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Photovoltaic Electric Vehicle Charging Station Under Jordanian Climate

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Abstract

With the advancement of the industry today and the increasing prices of fuel in the world, private businesses are looking for alternative and cheaper sources of energy, in this paper we will attempt to supply ELECTRIC VEHICLE with electrical energy using a PV system.

We discussed the type of station levels and the components of these station like Photovoltaic array, Inverter; on-grid and of grid, Charge Controllers, Maximum power point tracking (MPPT) , AC/DC main cable, battery. Then we studied the economic feasibility for all types of these stations.

By using Simulink and modeling programs; we obtain analytical electrical data for the system, such as load curves, output power curves, and various other characteristics curves.

Keywords: Photovoltaic, Electric Vehicle, Battery, Simulink.

1. Introduction

In this paper we are going to explain our applications which are charging stations for LEAF NISSAN electrical car, 24 kwh, 100miles, move 350-400 kwh/month, that mean 52 mile/day in average.

And we are going to compare between these stations depending on the economic feasibility for each, and compare between the electrical car and the oil car.

1.1 Charging Station:

This station is considered a residential station for LEAF NISSAN .move 52 mile/day in average. There are two types; off-grid, and on-grid charging station.

1.2 Off-Grid Charging Station:

This station is made for a house at Jordan – Amman – Khalda - King Abdullah II St, which has the following radiation data (Table 1):

Table 1. Radiation data for Amman, Khalda City.

Month	Daily radiation ($KWh\ m^{-2}\ day^{-1}$) on horizontal surface	Monthly Averaged Daylight Hours (hours)	Daily radiation for tilt 31^o ($KWh\ m^{-2}\ day^{-1}$)
January	2.85	10.3	3.90
February	3.54	11.0	4.44
March	4.76	11.9	5.33
April	6.08	12.9	6.05
May	6.98	13.7	6.39
June	7.77	14.2	6.77
July	7.53	14.0	6.70
August	6.67	13.3	6.43
September	5.7	12.3	6.16
October	4.17	11.4	5.11
November	3.17	10.5	4.25
December	2.63	10.1	3.75
	Avg = 5.27	Avg = 12, 133	Avg =5.44

- We use 3, 3 kw48/230Volt, off-grid inverter, and 30.35Volt, 8.24 A, 250 W Philadelphian PV module.
- Our car is LEAF NISSAN EV which has 24 kWh battery with 4.1667 miles/kwh, the car move 350-400 kwh/month, that mean 52 mile/day in average.

$$\text{miles/kwh} = \frac{100miles}{24kwh} = 4.166miles/kwh \quad (1)$$

$$\text{Total kwh/day} = \frac{52.0834}{4.1667} = 12.5\ \text{kwh/day} \quad (2)$$

Efficiency (η) = wiring η x inverter η x batteries η x Dry factor
(η) = 0.98 x 0.96 x 0.9 x 0.9 = 0.762

$$\text{Number of modules on series} = \frac{\text{inverter input voltage}}{\text{module nominal voltage}} \quad (3)$$

$$= \frac{60}{30.46} = 1.966 \simeq \mathbf{2\ modules}$$

$$\text{Number of modules on Parallel}$$

$$= \frac{kwh/day}{nominal\ module\ current\ x\ \eta\ x\ system\ voltage\ x\ LDSR}$$

$$= \frac{12.5\ x\ 10^3}{8.21\ x\ 0.762\ x\ (2\ x\ 30.46)x3.75} = 8.777 \simeq \mathbf{9\ modules} \quad (4)$$

Total number of modules=2 x9 = ***18 modules***
Total output power =18 x 250 = 4500 watt
Minimum Output Power of array (10-years) = 4500 x 0.9 = 4050 watt
Minimum Output Power of array (10-25years) = 4500 x 0.8 = 3600 watt

$$\text{Capacity of charge controller} = \frac{Power\ of\ PV}{\text{System Voltage}} = \frac{4500}{2\ x\ 30.46} = \mathbf{73.867\ A} \quad (5)$$

- So we use FLEX MAX charge controller MPPT 80 A capacity, which can receive 83.3A at maximum case.

