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“Design and Financial Offer for 1MW Solar system Power Plant”

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Project Overview

The aim of this project report is to estimate and calculate the approximate design of a 1MW solar PV power plant (utility scale).

The total number of solar panel required and the different parameters of the solar panel estimated. A site in Jericho is taken to estimate the solar intensity of the site which is most important for calculation of such type of report.

A Single Line Diagram (SLD) has been introduced in this report.

Also the brief details of the materials/equipment's (solar panels, inverters, Protection System) used to set up a 1MW power plant has been highlighted.

A financial overview with a possible income datasheet included in the project report .

Contents

List of Figures

Chapter 1 Introduction

1.1 Cover Letter

Dear Sir\Madam –

We are pleased to provide you our financial offer, preliminary technical designs ,and software simulation for the installation of a 1MWp PV power system in Jericho.

Please consider the following notes:

- The Prices are in US Dollars and include taxes.
- The prices include the cost of shipping goods from overseas, clearance charges from the port, inland transportation to site, installation, and commissioning.
- The cost of the design is included in the total price.
- All works are under full warranty for one year from date of commissioning of the system, and the warranties are specified in the warranties list enclosed.
- Datasheets for the relevant products are enclosed.
- Software simulations expected for the PV performance with electrical shop drawings are enclosed.

Best Regards,

1.2 Literature Review

Grid-Connected PV Systems

Grid-connected PV systems are systems connected to a large independent grid usually the public electricity grid and feed power directly into the grid. These systems are usually employed in both decentralized grid-connected PV applications and centralized grid-connected PV applications. Decentralized grid-connected PV applications include rooftop PV generators, where the PV systems are mounted on rooftops of buildings and building integrated system in which the PV systems are incorporated into the building. In the case of residential or building mounted grid connected PV systems, the electricity demand of the building is met by the PV system and the excess is fed into the grid; their capacities are usually in the lower range of kilowatts.

A typical grid-connected PV system comprises the following components:

• Solar PV Modules: these convert sunlight directly to electricity.

• Inverter: converts the DC current generated by the solar PV modules to AC current for the utility grid.

• Main disconnect/isolator Switch

• Utility Grid

Chapter 2

Design of the System

2.1 Irradiance Calculations

A Simulink model was built and used in order to calculate the irradiance along the year and the PSH for each month in order to simplify the design procedure.

The calculations were made for Jericho city, and the following parameters were used in order to get the maximum power transfer during summer.

City	Jericho
Country	Palestine
Latitude	31.8666700
Tilt Angle	16

Table1: Site Specifications

After simulating the model under the last parameters situation, the following results were obtained:

Fig. 2.1: Solar Irradiance During June

The average PSH during June was found to be = 7.88and it is the value the system will be designed around.

Simulation was done for all the months as well and the following results were obtained for each month:

The Global Irradiation for each month was found using SMA software as follows :

