand the ability.

Hence the question ,Why not take advantage of the area of the stadium and achieve a higher capacity covering the stadium and other areas?

Thus, we relied on the design of our project on the area to achieve the maximum benefit from the stadium.

Chapter 6

Calculations and Designs

6.1 Surplus

Today in electric power (in the concession areas of electric companies). On grid systems are created using several legislations and laws either.

1- The National Initiative for Solar Energy Systems: This initiative includes homes and the playground is not considered like homes, so the initiative cannot be used.

For stadiums, we can use two legislation that includes it:

2- Net metering system: The net metering system is calculated by which every kilowatt is calculated against a kilowatt and the increase is covered.

3- The investment system It is likely in the future to rely on the investment system because the profit for the buying company is better, because the system has high capabilities and belongs to local places and companies.

For the project, it is preferable to use the net metering system

As for the situation in the center of Dura, where the stadium is located, there is no problem because the area of the center of Dura is not completely saturated, the network can bear 25% of the Full load . Assuming the full load has 4 MW ,The project is 152 KW.

25% * full load = 25% * 4 MW = 1 MW.

so there is no problem with creating the project. [25]

6.2 Pv calculations and designs

In order to be able to do the necessary calculations and appropriate design, we must have a general idea of the stadium in terms of the area and the southern direction of the stadium as well, and the following figure shows the shape of the stadium, its area and the southern direction.

Total area of seats = 1118 m^2

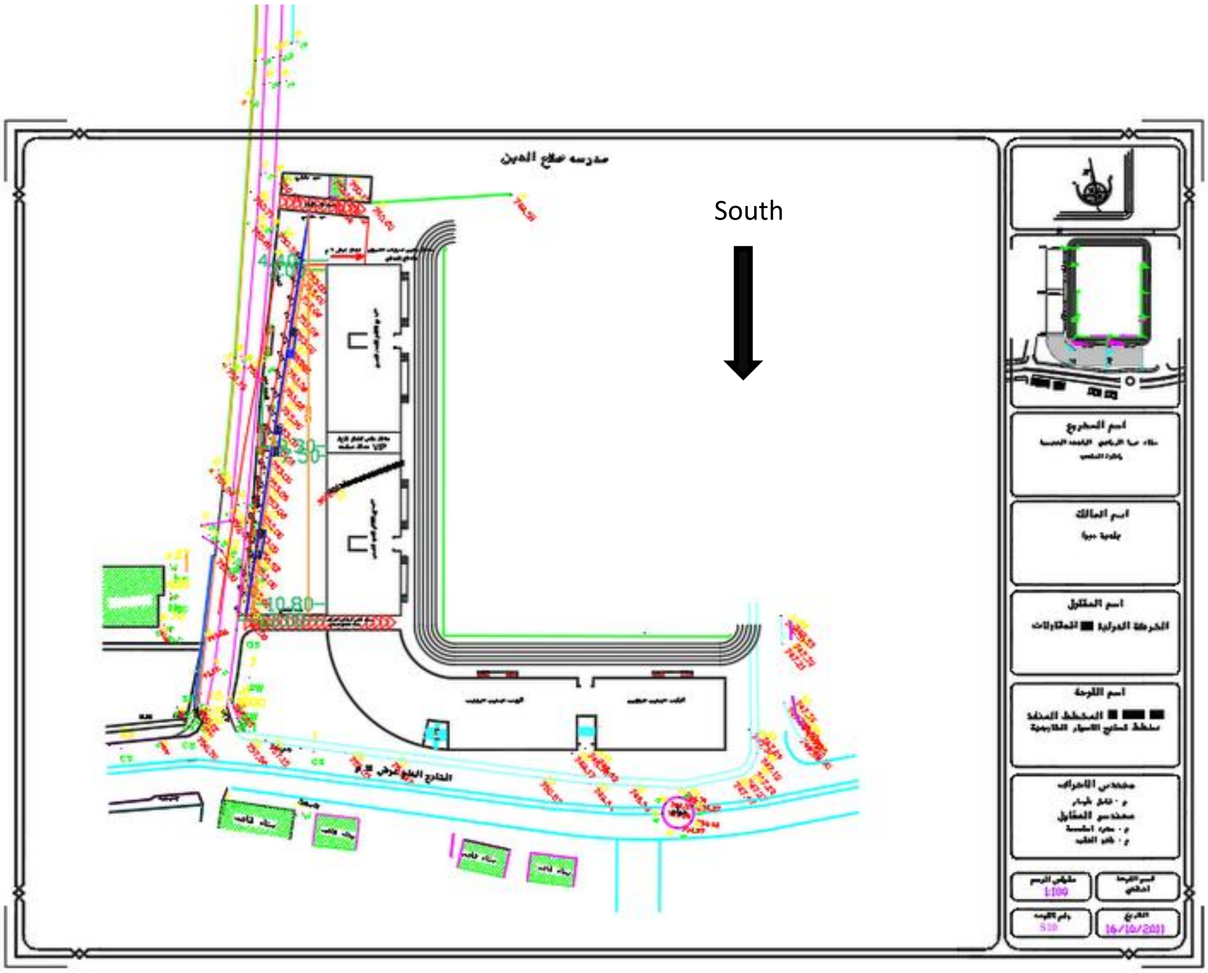


Figure 6.1 : Structural plan of the Dura stadium

6.2.1 Pv calculations

The Location for Dura stadium.

- The site was studied for longitude and width as shown :

Latitude: 31.5072°

Longitude : 35.0319°

The tilt angle for Dura is 27°

Altitude : 838 M above sea level

- The Solar bath diagram for the site is :

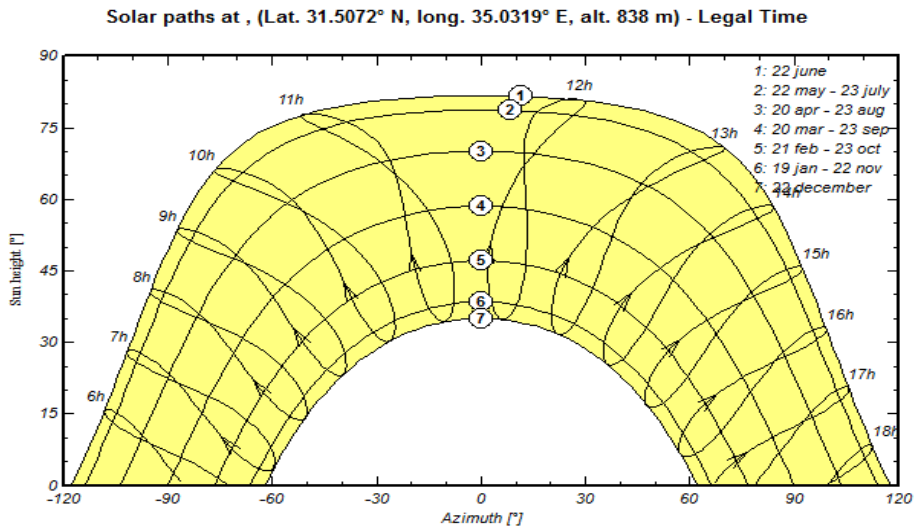


Figure 6.2 : Solar bath diagram.

Sun hours yearly in Palestine (1700 to 1800) so in Dura is (1700 sun hour)

The sun hours/day = $\frac{\text{Sun hours yearly}}{30*12} = \frac{1700}{30*12}$ = 4.7 h / day

The capacity of 285 panel 152Kwp

Panels: 535wp jinko solar

Module Type	JKM530M-7TL4-V		JKM535M-7TL4-V	
	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	530Wp	394Wp	535Wp	398Wp
Maximum Power Voltage (Vmp)	41.80V	38.66V	41.90V	38.72V
Maximum Power Current (Imp)	12.68A	10.20A	12.77A	10.28A
Open-circuit Voltage (Voc)	49.34V	46.47V	49.44V	46.57V
Short-circuit Current (Isc)	13.41A	10.83A	13.50A	10.90A
Module Efficiency STC (%)	20.96%		21.16%	

Figure 6.3 : Jinko solar datasheet

Inverters: capacity $\Rightarrow$ number of inverter

"ABB Inverter" : 50KVA $\Rightarrow$ 3

Type code	TRIO-TM-50.0-400	TRIO-TM-60.0-480
Input side		
Absolute maximum DC input voltage ($V_{max,abs}$)	1000 V	
Start-up DC input voltage (V_{start})	420…700 V (Default 420 V)	420…700 V (Default 500 V)
Operating DC input voltage range (V_{dcmin}…V_{dcmax})	0,7xV_{start} …950 V (min 300 V)	0,7xV_{start} …950 V (min 360 V)
Rated DC input voltage (V_{dcr})	610 Vdc	720 Vdc
Rated DC input power (P_{dcr})	52000 W	61800 W
Number of independent MPPT	3 (SX and SX2 version) / 1 (standard and SX version)	
Maximum DC input power for each MPPT ($P_{MPPTmax}$)	17500 W	21000 W
MPPT input DC voltage range ($V_{MPPTmin}$ … $V_{MPPTmax}$) at P_{acr}	480-800 Vdc	570-800 Vdc
Maximum DC input current (I_{dcmax}) for each MPPT	36 A	
Maximum input short circuit current for each MPPT	55 A (165 A in case of parallel MPPT)	
Number of DC input pairs for each MPPT	5	
DC connection type	Screw terminal block (Standard and -S version) or PV quick fit connector [3] (-SX and SX2 version)	
Input protection		
Reverse polarity protection	Yes, from limited current source	
Input over voltage protection for each MPPT - varistor	Yes, 1 for each MPPT	
Input over voltage protection for each MPPT - plug In modular surge arrester	Type 2 (option) with monitoring	
Photovoltaic array isolation control	According to local standard	
DC switch rating for each MPPT (version with DC switch)	60 A / 1000 V for each MPPT (180 A in case of parallel MPPT)	
Fuse rating (version with fuses)	15 A / 1000 V	
Output side		
AC grid connection type	Three-phase (3W+PE or 4W+PE)	
Rated AC power (P_{acr} @cosϕ=1)	50000 W	60000 W
Maximum AC output power (P_{acmax} @cosϕ=1)	50000 W	60000 W
Maximum apparent power (S_{max})	50000 VA	60000 VA
Rated AC grid voltage ($V_{ac,r}$)	400 V	480 V
AC voltage range	320...480 V [1]	384…571 V [1]
Maximum AC output current ($I_{ac,max}$)	77 A	
Contributory fault current	92 A	
Rated output frequency (f_r)	50 Hz / 60 Hz	
Output frequency range (f_{min}…f_{max})	47...53 Hz / 57…63 Hz [2]	
Nominal power factor and adjustable range	> 0.995; 0...1 inductive/capacitive with maximum S_{max}	
Total current harmonic distortion	<3%	
Maximum AC cable	95 mm² copper only (150 mm² copper/alluminum with TRIO-AC-WIRING-KIT)	
AC connection type	Screw terminal block, cable gland	
Output protection		
Anti-islanding protection	According to local standard	
Maximum external AC overcurrent protection	100 A	
Output overvoltage protection - varistor	Yes	
Output overvoltage protection - plug In modular surge arrester	Type 2 (option) with monitoring	
Operating performance		
Maximum efficiency (ηmax)	98.3%	98.5%
Weighted efficiency (EURO)	98.0% / -	98.0% / -

Figure 6.4: ABB inverter datasheet

Of panels = $\frac{\text{kwp for inverterl}}{wp\ for\ panel}$ = $\frac{50000}{535}$ =93.45 =94 panel For one inverter,

of panels=$\frac{152000}{535}$=284.11 ≅285

Max #of panels /series

$\frac{Vmax\ (inv)}{Vmax\ (panel)}$ =$\frac{800}{41.9}$=19

Min #of panels /series

$\frac{Vmin\ (inv)}{Vmin\ (panel)}$ =$\frac{480}{41.9}$=11.9 ≅12

String 1=19,19,19 ⇒ 57

String 2=19,19 ⇒ 38

57+38=95 "per inverter"

For 3 inverters ⇒ 95*3=285

Power rated test :

#of panels in string 1 * capacity of panels < rated Dc input power (52000 w)

57*535< 52000 w

30495 w < 52000 within range.