Wh = Power of PV x LDSR (Least Daily Solar Radiation) x η
= 4500 x 3.75 x 0.762 = ***12858.75 Wh/day***

$$\text{Ah} = \frac{Wh\ (\ watt\ hour\ corrected\ load)x\ Nd\ (\ autonmy\ days)}{\text{DOD (Deapth Of Discharge)}x\ system\ voltage} \quad (6)$$

Nd = -0.48 x LDSR + 4.58 = 2.78 ≃ ***3 days.***

$$\text{Ah} = \frac{12858.75\ x\ 3}{0.7\ \text{x}\ (2\text{x}30.46)} = \mathbf{904.69\ Ah}$$

- If we use 12 volt, 200Ah lead acid battery ;

$$\text{number of series battaries} = \frac{\text{inverter nominal voltage}}{battery\ voltage} = \frac{48}{12} = \mathbf{4\ battaries} \quad (7)$$

$$\text{number of Parallel battaries} = \frac{\text{Ah of the system}}{Ah\ of\ battery} = \frac{904.69}{200} = 4.523 \simeq \mathbf{5\ battaries} \quad (8)$$

Total number of batteries = 4 x 5 = ***20 batteries***

- The Economic Feasibility (Table 2):

Table 2. Off-Gird Economic Feasibility

Item	Price of the piece	Initial cost	Present Worth
Array of PV	316 $	5688.202 $	5688.202 $
Batteries	379 $	7580 $	7580 $
Array mounting	150 $	150 $	150 $
Charge controller	584 $	584 $	584 $
Inverter	1160 $	1160 $	1160 $
EVSE	2500 $	2500 $	2500 $
Batteries at 8th year	261.124 $	-	5222.48 $
Charge Controller at 10th year	366.583 $	-	366.583 $
Inverter at 10th year	728.144 $	-	728.144 $
Total Cost	-	17662.202 $	23979.409 $
		12575.487 JD	17073.34 JD

PW = C_o x 0.9545^N
C_o: initial cost
N: number of years

- As we consider that our car walks 52 mile / day; that mean about 83.6859 km / day:

$$\frac{\text{JD}}{\text{km}} = \frac{\text{Cost for first 8 years}}{83.6859\ km*365*8} = \frac{12575.487}{244362.828} = \mathbf{0.0514}\ \text{JD/km} \quad (8)$$

1.3 On-Grid Charging Station:
This station is made for a house at Jordan – Amman – Khalda - King Abdullah II St:

- We use 4 kw 230Volt, on-grid inverter, and 36.58Volt, 8.21 A, 300 W Philadelphian PV module:

$$\text{Total miles per day} = \frac{375}{30}\ \text{x}\ 4.1667 = \mathbf{52.08\ mile/day} \quad (9)$$

$$\text{Total kwh/day} = \frac{\text{total miles/day}}{mile/kwh} = \frac{52.08}{4.1667} = \mathbf{12.5\ kwh/day} \quad (10)$$

Efficiency (η) = wiring η x inverter η x Dry factor η (η) = 0.98 x 0.943 x 0.9 = ***0.832***

$$\text{Number of modules on series} = \frac{\text{inverter input voltage}}{\text{module nominal voltage}} \quad (11)$$

$$= \frac{250}{36.58} = 6.834 \simeq \mathbf{7\ modules}$$

Number of modules on Parallel

$$= \frac{kwh/day}{nominal\ module\ current\ x\ \eta\ x\ system\ voltage\ x\ LDSR}$$

$$= \frac{12.5\ x\ 10^3}{8.21\ x\ 0.832\ x(\ 7\ x\ 36.58\ )x\ 3.75} = 1.905 \simeq \mathbf{2\ modules} \quad (12)$$

Total number of modules=2 x7 = 14 modules
Total output power =14 x 300 = 4200 watt
Minimum Output Power of array (10-years) = 4200 x 0.9 = 3780 watt
Minimum Output Power of array (10-25years) = 4200 x 0.8 = 3360 watt
Average Wh/day = Power of PV x Average Daily Solar Radiation x η
= 4200 x 5.44 x 0.832 = **19009.536 Wh/day**