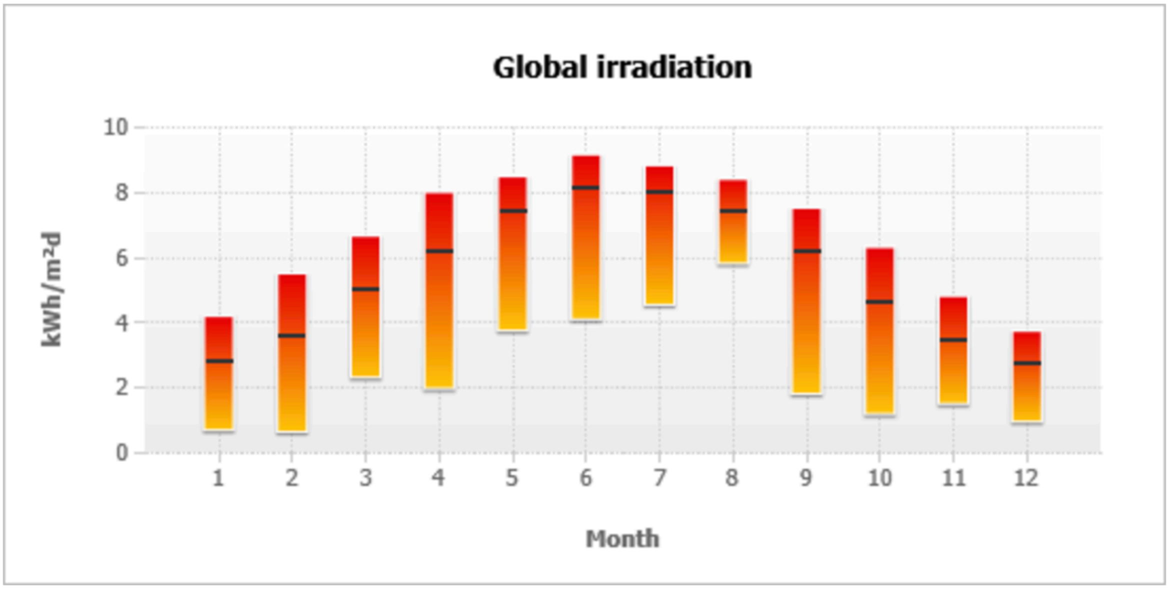


Fig. 2.2: Global Irradiation for the West Bank

Then using Simulink :

Month	**PSH**
January	3.58
February	4.27
March	5.35
April	6.5
May	7.06
June	7.88
July	7.66
August	7.6
September	6.93
October	5.66
November	4.12
December	3.7

AvgPSH= 5.85

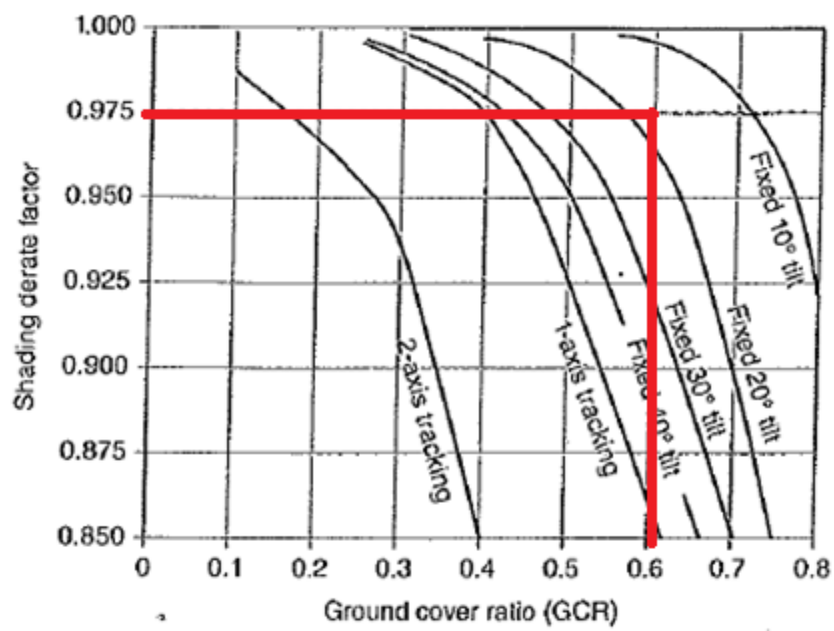
2.2 Area and Spacing Calculations

Spacing between panels to avoid shading between 9-3 Pm can be calculated using the GCR formula given as follows:

$$GCR = \frac{Ac}{Atot}$$

where Ac is the collector area in [m^2] and Atot is the total ground area occupied by the panel and spacing d.

A de-rating factor of 0.975 is chosen and the GCR is found as shown in figure:



$$GCR = \frac{2*0.99*1.956}{(0.99*2*cos16+d)*1.956} = 0.6$$

Solving the equations yields a distance of 1.4m between each row.

Notice that two modules are aligned with each other and the bottom of the lower module is 1.956m.

Total Area was found to be 1127m^2 using online software.

2.3 On-Grid System Design

2.3.1 PV Modules Design

In order to build the system, JA Shanghai Solar panels where chosen, the maximum power of the Mono- Crystalline Panel is equal to 345Wp and this is the highest value in the world, it was a new number this year with efficiency = 18.06%.

Fig. 2.3: JA Solar Panels.

In order to design the 1MWp power plant, 2899 PV modules were needed . The warranty of the modules are a "Linear" decrease through 25 years starting from 100% at the first year until it reaches 80% of its maximum power capability after 25 years.