#of panels in string 2 * capacity of panels < rated Dc input power (52000 w)

38*535< 52000 w

20330 w < 52000 within range

Voltage rated test :

(voltage range 480 - 800)

max # of panels in series * maximum power voltage (Vmp) for panel

19 * 41.9 = 796.1 within range

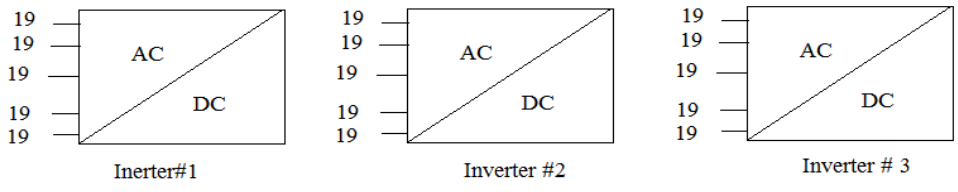


Figure 6.5: Distribution of cells on the three inverters.

The cable connecting the cells (UV_DC 6mm^2 cable) was chosen based on the lowest value that the electricity companies adopt to connect the solar cells.

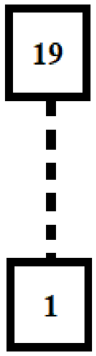
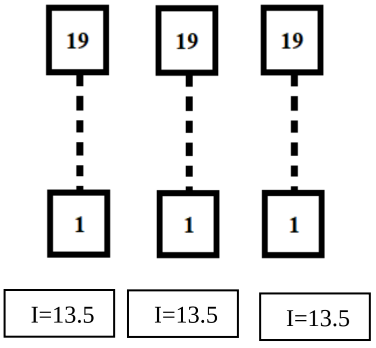


Figure 6.6: UV_DC 6mm^2 cable for panel

*19 cells are connected in series and the total current is equal to the current in the cell

$I_{tot} = I_{cell} = 13.5A$



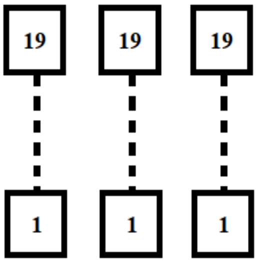
The 3 rows are connected in parallel.

Short circuit current from datasheet 13.5 A

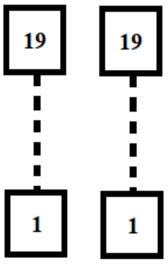
Total current = 3 * current through the row

$I_{tot} = I_{row} = 13.5A * 3 = 40.5A$

*DC sarge arrester (SPD):1000Vdc , They are placed in each section of the system at each inverter.



$I_{tot} = 3*13.5 = 40.5A$



$I_{tot} = 2*13.5 = 27A$

40.5A $\Rightarrow$ 50A $\Rightarrow$ DC CB

27A $\Rightarrow$ 32A $\Rightarrow$ DC CB

Max current = the total current for first string + the total current for second string

= The total current (for first string 19 19 19) + The total current (for first string 19 19)

= 40.5 +27 = 67.5 A

from table DC circuit breaker = 80 A

Wire cross-sectional area 10 mm^2

For inverter the AC output voltage is 77 A from Data sheet

from table the circuit breaker = 80 A

Wire cross-sectional area 5*25 mm^2

For 3 inverters

For 3 inverters the AC output voltage is 3*77 A = 231 A

from table the circuit breaker = 80 A *3 = 240 A

The typical current rating (216 - 250) A

from table the circuit breaker =225 A

Wire cross-sectional area 5*120 mm^2

AC sarge Arrester 4000 V ac

Wire cross-sectional area 5*120 mm^2

Table6.1: Cable rating

CABLE RATING TABLE

Cable Cross Sectional Area (mm^2)	Typical Current Rating (amps)	Recommended Circuit Breaker Rating (amps)
1.5 mm^2	7.9 - 15.9A	8A
2.5 mm^2	15.9 - 22A	15A
4 mm^2	22 - 30A	20A
6 mm^2	30 - 39A	30A
10 mm^2	39 - 54A	40A
16 mm^2	54 - 72A	60A
25 mm^2	71 - 93A	80A
50 mm^2	117 - 147A	125A
70 mm^2	147 - 180A	150A
95 mm^2	180 - 216A	200A
120 mm^2	216 - 250A	225A
150 mm^2	250 - 287A	275A
185 mm^2	287 - 334A	300A
240 mm^2	334 - 400A	350A

6.2.2 Pv design

The distribution of cells over the area of the stadium, which is 1,118 square meters, as it can accommodate 285 cells and more. We distributed 285 cells that filled the area and the capacity of each panel was 535 wp (here by distribution, we do not care about consumption because the consumption of the stadium does not cover half the area of the audience seats, and therefore we relied on the space in building the system.

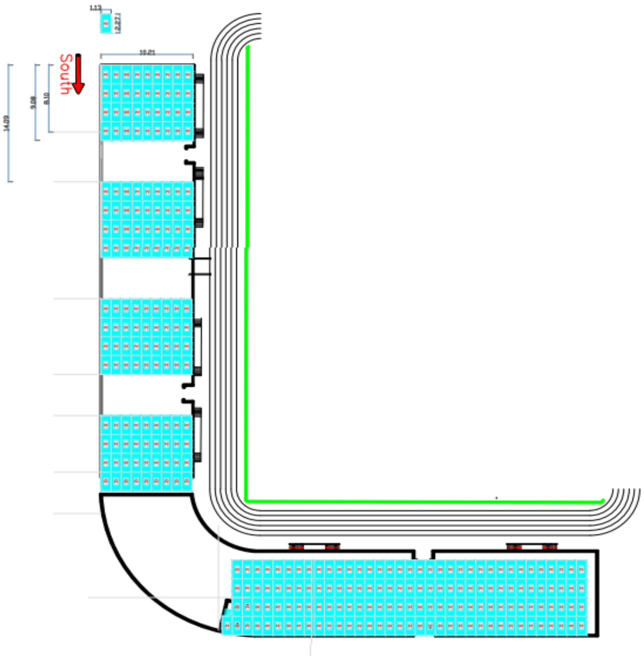


Figure 6.7: Distribution of cells over pitch area.

Inverter 1 $\Rightarrow$ 50kw

For the first inverter, we networked with 95 cells, the capacity of each cell is 535 Kwpeak, so the total power on the inverter is 50.8Kw, knowing that each inverter can be connected to a dirty network of up to 60 Kw , and the inverter two and three are connected with panels like the first inverter.

System 1 for Inverter 1:

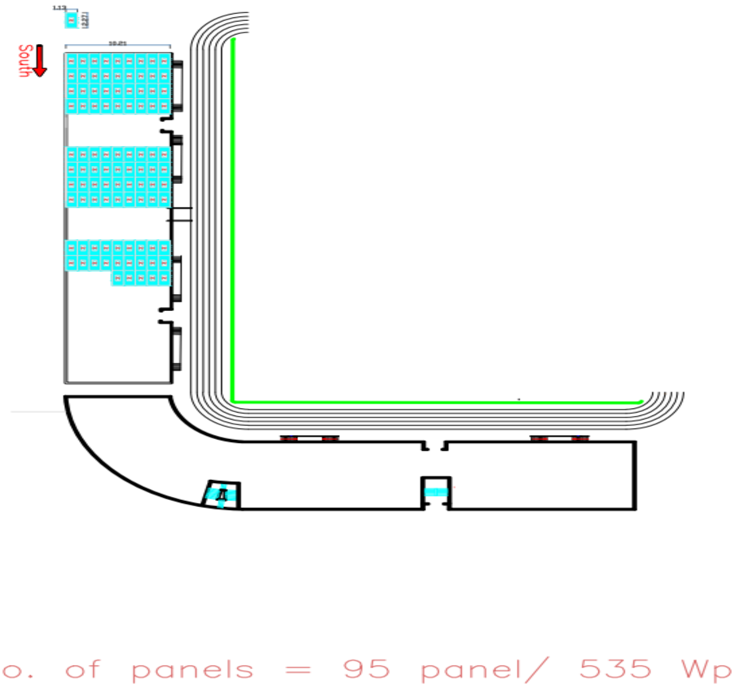
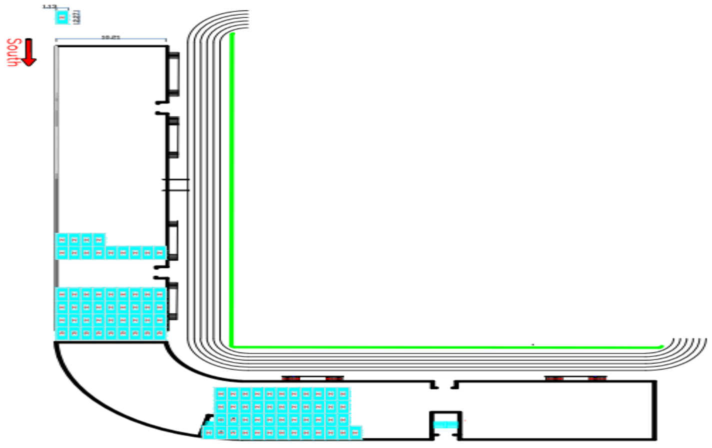


Figure6.8 : layout for panels connected with inverter1

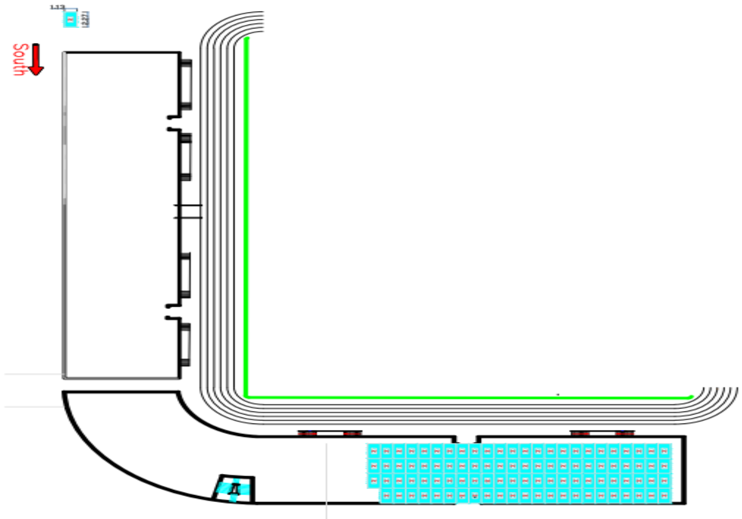
System 2 for Inverter 2:



No. of panels = 95 panel/ 535 Wp

Figure6.9 : layout for panels connected with inverter2

System 3 for Inverter 3:



No. of panels = 95 panel/ 535 Wp

Figure6.10 : layout for panels connected with inverter3

Earthing system for pv panel:

When installing panels on the iron, the cells must be connected to the lines of the tarith as follows, as in the picture, we note that each cell and cell have been connected to a target line 6mm^2 CU earth wire, also between cells with the rail to a target 6mm^2 CU earth wire, and between the middle of the cells with a 10mm^2 CU earth wire, and assembled in earth box, Lightning rod works to absorb the huge electrical current resulting from lightning strikes and protect electrical devices and equipment installed by air lines from increasing the voltage resulting from atmospheric factors and is placed in the highest place in the region because it is the most vulnerable to lightning and consists of the electrode embedded in the ground and a point of a ground and a pointed head at the top of this head is the one that receives the thunderbolt and unloads it in the system and then flattened, Considering the stadium is the highest place in the area, we've designed a lightning rod for it.