- If we feed the grid by 19.009 kwh /day that mean 570.286 kwh / month , according to the JEPCO tariff :

160*.033=5.28 JD
570.286 -160 = 410.286 kWh
300 * 0.072 = 21.6 JD
110.286 * .086 = 9.4846 JD
We have to get on (5.28 + 21.6 + 9.4846) = 36.3646 JD/month
In 8-years = (36.3646 /30) x 365 x 8= **3539.488 JD**

- On the other hand it will consume from the grid 12.5kwh/day according to the average usage in Jordan, that mean 375 kwh/month.

160 x 0.033 = 5.28 JD
375 – 160 = 215 kWh
215 x 0.072 = 15.48 JD
Total consuming from grid for month = 15.48 + 5.28= 20.76 JD
Total consuming for 8 years = 20.76 x 8 = **2020.64 JD**

- The economic feasibility:

Table. 3 On-Gird Economic Feasibility

Item	*Price of the piece*	*Initial cost*	*Present Worth*
Array of PV	379.2135 $	5308.988$	5308.988$
Array mounting	150 $	150 $	150 $
Inverter	1255 $	1255 $	1255 $
EVSE	2500 $	2500 $	2500 $
Inverter at 10th year	787.77$	-	787.77$
Total Cost	-	9213.988$	10001.758 $
		6560.36 JD	7121.2516 JD

- According to the previous consideration that our car walk 52 mile/day:

$$\frac{\text{JD}}{\text{km}} = \frac{\text{Cost for first 8 years}}{83.6859\ km*365*8} = \frac{6560.36+2020.64-3539.488}{257697.884} = \mathbf{0.02063}\ \mathbf{JD/km} \quad (13)$$

1.4 Conclusions:

For 1500 cc oil car, 83.6859 Km/day, it will consume 15272.677 JD in 8 years.

Table. 4 Fuel Consumption per year

	Level 1 off- grid	*Level 1 on-grid*	*Oil consuming for car, 1500cc*
Cost during 8-years,	12575.487 JD	6560.36 JD	15272.677 JD
Feeding the grid JD	-	3539.488 JD/8year	-
Consume from the grid. JD	-	2020.64 JD/8year	-
JD/km	0.0514 JD/km	0.02063 JD/km	0.0625 JD/km

- *This means that our car is not only protects the environment, it is also economical.*

2. Simulink And Modelling

2.1 The Model Of PV Array For Level 1 On Grid Charging Station Using MATLAP:

As we know that we use a 300 Wp, 45.58 open circuit voltage, 8.78 short circuit current Philadelphian module:

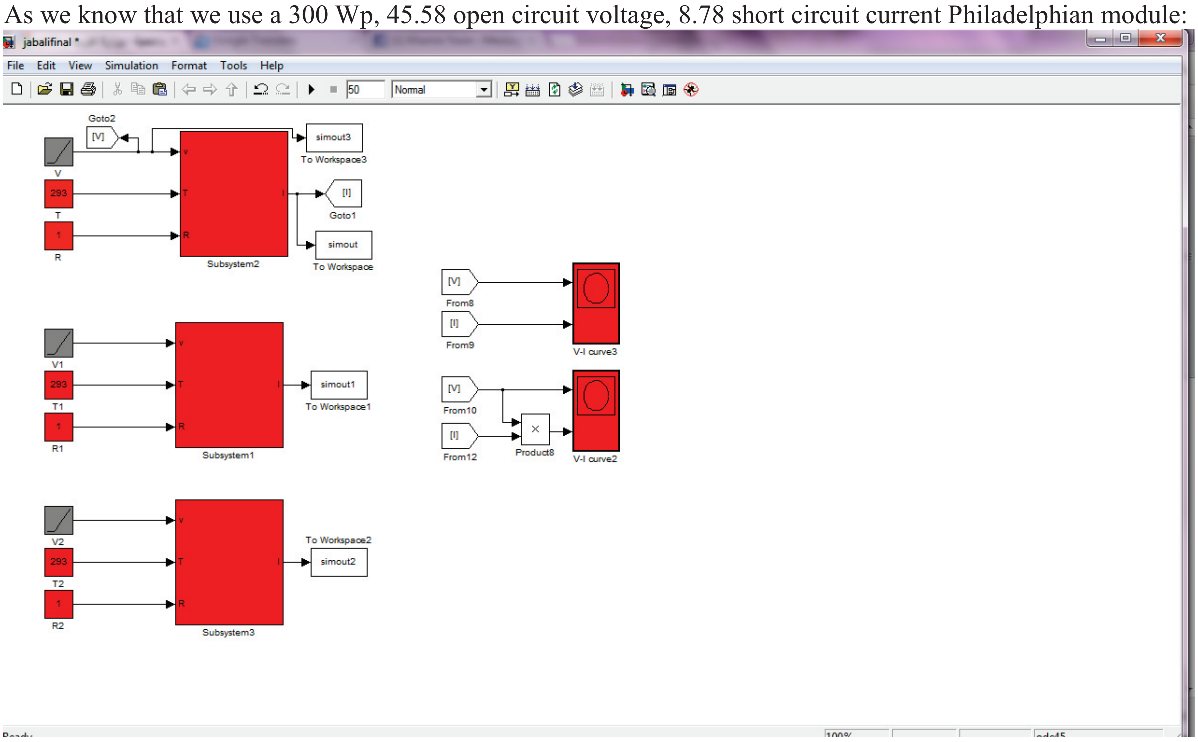

Figure 1. PV module modeling

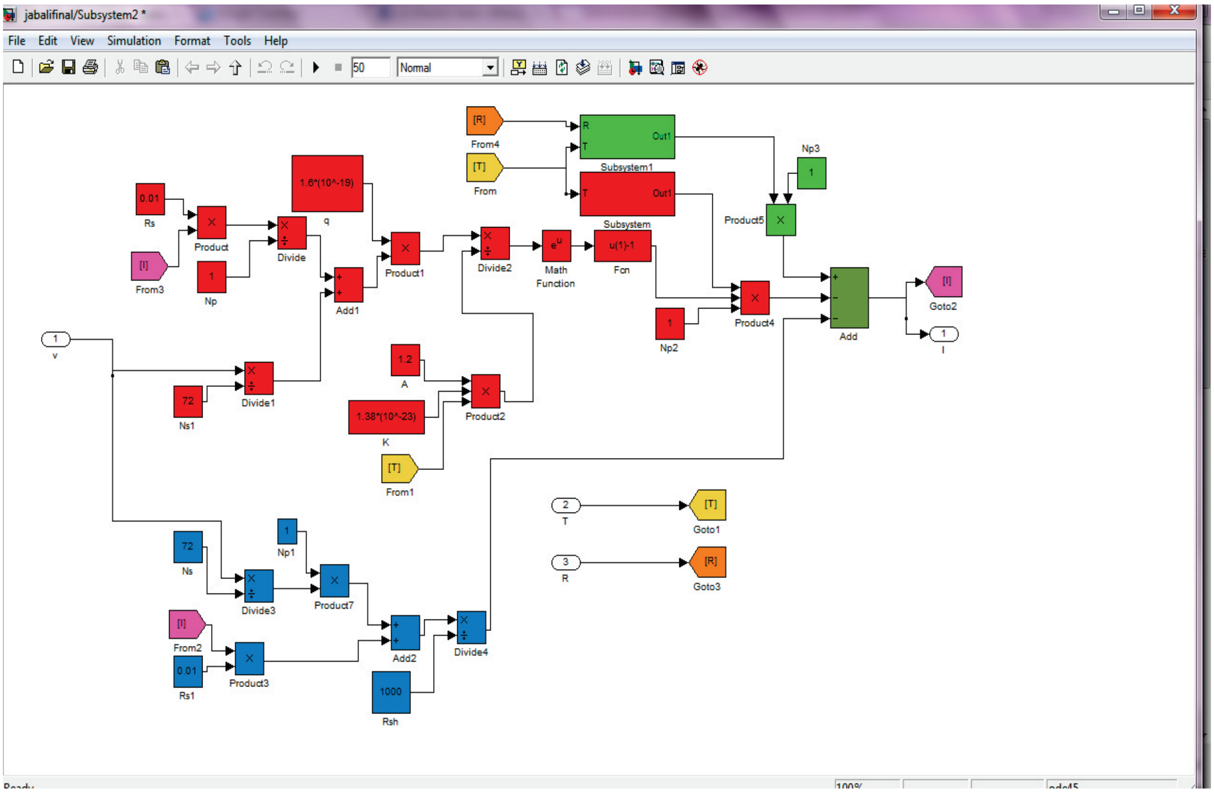

Figure. 2 The subsystem contents in PV module modeling

This model was done by using the following equation:

$$I = Np\ Iph - Np\ Is\left[\exp\left(\frac{q\left(\frac{V}{Ns}+I\ Rs\right)/Np}{K\ Tc\ A}\right)-1\right] - \frac{Np\ V}{Ns+I\ Rs}\ /Rsh \qquad (14)$$

Where,

I_{ph} :is a light-generated current or photocurrent.

I_s : is the cell saturation of dark current.

q : is an electron charge (1.6 x 10^{-19} C).

K : is a Boltzmann's constant (1.38 x 10^{-23} J/K).

T_c : is the cell's working temperature [K] .

R_{sh} : is a shunt resistance.

R_S : is a series resistance.

$$Iph = [Isc + K1(Tc - Tref)]\lambda \qquad (15)$$

Where,

I_{SC} : is the cell's short-circuit current at a 25 ℃ .

K_1 : is the cell's short-circuit current temperature coefficient.