- **The output power of the system is given by the following equation :**

$$P_{array} = one\ panel\ power \times number\ of\ panels \times average\ efficiency$$

the average efficiency along 25 years were found to be 90%.
Then :

$$P_{array} = 345 \times 2899 \times 0.9 = 900{,}139.5\ Watt$$

- **Considering Derating Factors and Losses**

The derating factor of the temperature was found to be = 0.004%/C ,
Then :

$P_{temp} = P_{array} \times \{(T_{max} - T_{nominal})\times 0.004\}$

Tmax = 45 then :

$P_{temp} = 900{,}139.5 \times \{(45 - 25)\times 0.004\}$ = 828,128.34 Watt

The mismatch factor plus the soiling factor was found considered as 1% due to its large system and continues maintenance.

$$P_{mismatch} = P_{temp}\times mismatch\ factor$$

Then :

$$P_{mismatch} = 828{,}128.34 \times 0.99 = 819{,}847$$

2.3.2 Inverters Design

inverters are needed in order to invert the DC power into an AC power, the value was chosen to be > Pmismatch.

With PV Modules parameters : **Vmpp= 38.39 Volt and Impp=8.99 A** for each module, the inverter system were designed to be :

50kW **ABB** inverters were used with efficiency of the inverter =98.6%.

$$P_{inv} = 0.986 \times 819{,}847 = 808369.14$$

inverter specifications:

Idc=100A , V=520-800 Volt

So the following design was done :

20 inverters : each inverters has 7 strings in parallel, each string has 20 panels
1 inverter : has 11 string each string with 9 panels.

2.3.3 Design Schematics

The following figure represents the single line diagram for the 20 inverters, the figure was drawn using Autocad software :