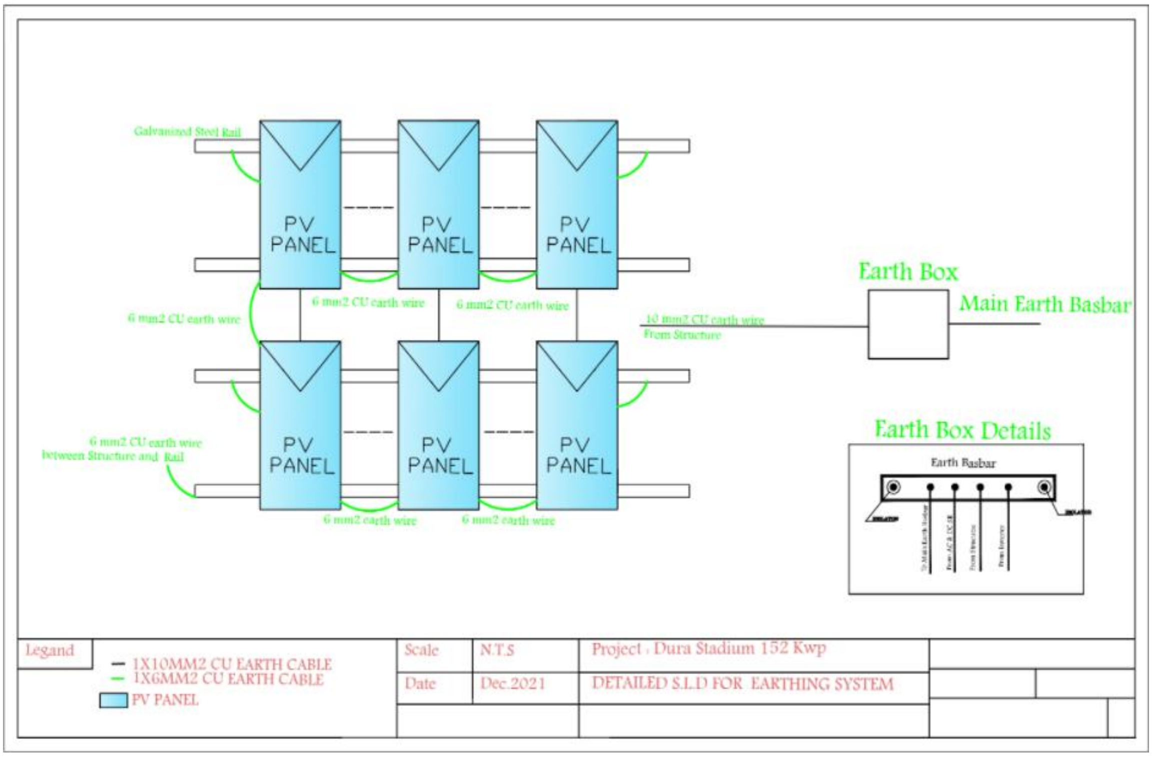


Figure 6.11: Single line diagram for Earthing system

Single line diagram for the system

We will protect the solar cells in two ways:

1. surge arrester (DC SR 1000V_{dc}): is a device to protect electrical equipment (Cells) from over-voltage transients caused by external (lightning) or internal events.

2. Circuit breaker (DCCB): A general DC Circuit Breaker must be installed between the solar panels and the charging regulator or the inverter, and there is no case or situation that dispenses with the installation of this important circuit breaker in protecting the solar energy system.

Universal breaker function:

- Protection of solar panels in case of damage to the inverter and the occurrence of a short circuit

- Protection of the inverter in the event of a short circuit on the side of the panels as a result of a water leak.

- The possibility of separating the panels from the rest of the components manually

We used a 32 circuit breaker and 50 circuit breaker to protect the cells , based on the 13.5 .short circuit current of the cells.

Thus, the current is 13.5 times the number of strings: (13.5 * 3 = 40.5) and thus we choose the circuit breaker 50 A
And in the same way for secant 32 A (13.5 * 2 = 27)

To increase safety, we used another Circuit Breaker, because we have Circuit Breaker (50 A) and Circuit Breaker (32 A), so the selection of our Circuit Breaker is based on the first values of the current (40.5 A and 27 A) you choose the Circuit Breaker 80 A.

As for the circuit breaker used for the inverter, when looking at the data sheet, we will notice that the Maximum AC output current (Iac,max) 77 A, and so the circuit chosen for it will be 80 A.

In the same way, we protect the system of the second and third inverter .

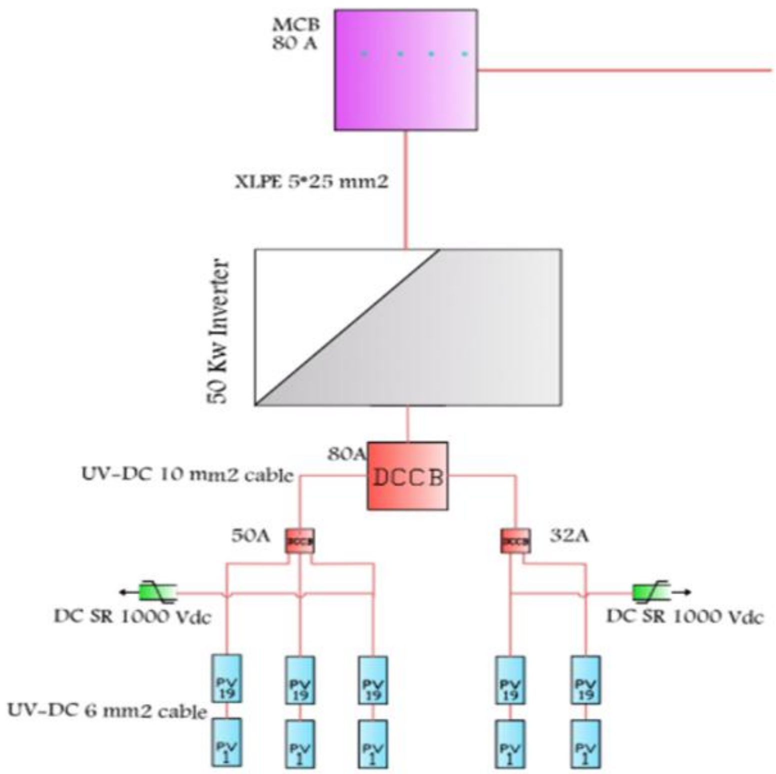


Figure 6.12: Single line protection diagram for the system

In order to increase safety to maintain the inverters, first we used Circuit Breaker (225 A) and it was chosen based on the following (77 + 77 + 77) = 231A, and based on the circuit breaker rating values, Circuit Breaker 225 A was chosen.

Second, we use AC Surge Arrester 400 Vac To provide efficient protection for a photovoltaic system the alternate. current side must also be protected against overvoltage.

The system is fully protected and compiled in MDB.

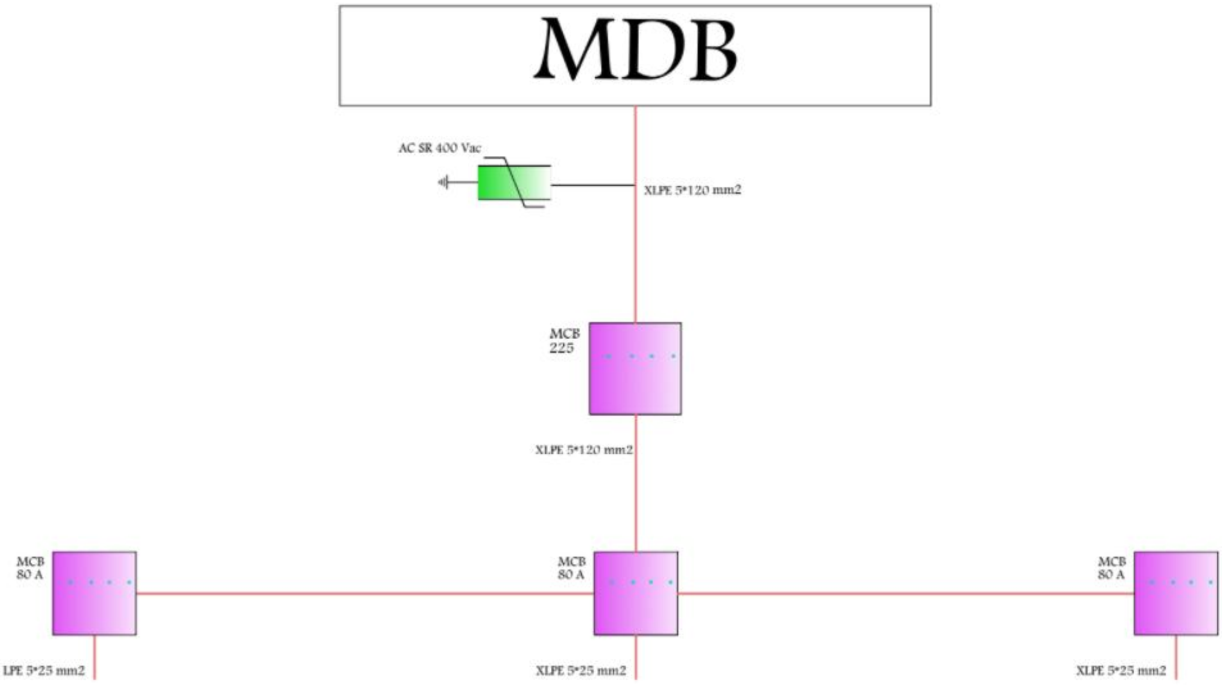


Figure 6.13: single line diagram for ac circuit breaker.