T_{ref} : is the cell's reference temperature [K].

λ : is the solar insolation in [kW/m^2].

$$Is = Irs\left(\frac{Tc}{Tref}\right)^3 \exp\left[\frac{q\ Eg\left(\frac{1}{Tref}-\frac{1}{Tc}\right)}{K\ A}\right] \qquad (16)$$

Where,

I_{rs} : is the cell's reverse saturation current at a reference temperature and a solar radiation.

E_g : is the bang-gap energy of the semiconductor used in the cell.

A :is a factor dependent on PV technology, for [Mon-crystalline silicon Si]is (1.2) and for [Polycrystalline silicon Si] is (13)

$$Irs = \frac{Irs}{\exp\left(\frac{q\ Voc}{Ns\ K\ Tc\ A}\right)-1} \qquad (17)$$

The results were as the following

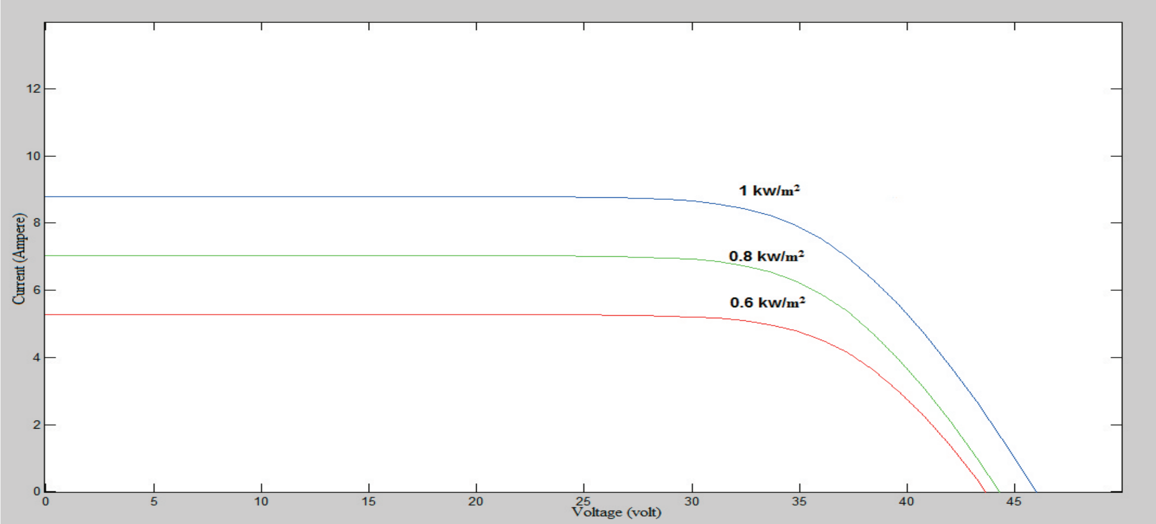

Figure 3. I-V curve for different insulation levels

- We note that the Isc and Voc are affected by varying the insolation levels.