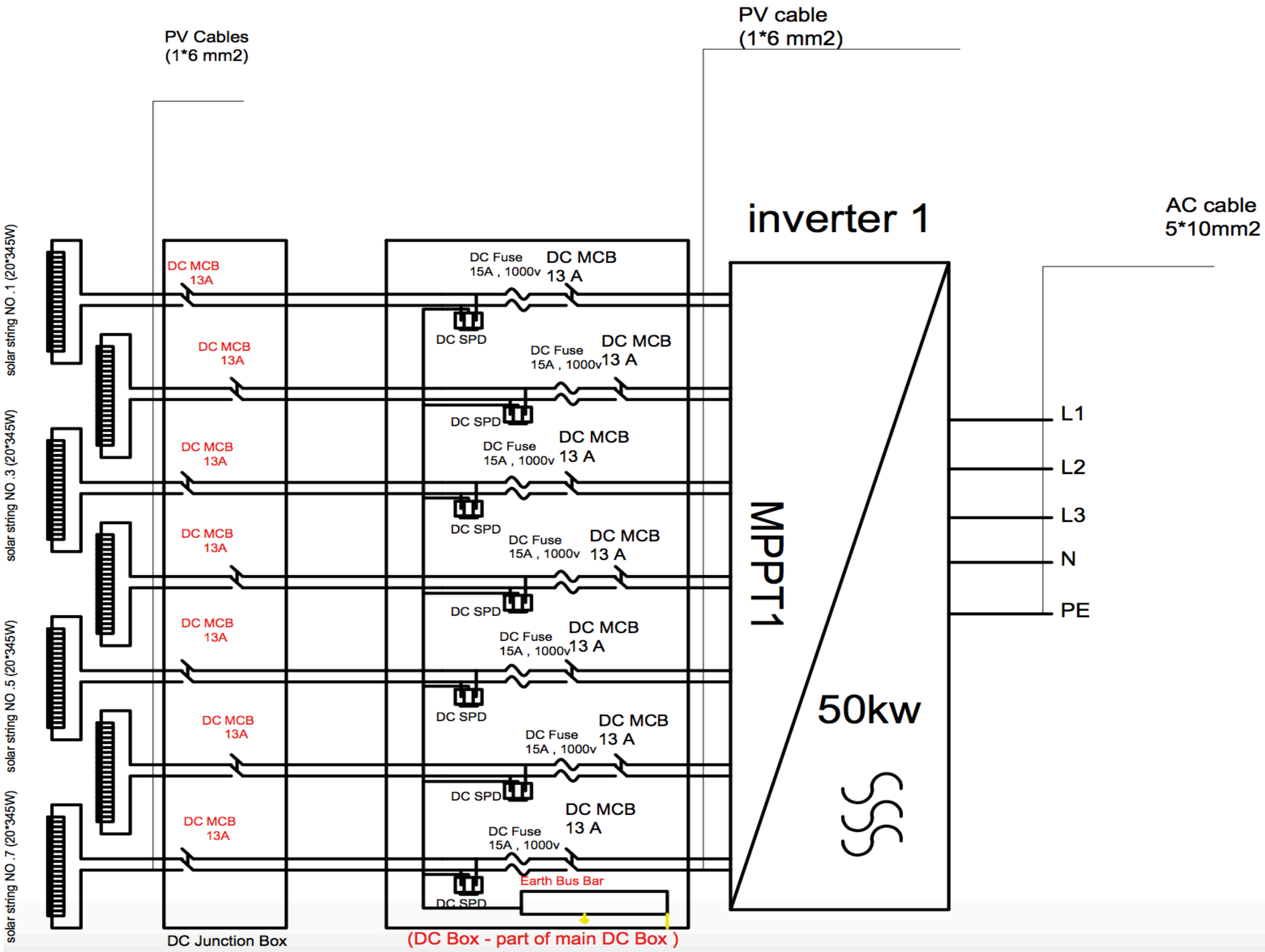


Fig. 2.4: Single Line Diagram for 20 Inverters.

The following figure shows the single line diagram for the last inverter :