Block Diagram for the system

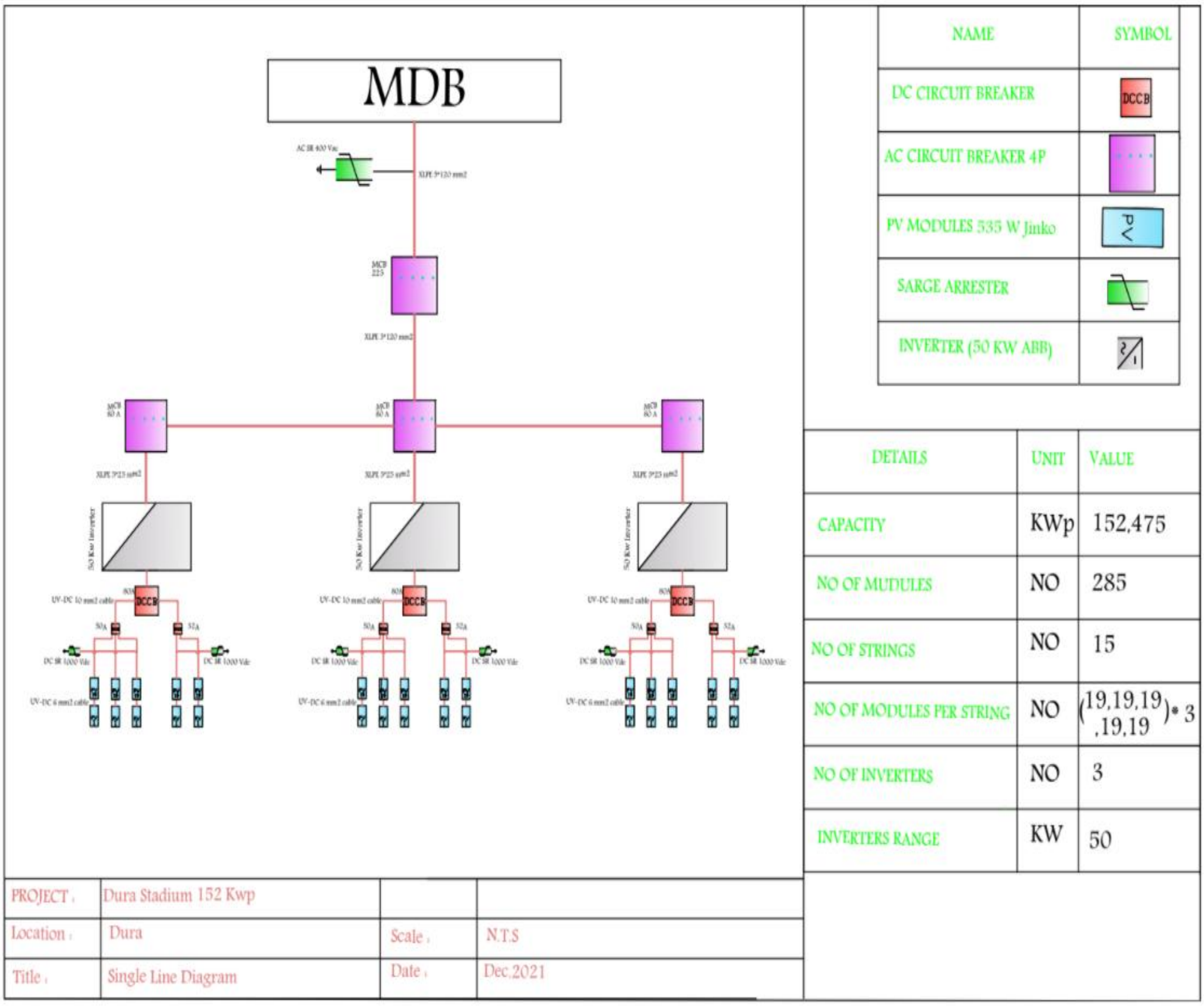
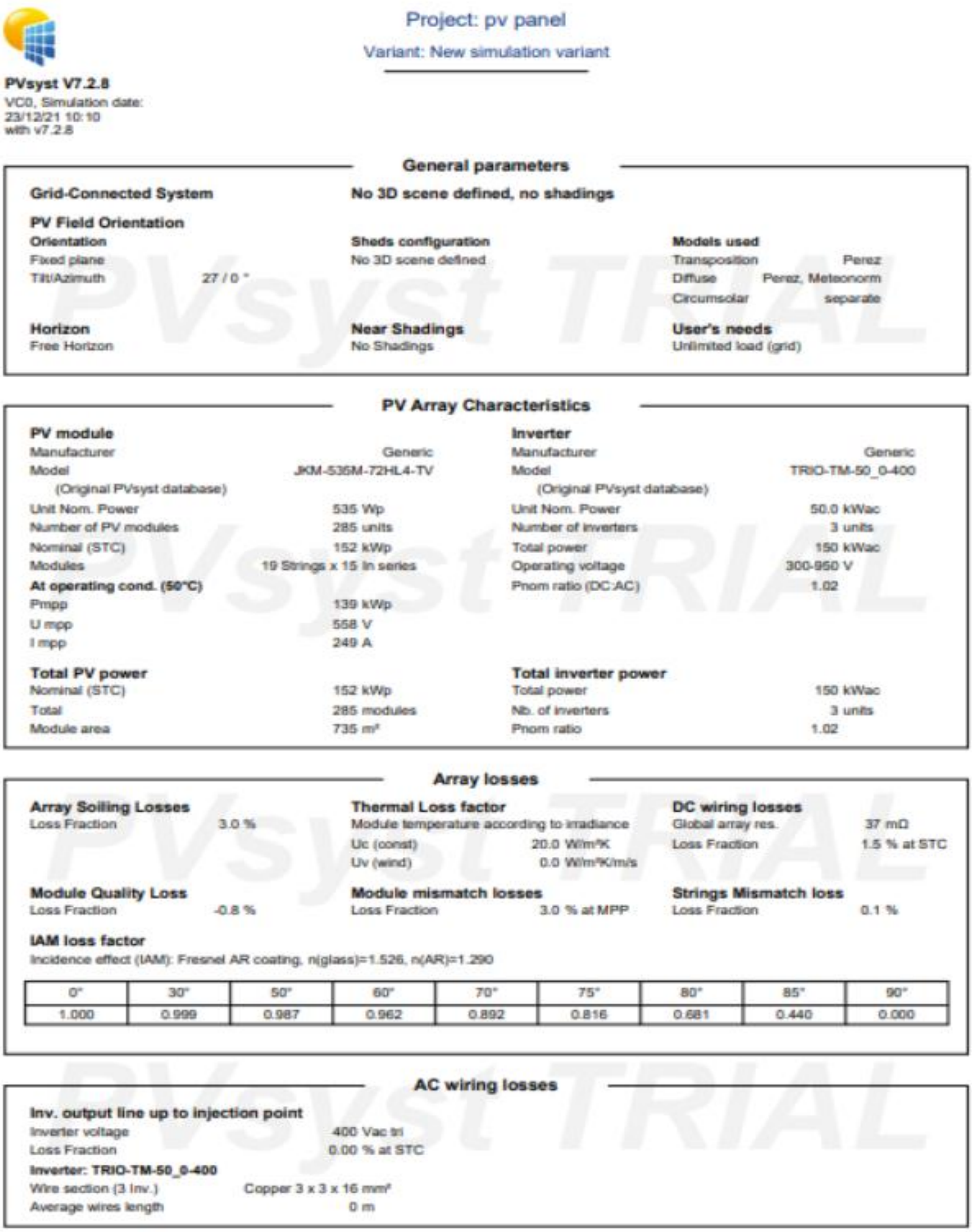


Figure 6.14: Single line Diagram for the system.

6.3 Pv system result

The design using the PV system program, and the results of the program were close to our calculations.



PVsyst V7.2.8
VC0, Simulation date:
23/12/21 10:10
with v7.2.8

Project: pv panel
Variant: New simulation variant

General parameters

Grid-Connected System — **No 3D scene defined, no shadings**

PV Field Orientation
Orientation: Fixed plane
Tilt/Azimuth 27 / 0 °

Sheds configuration
No 3D scene defined

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module		Inverter	
Manufacturer	Generic	Manufacturer	Generic
Model	JKM-535M-72HL4-TV	Model	TRIO-TM-50_0-400
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	535 Wp	Unit Nom. Power	50.0 kWac
Number of PV modules	285 units	Number of inverters	3 units
Nominal (STC)	152 kWp	Total power	150 kWac
Modules	19 Strings x 15 In series	Operating voltage	300-950 V
At operating cond. (50°C)		Pnom ratio (DC:AC)	1.02
Pmpp	139 kWp		
U mpp	558 V		
I mpp	249 A		
Total PV power		**Total inverter power**	
Nominal (STC)	152 kWp	Total power	150 kWac
Total	285 modules	Nb. of inverters	3 units
Module area	735 m²	Pnom ratio	1.02

Array losses

Array Soiling Losses
Loss Fraction 3.0 %

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 37 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction -0.8 %

Module mismatch losses
Loss Fraction 3.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

IAM loss factor
Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

AC wiring losses

Inv. output line up to injection point
Inverter voltage 400 Vac tri
Loss Fraction 0.00 % at STC
Inverter: TRIO-TM-50_0-400
Wire section (3 Inv.) Copper 3 x 3 x 16 mm²
Average wires length 0 m

Figure 6.15: pv syst

6.4 Structural design and calculation of solar cell shades.

To build any solar energy system we must have a sturdy metal structure, and we are here because we are going to make shades for cells in a stadium, the design must be solid.

6.4.1 Structure calculation

Calculate the value of the loads:

A. Dead Load.

The weight of one panel is 28.9 K.gm , in an area equal to (2.23 * 1.134) m

D = Density * Volume .

D = 0.5 + ($\frac{28.9/9.81}{2.23*1.134/10}$) = 0.61 KN/m^2

B. Snow Load .

According to the Jordanian code for loads from Table (3-5), according to the height of the building above sea level, which is estimated to be 800 m above sea level in Dura.[26].

$S_0 = \frac{h-400}{320}$ ………………………………………………………………………………………

$S_0 = \frac{800-400}{320}$ = 1.25 KN/m^2

Table 6.2: Snow Load

حمل الثلـ . ـج (S_0) (كن/م٢)	ارتفاع المنشأ عـ . ـن سطح البحر (h) (بالمتر)
0	250 > h
(h-250)/800	500 > h > 250
(h-400)/320	1500 > h > 500

C. Wind Load.

Relying on the American code for describing loads (2002).

1- Average wind speed (Vs) = 35 m/s.

2- Directlnodty factor (Kd) = 0.85.

3- Topographic factor (Kzt) = 1.

4- According to the height of the building (Kz) = 0.8

$q_z = 0.613*Kz*Kzt*Kd*Vs^2$

$q_z = 0.613*1*0.85*0.8*(35)^2 = 0.64\ KN/m^2$

p = qz (External pressure (CTcp) - internal pressure(CTpi))

$p = 0.64(0.8 - 0) = 0.512\ KN/m^2$.

For load compilation:

Q=1.2D+1.5S+0.8W

, L=0

The value of living loads has been neglected.

Calculating quantities:

Calculating the amount of iron for the first section, overlooking the south.

The longitudinal meter mass of SHH 4*100*100 =12.06Kg

The first section contains 21m of SHH 4*100*100 =21*12.06=253.26Kg

Longitudinal meter weight 65.22 kg

6.5*65.22 = 423.982 Kg

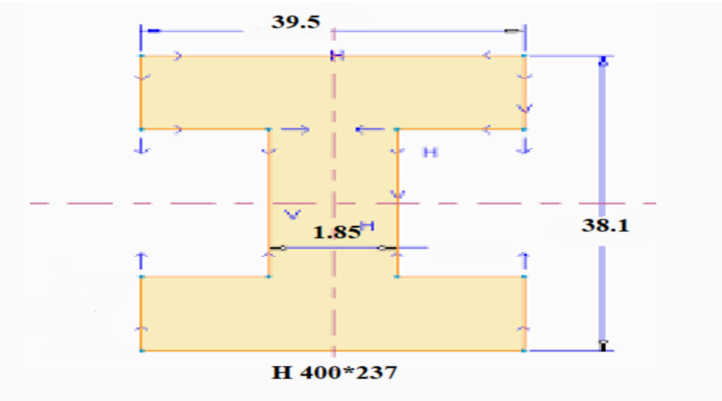


Figure 6.16: H 400*237

The piece RSH 5*200*200

The longitudinal meter mass of RSH 5*200*200 =30.62Kg

The longest pieces= 9+9.5+4.5=23m

Mass=23*30.62=704.26Kg

The pieces SHH 70*70*3.5

weight =7.31 Kg/m

W_{SHH}=7.31*36=263.16

W_{tot}=263.16+704.26+423.98+253.26= 1650 " Per piece " .

Calculating the amount of iron for the second section, overlooking the east .

1. SHF (100*100*4)=22.5m *12.06Kg/m =293.85
2. SHCF (200*200*5)=26m *30.62Kg/m =796.12
3. H 400 *237 =6m*65.22 Kg/m=391.32
4. 8HF (100*100*3)=130.5*9.14 Kg/m=1192.77

Total summation=2674.06 Ton.

the total weight= number of piece *weight for first section +

number of piece * weight for second section

The total weight= 11*1.65+12*2.65=49.95 Ton.

6.4.2 Structure Design

Structure Design for the first section, overlooking the south.

In this part of the structure, the iron was built directly towards the south, because it is in the southern direction of the stadium.

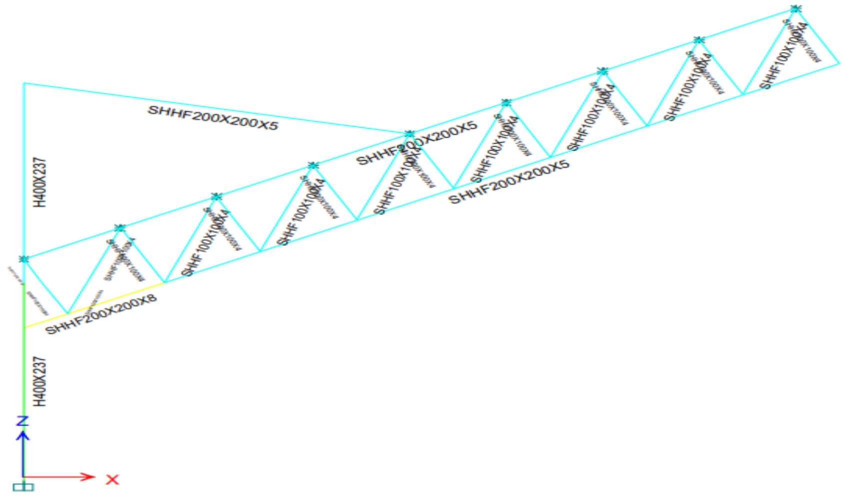


Figure 6.17: Steel structure iron for the first part .

In this southern part, the structure can accommodate 144 cells, but we will add 141 cells, as we will leave room for addition in the future .

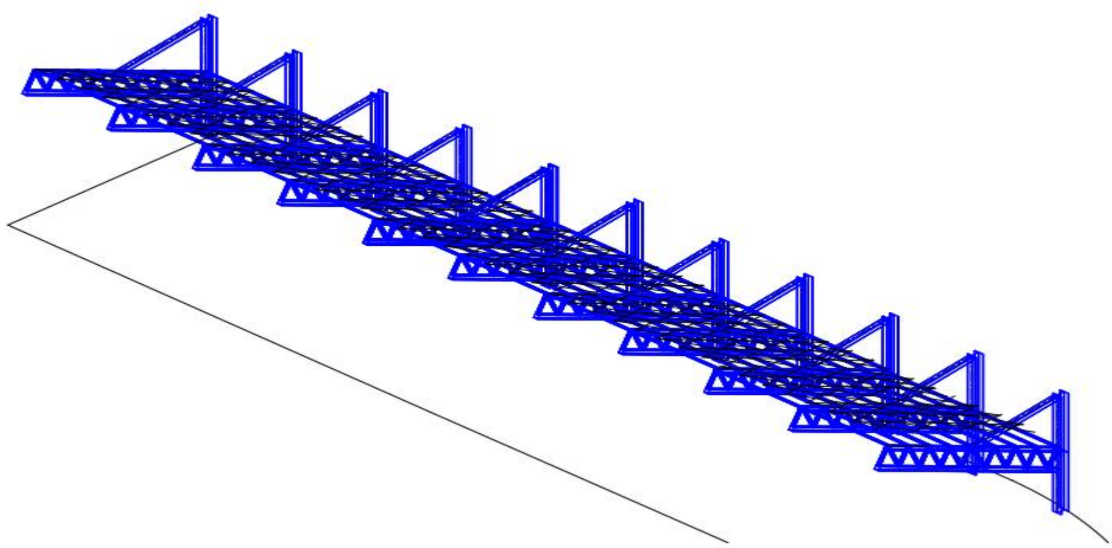


Figure 6.18: Steel structure shads for the south part

Structure Design for the second section, overlooking the east.

On the eastern side of the stadium, there are two parts of the design for the iron, first a straight design and a composite design above the straight design, which is in the form of a triangle, as the triangle will be installing solar cells on it and it will be towards the south.

The first section :

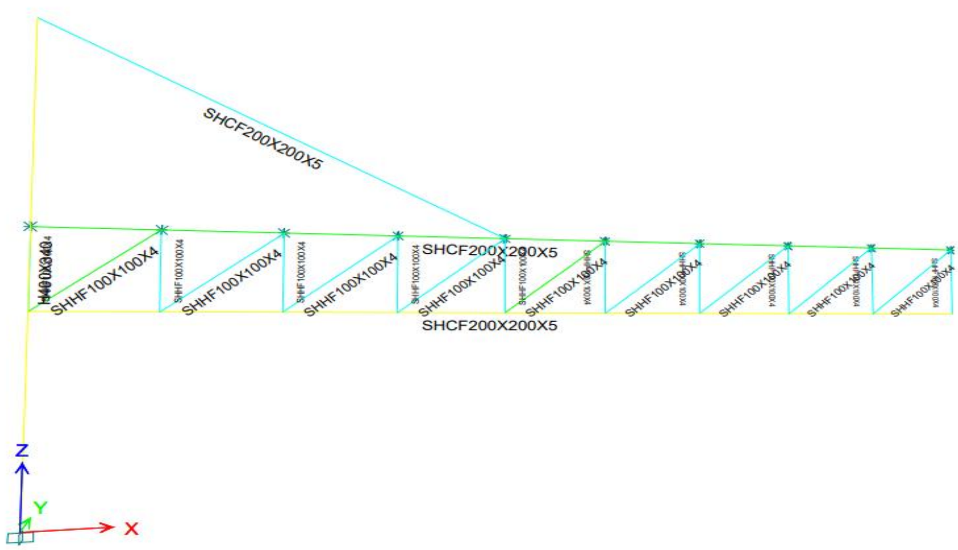


Figure 6.19 : Steel structure iron for the straight part

The second section :

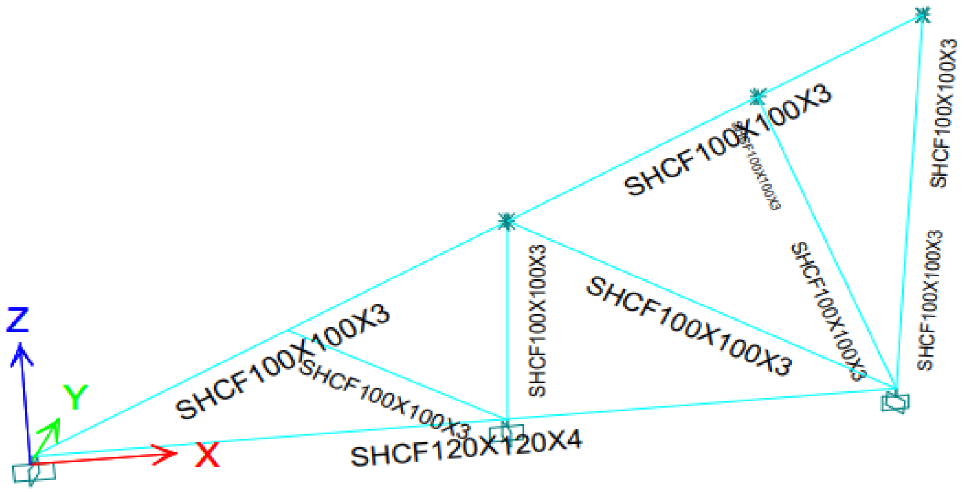


Figure 6.20 : Steel structure for the triangle part.

Thus, the final shape of the eastern part of the stadium will be (the direction of the solar cells will be to the south) . On the eastern side, there are four parts of this structure, each part accommodating 36 cells.

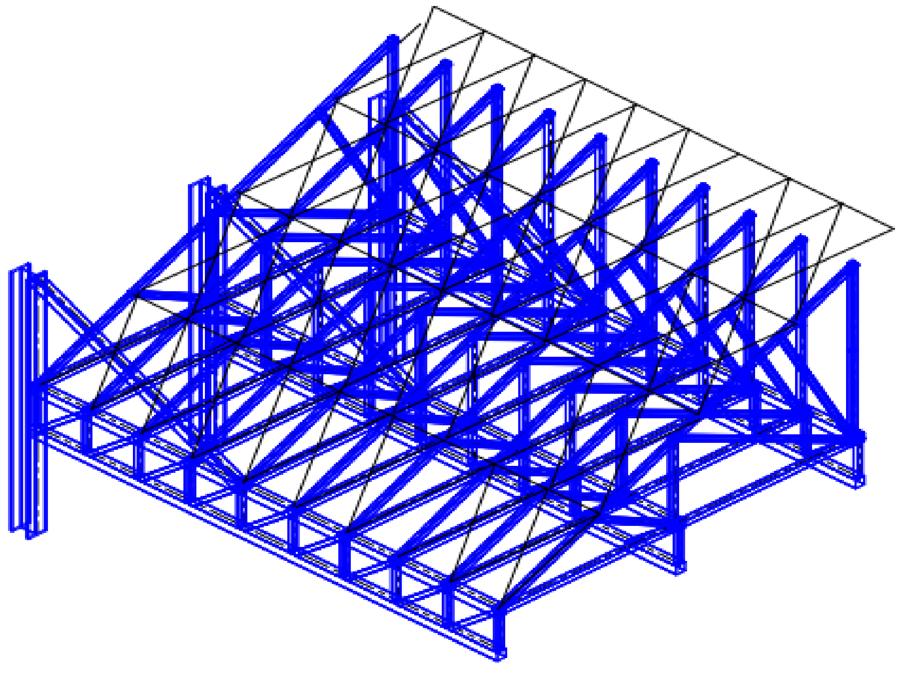


Figure 6.21: Steel structure shads for the second part .

Each cell or group of cells needs a piece of iron (SHCF) to install it on it and on the strut. Here we have installed every four cells on a piece.

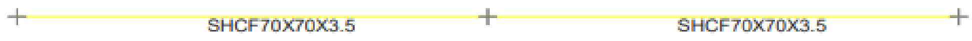


Figure 6.22 : SHCF steel section .

Cutting iron for the first shape(overlooking the south) , knowing that it is repeated 11 times.