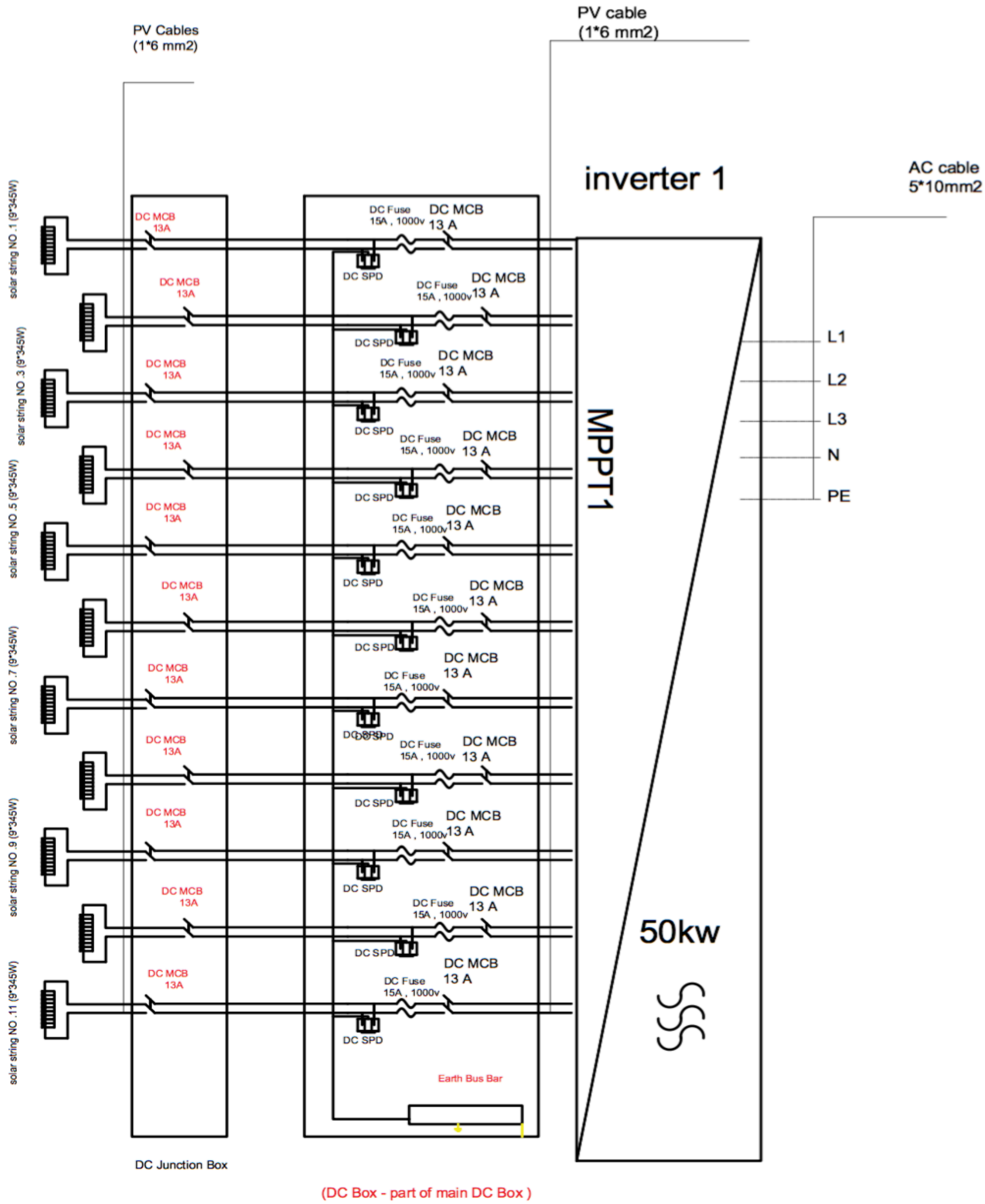


Fig. 2.5: Single Line Diagram for the last Inverter.

The following figures show the PV Panels arrangements for a part of the system using SolidWork software:

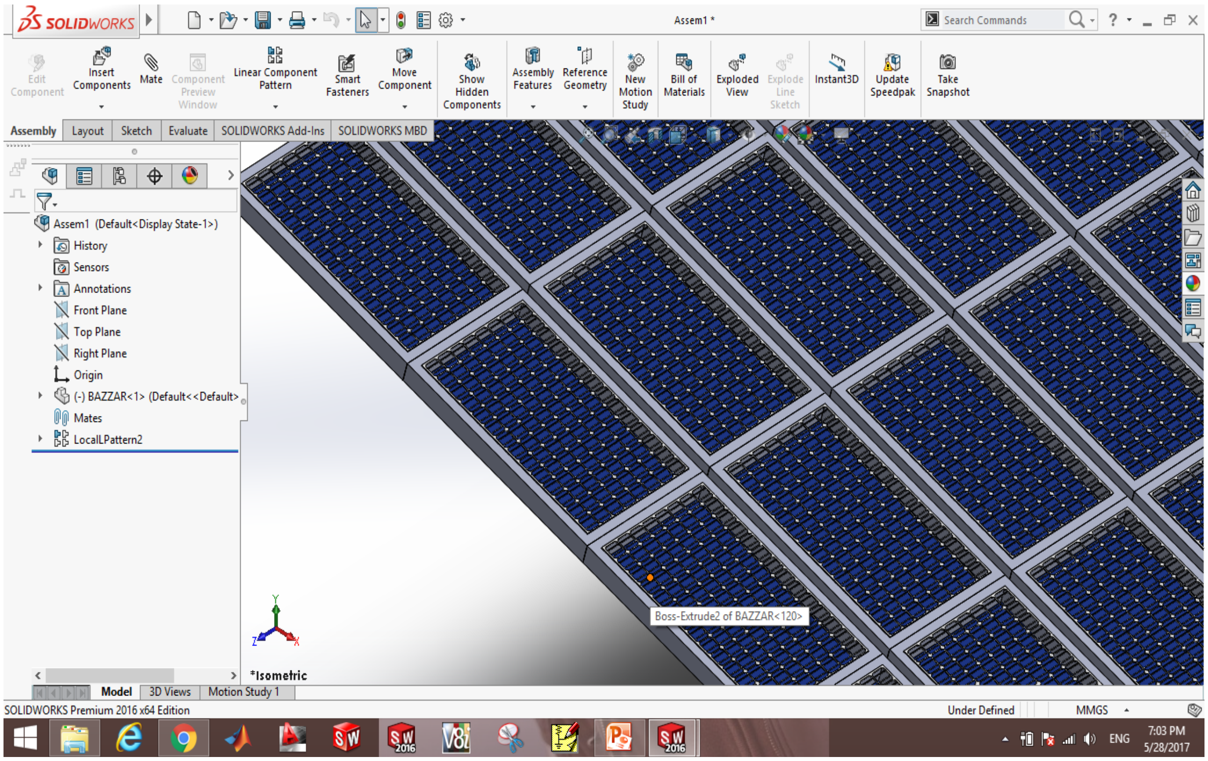


Fig. 2.6: Panels arrangement using SolidWork.