Table 6.3: Shape overlooking the south

#	shapes	Dimensions(cm)	length(m)	#of shape	repetition	final requirement
1	RHS	20*20*0.5	9.5	1	11	11
2	RHS	20*20*0.5	9	1	11	11
3	RHS	20*20*0.5	4	1	11	11
4	H	38*40*3	6.5	1	11	11
5	SHS	10*10*0.4	1	9	11	99
6	SHS	10*10*0.5	1.5	8	11	88
7	SHS	7*7*.35	8	9	5	45

Cutting iron to the second shape, knowing that it is repeated 12 times

Table 6.4: Shape straight part

#	shapes	Dimensions(cm)	length(m)	#of shape	repetition	final requirement
1	RHS	20*20*0.5	10.35	2	12	24
2	RHS	20*20*0.5	4	1	12	12
3	H	38*40*3	6	1	12	12
4	SHS	10*10*0.4	1	9	12	108
5	SHS	10*10*0.5	1.5	9	12	108
6	SHS	7*7*.35	8	9	12	108

Cutting iron to the triangle shape, knowing that it is repeated 40 times

Table 6.5: Shape triangle part

#	shapes	Dimensions(cm)	length(m)	#of shape	repetition	final requirement
1	SHS	10*10*0.3	9	1	40	40
2	SHS	10*10*0.3	8	1	40	40
3	SHS	10*10*0.3	4.5	1	40	40
4	SHS	10*10*0.3	4	1	40	40
5	SHS	10*10*0.3	2.2	1	40	40
6	SHS	10*10*0.3	2	1	40	40

When all these pieces are assembled and built according to what is required, the final form will be as follows (as the eastern part of the stadium can be added 144 cells, and the southern part can be added 141 cells, so the total number of cells is 285 cells.

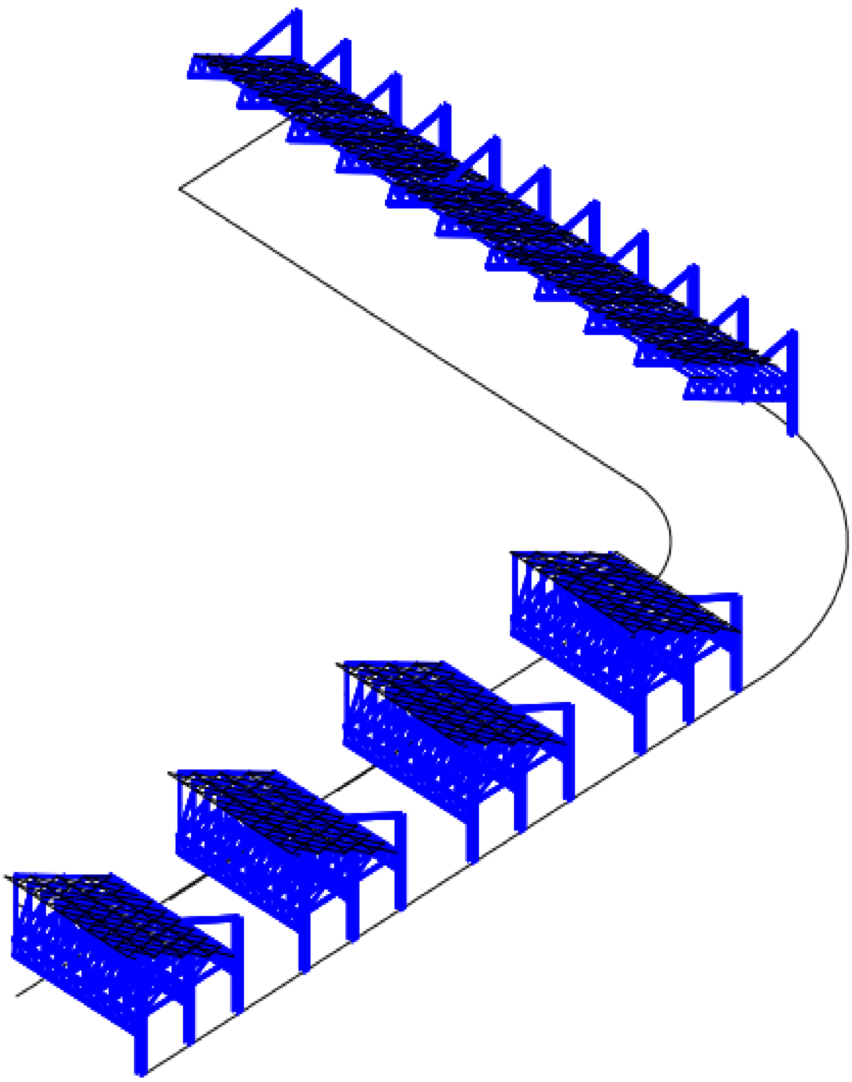


Figure 6.23 : Steel structure shads for Dura stadium

6.5 Material bill of quantities for 152Kwp pv system

The most important step after completing the project is to inventory the materials and tools needed to know the total cost of the project, and our project has been listed as follows. Where the whole project will cost 557669 ILS.

Project :	Dura Stadium				
Main contractor : SP					
Subject :	Material Bill of Quantities for 152 Kwp PV System				
NO.	Item describtion	Qty	Quantity	Unit Price ILS	Total Actual
1	– Monocrystalline PV Module 535 Wp.	Each	285	650	185,250
2	– 50 Kw Three Phase Dual MPPT Grid Tie Inverter.	Each	3	18,550	55,650
3	– Mounting Structure				
	Steel Structure	Ton	49.95	6,000	299,700
	قص و لحام وتثبيت	L.S	1	8,000	8,000
4	– Cables				
	DC Cables				
	10 mm2 for 3 phase power system	m	50	4.5	225
	6 mm2 cross section for PV modules to junction box.	m	130	3.6	468
	AC Cables				
	5*25 mm2 for 3 phase power system	m	6	50	300
	5*120 mm2 for 3 phase power system	m	6	70	420
	Earthing System Cables				
	10 mm2 for 3 phase power system.	m	50	4.5	225
	6 mm2 cross section.	m	260	3.6	936
	لوازم لتوصيل الكوابل	L.S	1	2,200	2,200
5	– Protection Devices				
	DC CircuitBreaker 32 A	Each	3	165	495
	DC CircuitBreaker 50 A	Each	3	190	570
	DC CircuitBreaker 80 A	Each	3	430	1,290
	DC SPD , Surge Arrester. 1000 V	Each	6	165	990
	AC SPD 400V.	Each	1	220	220
	Earth Leackage 80A.	Each	1	300	300
	4 Pole Circuit Breaker 80A. حراري	Each	3	320	960
	4 Pole Circuit Breaker 225A.	Each	1	500	500
			TOTAL COST (ILS)		558,699

Figure 6.24: Total cost

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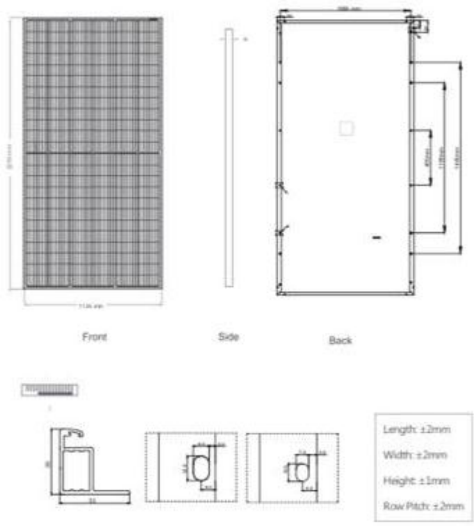
Appendix A

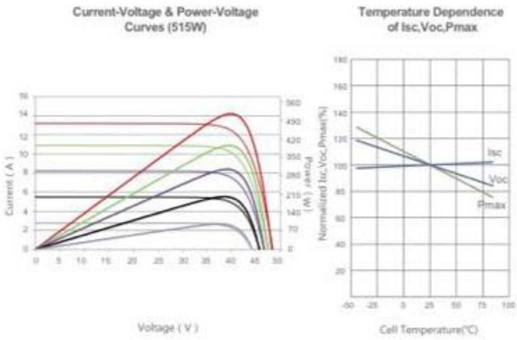
Data sheets

- Jinko solar datasheet
- ABB inverter datasheet
- DC cable datasheet
- PULSAR 30 STAINLESS STEEL
- AC & DC cable
- AC & DC protection devices

Engineering Drawings



Electrical Performance & Temperature Dependence



Packaging Configuration

(Two pallets = One stack)

31pcs/pallets, 62pcs/stack, 620pcs/ 40'HQ Container

Mechanical Characteristics

Cell Type	P type Mono-crystalline
No.of cells	144 (2×72)
Dimensions	2230×1134×35mm (87.80×44.65×1.38 inch)
Weight	28.79 kg (62.47 lbs)
Front Glass	3.2mm,Anti-Reflection Coating, High Transmission, Low Iron, Tempered Glass
Frame	Anodized Aluminium Alloy
Junction Box	IP68 Rated
Output Cables	TUV 1×4.0mm² (+): 290mm , (-): 145 mm or Customized Length

SPECIFICATIONS

Module Type	JKM515M-7TL4-V		JKM520M-7TL4-V		JKM525M-7TL4-V		JKM530M-7TL4-V		JKM535M-7TL4-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	515Wp	383Wp	520Wp	387Wp	525Wp	391Wp	530Wp	394Wp	535Wp	398Wp
Maximum Power Voltage (Vmp)	41.50V	38.35V	41.60V	38.46V	41.70V	38.56V	41.80V	38.66V	41.90V	38.72V
Maximum Power Current (Imp)	12.41A	9.99A	12.50A	10.06A	12.59A	10.13A	12.68A	10.20A	12.77A	10.28A
Open-circuit Voltage (Voc)	49.04V	46.19V	49.14V	46.28V	49.24V	46.38V	49.34V	46.47V	49.44V	46.57V
Short-circuit Current (Isc)	13.14A	10.61A	13.23A	10.69A	13.32A	10.76A	13.41A	10.83A	13.50A	10.90A
Module Efficiency STC (%)	20.37%		20.56%		20.76%		20.96%		21.16%	
Operating Temperature(°C)	-40°C~+85°C									
Maximum system voltage	1500VDC (IEC)									
Maximum series fuse rating	25A									
Power tolerance	0~+3%									
Temperature coefficients of Pmax	-0.35%/°C									
Temperature coefficients of Voc	-0.28%/°C									
Temperature coefficients of Isc	0.048%/°C									
Nominal operating cell temperature (NOCT)	45±2°C									

*STC: Irradiance 1000W/m² Cell Temperature 25°C AM=1.5

NOCT: Irradiance 800W/m² Ambient Temperature 20°C AM=1.5 Wind Speed 1m/s

Figure A.1: Jinko solar datasheet

ABB string inverters
TRIO-TM-50.0-400
TRIO-TM-60.0-480
50 to 60 kW

Technical data and types

Type code	TRIO-TM-50.0-400	TRIO-TM-60.0-480
Input side		
Absolute maximum DC input voltage ($V_{max,abs}$)	1000 V	
Start-up DC input voltage (V_{start})	420...700 V (Default 420 V)	420...700 V (Default 500 V)
Operating DC input voltage range ($V_{dcmin}...V_{dcmax}$)	0,7xV_{start} ...950 V (min 300 V)	0,7xV_{start} ...950 V (min 360 V)
Rated DC input voltage (V_{dcr})	610 Vdc	720 Vdc
Rated DC input power (P_{dcr})	52000 W	61800 W
Number of independent MPPT	3 (SX and SX2 version) / 1 (standard and SX version)	
Maximum DC input power for each MPPT ($P_{MPPT,max}$)	17500 W	21000 W
MPPT input DC voltage range ($V_{MPPTmin}$ ... $V_{MPPTmax}$) at P_{acr}	480-800 Vdc	570-800 Vdc
Maximum DC input current (I_{dcmax}) for each MPPT	36 A	
Maximum input short circuit current for each MPPT	55 A (165 A in case of parallel MPPT)	
Number of DC input pairs for each MPPT	5	
DC connection type	Screw terminal block (Standard and -S version) or PV quick fit connector [3] (-SX and SX2 version)	
Input protection		
Reverse polarity protection	Yes, from limited current source	
Input over voltage protection for each MPPT - varistor	Yes, 1 for each MPPT	
Input over voltage protection for each MPPT - plug In modular surge arrester	Type 2 (option) with monitoring	
Photovoltaic array isolation control	According to local standard	
DC switch rating for each MPPT (version with DC switch)	60 A / 1000 V for each MPPT (180 A in case of parallel MPPT)	
Fuse rating (version with fuses)	15 A / 1000 V	
Output side		
AC grid connection type	Three-phase (3W+PE or 4W+PE)	
Rated AC power (P_{acr} @cosϕ=1)	50000 W	60000 W
Maximum AC output power (P_{acmax} @cosϕ=1)	50000 W	60000 W
Maximum apparent power (S_{max})	50000 VA	60000 VA
Rated AC grid voltage ($V_{ac,r}$)	400 V	480 V
AC voltage range	320...480 V [1]	384...571 V [1]
Maximum AC output current ($I_{ac,max}$)	77 A	
Contributory fault current	92 A	
Rated output frequency (f_r)	50 Hz / 60 Hz	
Output frequency range ($f_{min}...f_{max}$)	47...53 Hz / 57...63 Hz [2]	
Nominal power factor and adjustable range	> 0.995; 0...1 inductive/capacitive with maximum S_{max}	
Total current harmonic distortion	<3%	
Maximum AC cable	95 mm² copper only (150 mm² copper/alluminum with TRIO-AC-WIRING-KIT)	
AC connection type	Screw terminal block, cable gland	
Output protection		
Anti-islanding protection	According to local standard	
Maximum external AC overcurrent protection	100 A	
Output overvoltage protection - varistor	Yes	
Output overvoltage protection - plug In modular surge arrester	Type 2 (option) with monitoring	
Operating performance		
Maximum efficiency (ηmax)	98.3%	98.5%
Weighted efficiency (EURO)	98.0% / -	98.0% / -
Communication		
Embedded communication interfaces	2x RS485, 2x Ethernet (RJ45), WLAN (IEEE802.11 b/g/n @ 2,4 GHz)	
Communication protocols	Modbus RTU / TCP (Sunspec compliant); Aurora Protocol	
Remote monitoring services	Standard level access to Aurora Vision monitoring portal	
Advanced features	Integrated Web User Interface; Display (option); Embedded logging and direct transferring of data to Cloud	
Environmental		
Ambient temperature range	-25...+60°C (-13...140 °F) with derating above 45 °C (113 °F)	-25...+60°C (-13...140 °F) with derating above 45 °C (113 °F)
Relative humidity	4%... 100% condensing	
Sound pressure level, typical	75 dB(A) @1 m	
Maximum operating altitude	2000m / 6561ft	
Physical		
Environmental protection rating	IP65 (IP54 for cooling section)	
Cooling	Forced air	
Dimension (H x W x D)	725 mm x 1491 mm x 315 mm / 28.5" x 58.7" x 12.4"	
Weight	95 kg / 209 lbs overall, 66 kg / 145 lbs electronic compartment, 15 kg / 33 lbs AC wiring box (full optional), 14kg / 31 lbs DC wiring box (full optional)	
Mounting system	Wall bracket, horizontal support	

Figure A.2: ABB inverter

LV POWER CABLES DATA SHEET Ed. 08/2018-05-16

Kabelwerk EUPEN AG cable

EUCASOLAR PV1-F E_{ca}

Besondere Eigenschaften

- Hervorragende UV-Beständigkeit gemäß HD 605/A1
- Hervorragende Witterungs- und Ozonbeständigkeit gemäß EN 50396
- Hervorragende Säure- und Laugenbeständigkeit gemäß IEC/EN 60811-2-1
- Hervorragende Kältebeständigkeit gemäß IEC/EN 60811-1-4
- Hervorragende Mikrobenbeständigkeit
- Hervorragende Ammoniakbeständigkeit
- Hervorragende Beständigkeit gegen Öle und Fette
- Hydrolysebeständig
- Geringe Wasseraufnahme
- Hohe Verschleiß- und Abriebfestigkeit
- Einfache Abisolierbarkeit
- Gutes Einziehverhalten
- Verzinnter Leiter, verhindert Korrosionsprobleme an Anschluß- und Verbindungsschellen

Special properties

- Outstanding UV-resistance acc. to HD 605/A1
- Outstanding ozone and weather resistance acc. to EN 50396
- Outstanding acid and alkaline resistance acc. to IEC/EN 60811-2-1
- Outstanding cold resistance acc. to IEC/EN 60811-1-4
- Outstanding microbe resistance
- Outstanding ammoniac resistance
- Outstanding oil- and grease resistance
- Hydrolysis resistance
- Very low water absorption
- High wear and abrasion resistance
- Easy cable stripping
- Easy feeding
- Tinned conductors prevent corrosion at junction and connection points

Eigenschaften im Brandfall

- Geringe Rauchentwicklung gemäß IEC/EN 61034
- Geringe Brandfortleitung gemäß EN 60332-1-2 E_{ca} IEC 60332-1-2
- Halogenfrei gemäß EN 50267-2-1, IEC/EN 60684-2
- Geringe Korrosivität der Brandgase gemäß EN 50267-2-2
- Geringe Toxizität der Brandgase gemäß NF X70-100-1+2

Properties in case of fire

- Low smoke emission acc. to IEC/EN 61034
- Flame retardant acc .to EN 60332-1-2 E_{ca} IEC 60332-1-2
- Halogen free acc. to EN 50267-2-1, IEC/EN 60684-2
- Low corrosivity of gases acc. to EN 50267-2-2
- Low toxicity of gases acc. to NF X70-100-1+2

Querschnitt Cross-section mm^2	Außendurchmesser Outer diameter mm	Gewicht Weight kg/km	Leiterwiderstand bei 20 °C Conductor resistance at 20 °C Ω/km
4	5,1	53	5,09
6	5,8	75	3,39
10	7,5	130	1,95
16	8,5	185	1,24
25	9,8	268	0,795
35	10,9	363	0,565

Strombelastbarkeit **Current carrying capacity**

Querschnitt Cross-section	Strombelastbarkeit in Abhängigkeit der Verlegeart Current carrying capacity acc. to the method of installation		
	einzeln frei in Luft Single cable free in air	einzeln an Flächen single cable on a surface	2 berührend an Flächen 2 cables in contact on a surface
4	55	52	44
6	70	67	57
10	98	93	79
16	132	125	107
25	176	167	142
35	218	207	176

Umrechnungsfaktoren für höhere Umgebungstemperaturen **Conversion factor for higher temperature**

Umgebungstemperatur Ambient temperature	Umrechnungsfaktor Conversion factor
bis 60 °C / up to 60 °C	1,00
70 °C	0,91
80 °C	0,82
90 °C	0,71
100 °C	0,58
110 °C	0,41

Reduktionsfaktoren bei Häufung
Siehe IEC 60364-5-52 Tabelle A.52-17

Groups rating factors
Refer to IEC 60364-5-52 Table A.52-17

ISO Certified Company

KABELWERK EUPEN AG - Malmedyer Straße 9 - 4700 EUPEN - BELGIUM Tel.: +32(0)87.59.70.00 - Fax : +32(0)87.59.71.00 - http://www.eupen.com

Figure A.3: DC cable

PULSAR 30 STAINLESS STEEL

ABB

PULSAR 30 STAINLESS STEEL

General Information

Extended Product Type	PULSAR 30 STAINLESS STEEL
Product ID	2CTH030002R0000
EAN	3660308521354
Catalog Description	PULSAR 30 STAINLESS STEEL
Long Description	B752135

Ordering

EAN	3660308521354
Minimum Order Quantity	1 piece
Customs Tariff Number	85359000

Dimensions

Product Net Width	7.4 cm
Product Net Height	20 cm
Product Net Depth / Length	78 mm
Product Net Weight	2.1 kg

Container Information

Package Level 1 Units	1 piece
Package Level 1 Width	130 mm
Package Level 1 Height	85 mm
Package Level 1 Depth / Length	387 mm
Package Level 1 Gross Weight	3298 g
Package Level 1 EAN	3660308521354

Additional Information

Brand / Label	Hélita
Options Provided	ESEAT Helita
Product Main Type	ESEAT
Product Name	Lightning Potection Devices
Suitable For	To protect the systems against the transient overvoltage (lightning)

PULSAR 30 STAINLESS STEEL 2

Certificates and Declarations (Document Number)

Data Sheet, Technical Information	2CTC435720D1701

Classifications

ETIM 4	EC000505 - Air-termination equipment for lightning protection
ETIM 5	EC000505 - Air-termination equipment for lightning protection
Object Classification Code	142JZC
WEEE Category	5. Small Equipment (No External Dimension More Than 50 cm)

Categories

Low Voltage Products and Systems → Lightning Protection Products

Paratonnerres **hélita**®
hélita® Lightning protection systems

Figure A.4: PULSAR 30 STANLESS STEEL

LV POWER CABLES DATA SHEET Ed. 06/2014-08-07

Kabelwerk EUPEN AG cable

EUCASOLAR PV1-F

Besondere Eigenschaften

- Hervorragende UV-Beständigkeit gemäß HD 605/A1
- Hervorragende Witterungs- und Ozonbeständigkeit gemäß EN 50396
- Hervorragende Säure- und Laugenbeständigkeit gemäß IEC/EN 60811-2-1
- Hervorragende Kältebeständigkeit gemäß IEC/EN 60811-1-4
- Hervorragende Mikrobenbeständigkeit
- Hervorragende Ammoniakbeständigkeit
- Hervorragende Beständigkeit gegen Öle und Fette
- Hydrolysebeständig
- Geringe Wasseraufnahme
- Hohe Verschleiß- und Abriebfestigkeit
- Einfache Abisolierbarkeit
- Gutes Einziehverhalten
- Verzinnter Leiter, verhindert Korrosionsprobleme an Anschluß- und Verbindungsschellen

Special properties

- Outstanding UV-resistance acc. to HD 605/A1
- Outstanding ozone and weather resistance acc. to EN 50396
- Outstanding acid and alkaline resistance acc. to IEC/EN 60811-2-1
- Outstanding cold resistance acc. to IEC/EN 60811-1-4
- Outstanding microbe resistance
- Outstanding ammoniac resistance
- Outstanding oil- and grease resistance
- Hydrolysis resistance
- Very low water absorption
- High wear and abrasion resistance
- Easy cable stripping
- Easy feeding
- Tinned conductors prevent corrosion at junction and connection points

Eigenschaften im Brandfall

- Geringe Rauchentwicklung gemäß IEC/EN 61034
- Geringe Brandfortleitung gemäß IEC/EN 60332-1-2
- Halogenfrei gemäß EN 50267-2-1, IEC/EN 60684-2
- Geringe Korrosivität der Brandgase gemäß EN 50267-2-2
- Geringe Toxizität der Brandgase gemäß NF X70-100-1+2

Properties in case of fire

- Low smoke emission acc. to IEC/EN 61034
- Flame retardant acc .to IEC/EN 60332-1-2
- Halogen free acc. to EN 50267-2-1, IEC/EN 60684-2
- Low corrosivity of gases acc. to EN 50267-2-2
- Low toxicity of gases acc. to NF X70-100-1+2

Querschnitt Cross-section mm²	Außendurchmesser Outer diameter mm	Gewicht Weight kg/km	Leiterwiderstand bei 20°C Conductor resistance at 20°C Ω/km
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10	7,5	130	1,95
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25	9,8	268	0,795
35	10,9	363	0,565