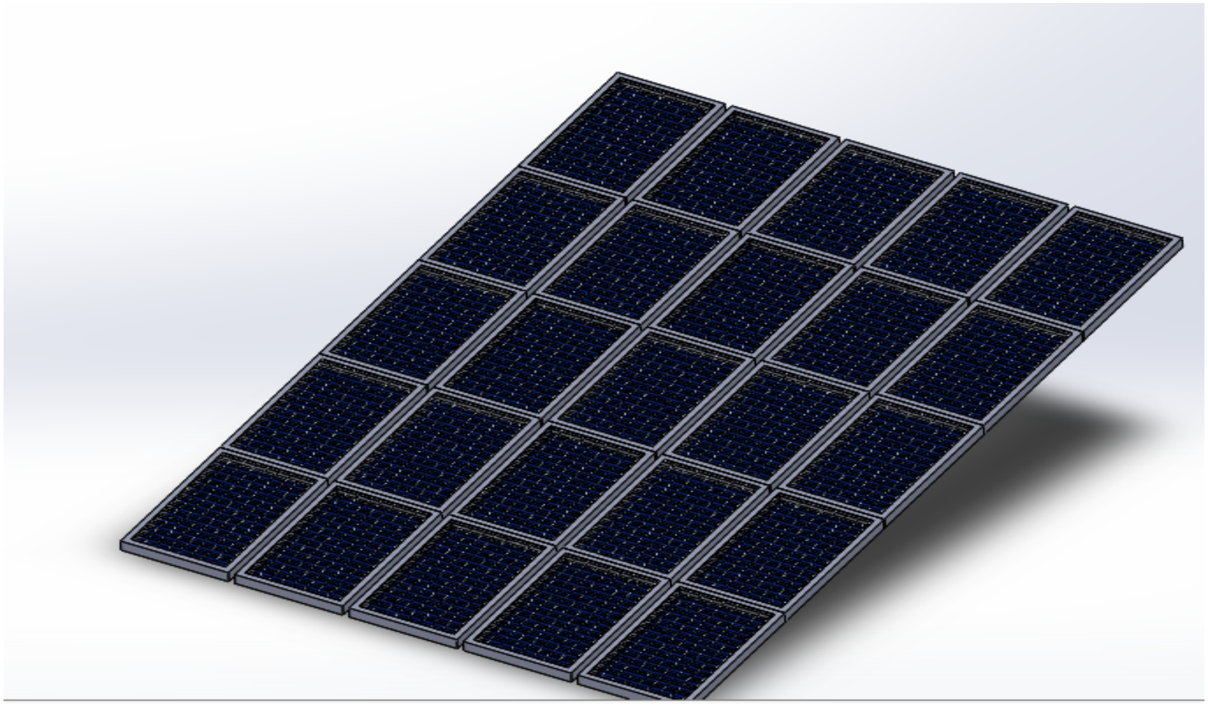


Fig. 2.7: Panels arrangement for part of the plant.

2.4 Bill of Quantities

Item	*Brand*	*Quantity*
Solar Panels 345w	JA Solar	*2899*
Inverter 50 kw	*ABB (ITALY)*	*21*
DC cables	*6 mm cross-section*	*A.N*
AC Cable	*16 mm cross section*	*A.N*
MC4	*****	*300*
DC String protection	*ABB Box with appropriate compnentes(Italy)*	*151*
AC String protection	*ABB Box with appropriate compnentes(Italy)*	*21*
Junction Box	*Water proof*	*21*
Surge Arrester	*Schneider \ ABB*	*2*
Earth cable	*Based on JDECO Requirments*	*A.N*
Structure	*Galvanized (Local Manufacturer)*	*1*
Structure Accessories	*****	*A.N*

Chapter 3

Simulation Results

Simulation were done just for 100kW of the system due to the lack of suitable components to perform all the panels capability.