Strombelastbarkeit / Current carrying capacity

Querschnitt Cross-section	Strombelastbarkeit in Abhängigkeit der Verlegeart Current carrying capacity acc. to the method of installation		
	einzeln frei in Luft Single cable free in air	einzeln an Flächen single cable on a surface	2 berührend an Flächen 2 cables in contact on a surface
mm²	A	A	A
4	55	52	44
6	70	67	57
10	98	93	79
16	132	125	107
25	176	167	142
35	218	207	176

Umrechnungsfaktoren für höhere Umgebungstemperaturen / Conversion factor for higher temperature

Umgebungstemperatur Ambient temperature	Umrechnungsfaktor Conversion factor
bis 60 °C / up to 60°C	1,00
70°C	0,91
80°C	0,82
90°C	0,71
100°C	0,58
110°C	0,41

Reduktionsfaktoren bei Häufung
Siehe IEC 60364-5-52 Tabelle A.52-17

Groups rating factors
Refer to IEC 60364-5-52 Table A.52-17

Figure A.5: AC & DC cable

Miniature circuit-breakers
S800 PV-S

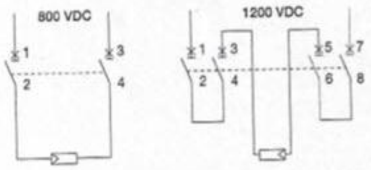
(1) DC- Circuit Breaker

The S800 PV-S modular miniature circuit-breakers can be used in networks up to 1200 VDC (4-poles execution). The S800 PV-S circuit breakers and its range of accessories (auxiliary contacts, undervoltage releases, motorized commands) allow for a wide spectrum of configurations.
The main features of the S800 PV-S circuit breakers include:
- interchangeable terminals
- central trip safe disconnection of all poles
- contact status displayed for each pole
- polarity independent wiring

Main technical specifications		S800 PV-S	
Reference Standards		IEC EN 60947-2	
Rated current	A	10...80	100, 125
Number of poles		2, 4	
Rated voltage Ue			
(DC) 2 poles*	V	800	600
(DC) 4 poles*	V	1200	1200
Ultimate rated short-circuit breaking capacity Icu			
(DC) 2 poles* 800 V	kA	5	5
(DC) 4 poles* 1200 V	kA	5	5
Thermomagnetic release characteristic		4 In ≤ Im ≤ 7 In	
Class of use		A	
Operating temperature	°C	-25...+60	
Mounting		DIN rail EN 60715 (35 mm) by means of fast clip device	

* Please refer to the wiring diagrams

Panel network in earth-insulated systems
≤ 80A



100, 125A

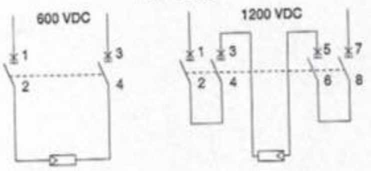


Figure A.6: DC circuit breaker

Surge protective devices
OVR PV

(2) DC- Surge Arrester

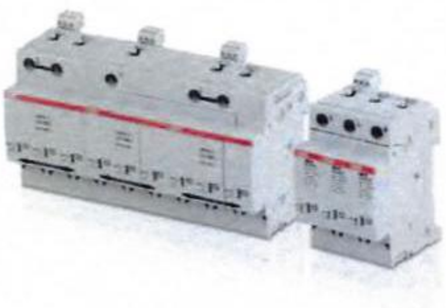
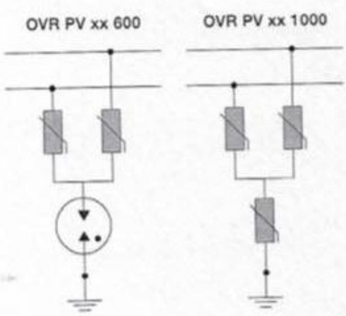


ABB offers a wide range of surge protection devices specifically designed for photovoltaic systems. The main features of the OVR PV SPDs include:
- OVR PV T1 and T2 version
- Auto-protected from end-of-life short circuits up to 100 A DC thanks to the integrated thermal protection with direct current breaking capacity
- pluggable cartridges for easy maintenance, no need to disconnect the line
- auxiliary contact for remote signaling of line status ("TS" version)
- absence of short circuit follow current
- absence of risk for reversed polarity
- "Y" configuration for a safer protection



Main technical specifications		OVR PV T1	OVR PV 40
Reference standards		IEC 61643-11 / UTE C 61740-51 prEN 50539-11 UL 1449 3rd edition*	
Configuration		Y	Y
SPDs Type / Test Class		T1 / I	T2 / II
Max. cont. Operating voltage Ucpv	V	670 / 1000	670 / 1000
Nominal discharge current In (8/20 µs)	kA	6.25	20
Impulse current Iimp (10/350 µs)	kA	6.25	-
Maximum discharge current Imax (8/20 µs)	kA	-	40
Voltage protection level Up	kV	1.9 / 2.5	2.8 / 3.8
Short circuit DC current withstand Iscwpv	A	100	100
Back-up protection: - if Iscwpv ≤100A - if Iscwpv >100A		- not required - 10A gPV fuse	- not required - 10A gPV fuse or MCB
Response time	ns	≤25	≤25
Specific integrated PV thermal disconnector		Yes	Yes
Pluggable		Yes	Yes
Auxiliary contact		TS	TS

*UL version only for OVR PV 40

OVR TC
With increasing request of monitoring systems, OVR TC data line SPDs are right choice to protect the monitoring lines of the PV plants from surges. They are installed in series with the network and have removable cartridges, making maintenance simple, without having to cut the power to the telecommunications line.

Main technical specifications		OVR TC
Reference Standard		IEC/EN 61643-21 - UL497B
IEC type		C2
Max. cont. operating voltage Uc	V	7 to 220V (AC/DC)
Nominal Discharge current In (8/20us)	kA	5
Max. discharge current Imax (8/20us)	kA	10
Response time	ns	1
Pluggable		Yes

Figure A.7: DC_surge arrester

Surge protective devices
OVR T1 & T2, OVR TC

(4)
Ac - Surge Arrester

To provide efficient protection for a photovoltaic system the alternate current side must also be protected against overvoltage.
OVR T1, Type-1 SPD, is installed in the main (AC side) switchboard at the system input and is able to conduct the direct lightning current to earth and to ensure safety in the case of a direct lightning strike.
OVR T2, Type-2 SPDs, are installed on the load side of the inverter and in possible other sub-switchboard to protect against switching surges and the indirect effect of lightning.

The main features of the OVR range are:
- Network configuration in single pole, 3 poles, 1 Phase+N and3 Phases+N
- Simplified maintenance with the pluggable cartridges (P option)
- Increased security with the safety reserve (S option)
- Remote indication with the auxiliary contact (TS option).

Main technical specifications		OVR T1	OVR T2
Reference Standards		IEC EN 61643-11 / UL 1449 3rd edition*	
IEC Type		T1 / I	T2 / II
Max. cont. Operating Voltage Uc	V	255	275
Nominal discharge current In (8/20 μs)	kA	15 and 25	5, 20 and 30
Impulse current Iimp In (10/350 μs)	kA	15 and 25	/
Maximum discharge current Imax (8/20 μs)	kA	/	20, 40 and 70
Response time	ns	< 100	< 25
Safety reserve		/	"S" Version
Pluggable		/	"P" Version
Remote indicator		"TS" Version	"TS" Version

Figure A.8: AC_surge arrester

S204-C40

(5) AC - 4pole CB

General Information

Extended Product Type:	S204-C40
Product ID:	2CDS254001R0404
EAN:	4016779529259
Catalog Description:	Miniature Circuit Breaker - S200 - 4P - C - 40 ampere
Long Description:	System pro M compact S200 miniature circuit breakers are current limiting. They have two different tripping mechanisms, the delayed thermal tripping mechanism for overload protection and the electromechanic tripping mechanism for short circuit protection. They are available in different characteristics (B,C,D,K,Z), configurations (1P,1P+N,2P,3P,3P+N,4P), breaking capacities (up to 6 kA at 230/400 V AC) and rated currents (up to 63A). All MCBs of the product range S200 comply with IEC/EN 60898-1, IEC/EN 60947-2, UL1077 (for this code purchased in South America there is no UL certificate), allowing the use for residential, commercial and industrial applications. Bottom-fitting auxiliary contact can be mounted on S200 to save 50% space.

Categories

Products » Low Voltage Products and Systems » Modular DIN Rail Products » Miniature Circuit Breakers MCBs

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\+ Accessories

Technical

Standards:	IEC/EN 60898-1 IEC/EN 60947-2 UL 1077
Number of Poles:	4
Number of Protected Poles:	4
Tripping Characteristic:	C
Rated Current (I_n):	40 A
Rated Operational Voltage:	acc. to IEC 60898-1 400 V AC acc. to IEC 60947-2 440 V AC
Power Loss:	19.2 W at Rated Operating Conditions per Pole 4.8 W
Rated Insulation Voltage (U_i):	acc. to IEC/EN 60664-1 440 V
Operational Voltage:	Maximum (Incl. Tolerance) 440 V AC Maximum 440 V AC Minimum 12 V AC Minimum 12 V DC
Rated Frequency (f):	50 Hz 60 Hz
Rated Short-Circuit Capacity (I_{cn}):	(400 V AC) 6 kA
Rated Ultimate Short-Circuit Breaking Capacity (I_{cu}):	(230 V AC) 20 kA (440 V AC) 10 kA
Rated Service Short-Circuit Breaking Capacity (I_{cs}):	(230 V AC) 15 kA
Energy Limiting Class:	3
Overvoltage Category:	III
Pollution Degree:	3
Rated Impulse Withstand Voltage (U_{imp}):	4 kV (6.2 kV @ sea level) (5.0 kV @ 2000 m)
Dielectric Test Voltage:	50/60 Hz, 1 min: 2 kV
Housing Material:	Insulation Group II, RAL 7035
Actuator Type:	Insulation group II, black, sealable
Actuator Material:	Insulation Group II, Black, Sealable
Actuator Marking:	I / O
Contact Position Indication:	Red ON / Green OFF
Degree of Protection:	IP20

Figure A.9: AC 4 poles circuit breaker

DC string boxes

(3) - String box

ABB catalog of photovoltaic systems is complemented by a wide range of field switchboards, string switchboards and parallel switchboards ready to install. These products, based on insulation class II units, are equipped with all the necessary components to realize the functions of protection and isolation, according to the type of system.

1 string
Europa consumer units
IP65 8 modules
10 A, 800 V
Miniature circuit breaker
S802PV-S10
Surge arrester
OVR PV 40 1000 P TS

Europa consumer units
IP65 12 modules
16 A, 660 V
Switch-disconnector
OTDC 16 F2
Surge arrester
OVR PV 40 1000 P TS
Disconnecting fuses
E 92/32 PV

16 A, 1000 V
Switch-disconnector
OTDC 16 F3
Surge arrester
OVR PV 40 1000 P TS
Disconnecting fuses
E 92/32 PV

2 strings
Europa consumer units
IP65 12 modules
16 A, 800 V
Miniature circuit breaker
S802PV-S16
Surge arrester
OVR PV 40 1000 P TS

Europa consumer units
IP65 18 modules
25 A, 660 V
Switch-disconnector
OTDC 25 F2
Surge arrester
OVR PV 40 1000 P TS
Disconnecting fuses
E 92/32 PV for each string

25 A, 1000 V
Switch-disconnector
OTDC 25 F3
Surge arrester
OVR PV 40 1000 P TS
Disconnecting fuses
E 92/32 PV for each string

Figure A.10: String Box