3.1 Irradiance

Irradiance was built as a function as follows:

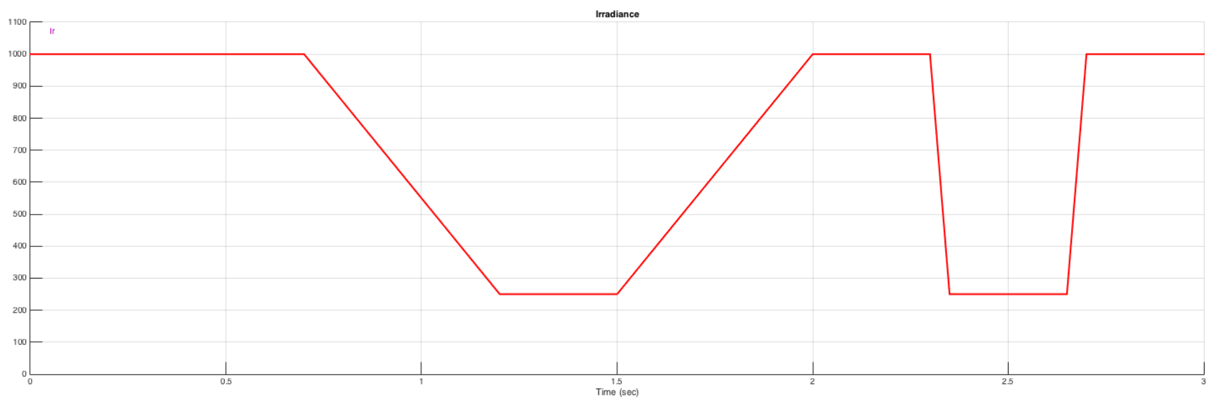


Fig. 3.1: Irradiance

3.2 MPPT Algorithm

Incremental conductance method were used to build the MPPT system , the following result shows how the maximum power point were achieved and dI\dV was almost always equal to zero :

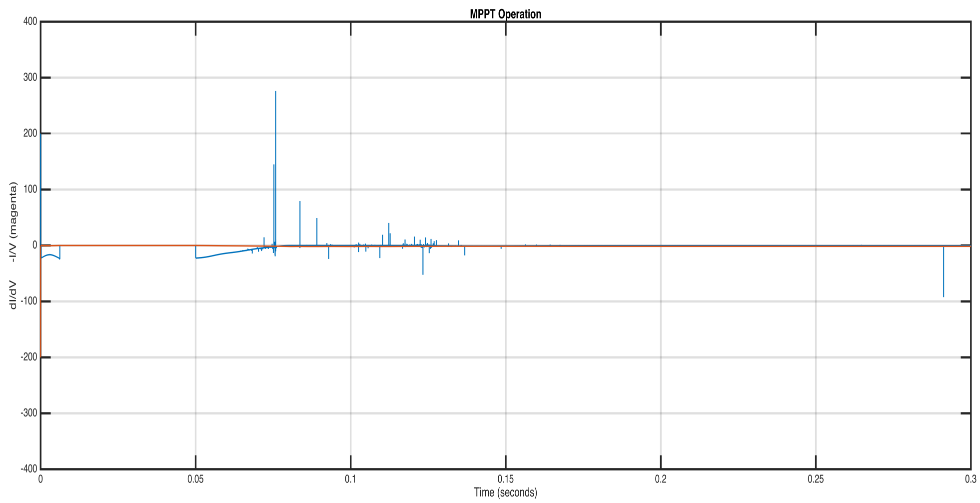


Fig. 3.2: MPPT Operation

The MPPT was achieved by changing the duty cycle, the following figure shows how the duty cycle was changed:

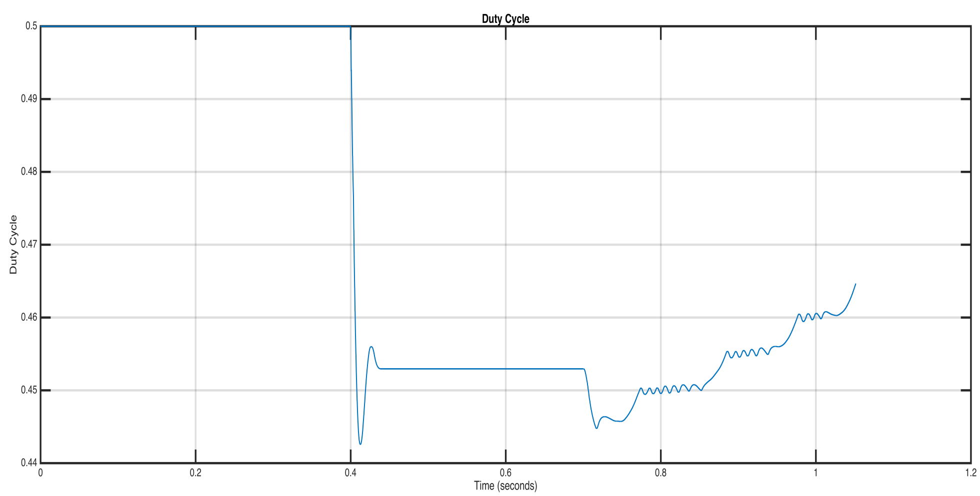


Fig. 3.3: Duty Cycle

3.3 Output Power

The following figure shows the output power, and how it achieved 100kw when the Irradiance was = 1 sun /hour

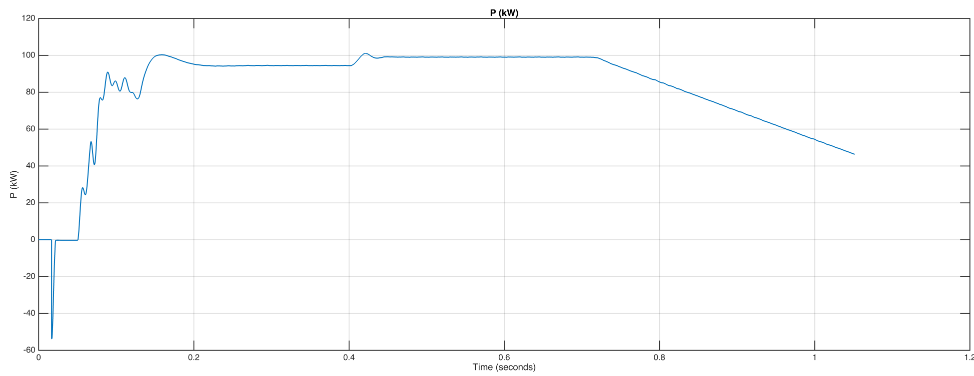


Fig. 3.4: Output Power

Chapter 4

Financial Offer

4.1 Products and Technical Specifications

The following table shows the used equipment's with its warranties and cost:

Solar Panels:

after we contacted companies in the country, we knew that they buy the solar panels for 0.35 $ for each watt for a system this big, and sell it for 0.7$.

Company	Country	Warranty
JA Solar	China	Years 25

:

Inverter:

The cost of each inverter is 18,000$

Company	Country	Warranty
ABB	Italy	Years 10

4.2 Financial Analysis Conclusion

This chapter studies the income of the investment depending on the financial offer and the design in the previous chapters.

$$Cost = PanelsCost + InvertersCost + Structure + Cables\,\&\,Brea\text{ker}\,andOthers + InstallationCosts$$

$$= 0.7 \times 1000{,}000 + 18{,}000 \times 21 + 20{,}000 + 50{,}000 + 120{,}000$$

Total Cost=1,268,000 $
Annual Maintenance cost= 1000$

Considering the cost of each Kw= 0.54 shekel = 0.15$

	Year	**Payments($)**	**Annual Production(MWatt)**	**Saved Money**
1	2018	1,268,000	2135.25	320287.5
2	2019	1000	2113.9	317084.6
3	2020	1000	2092.5	313881.8
4	2021	1000	2071.2	310678.9
5	2022	1000	2049.8	307476
6	2023	1000	2028.5	304273.1
7	2024	1000	2007.1	301070.3
8	2025	1000	1985.8	297867.4
9	2026	1000	1964.4	294664.5
10	2027	1000	1943.1	291461.6
11	2028	1000	1921.7	288258.8
12	2029	1000	1900.4	285055.9
13	2030	1000	1879	281853
14	2031	1000	1857.7	278650.1
15	2032	1000	1836.3	275447.3
16	2033	1000	1815	272244.4
17	2034	1000	1793.6	269041.5
18	2035	1000	1772.3	265838.6
19	2036	1000	1750.9	262635.8
20	2037	1000	1729.6	259432.9

Total Saving =5,797,204$

Average Annual Saving = 289,860$

Payback Period =4.23 years