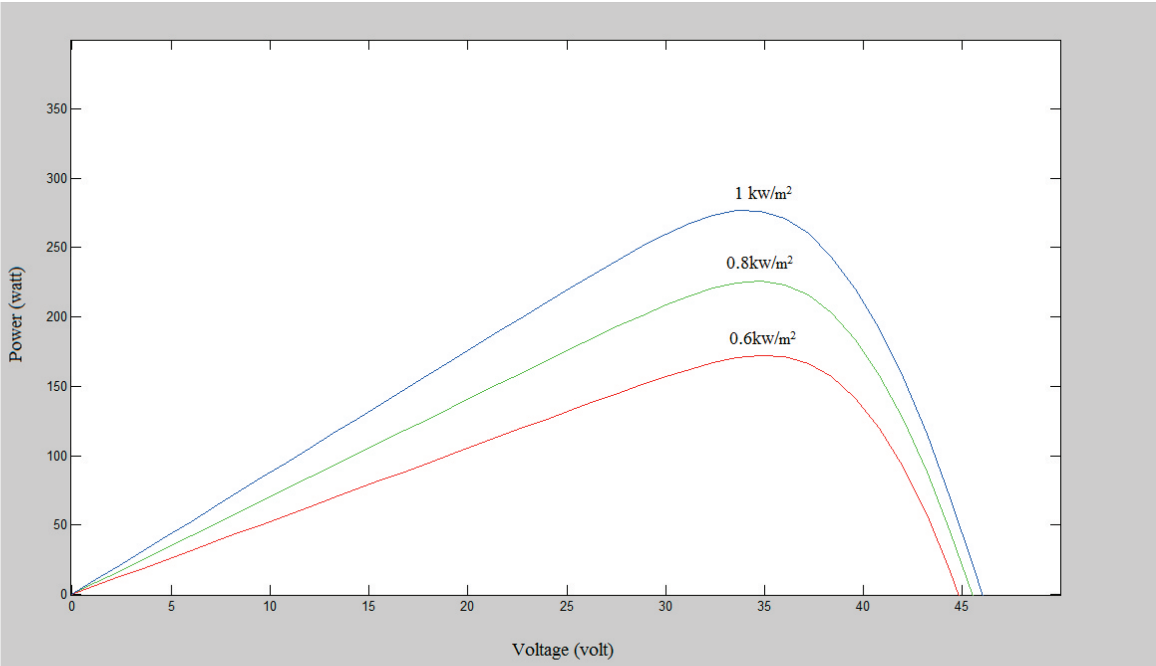

Figure. 4 P-V curve for different insulation levels

- As we note that the peak power increase when the insolation level increase:

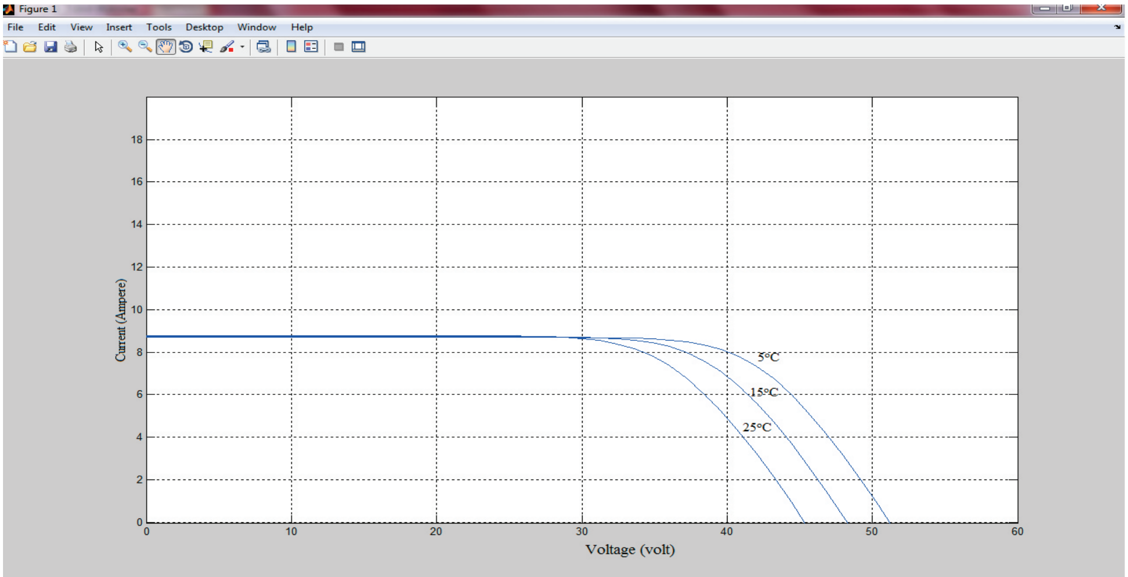

Figure. 5 I-V curve for different ambient temperatures

- As we note that Voc increase when the ambient temperature increase.

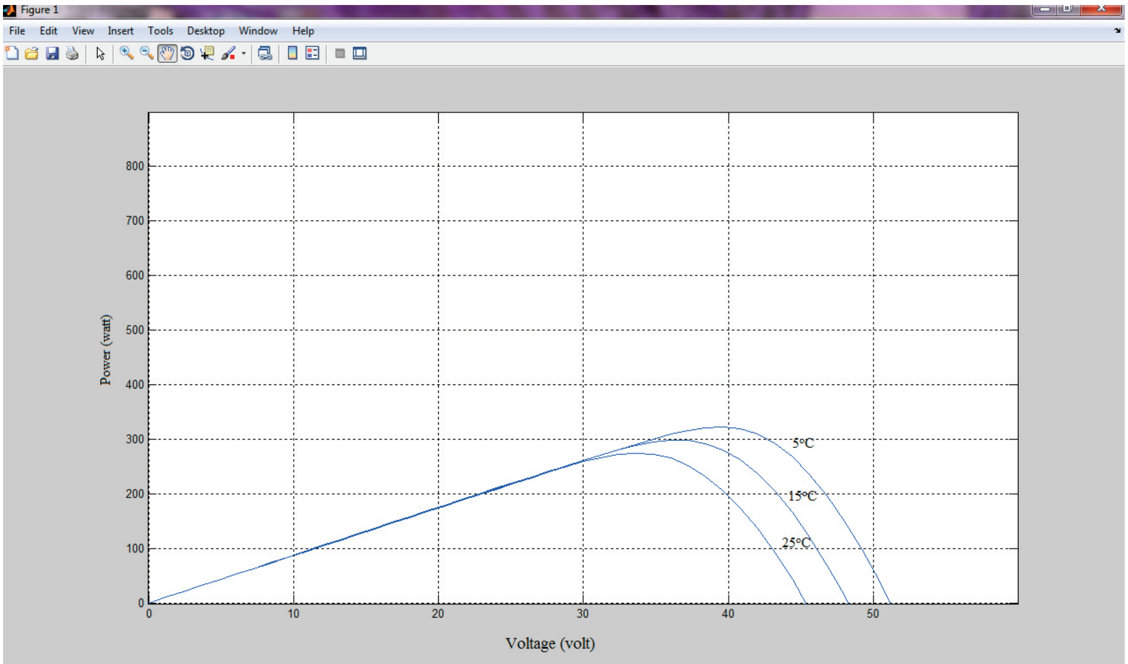

Figure. 6 P-V curve for different ambient temperatures

- As we note that the peak power of the module is affected by varying the ambient temperature; peak power increases when the temperature decreases.

2.2 Simulink of on-grid charging station using Solarius PV Program

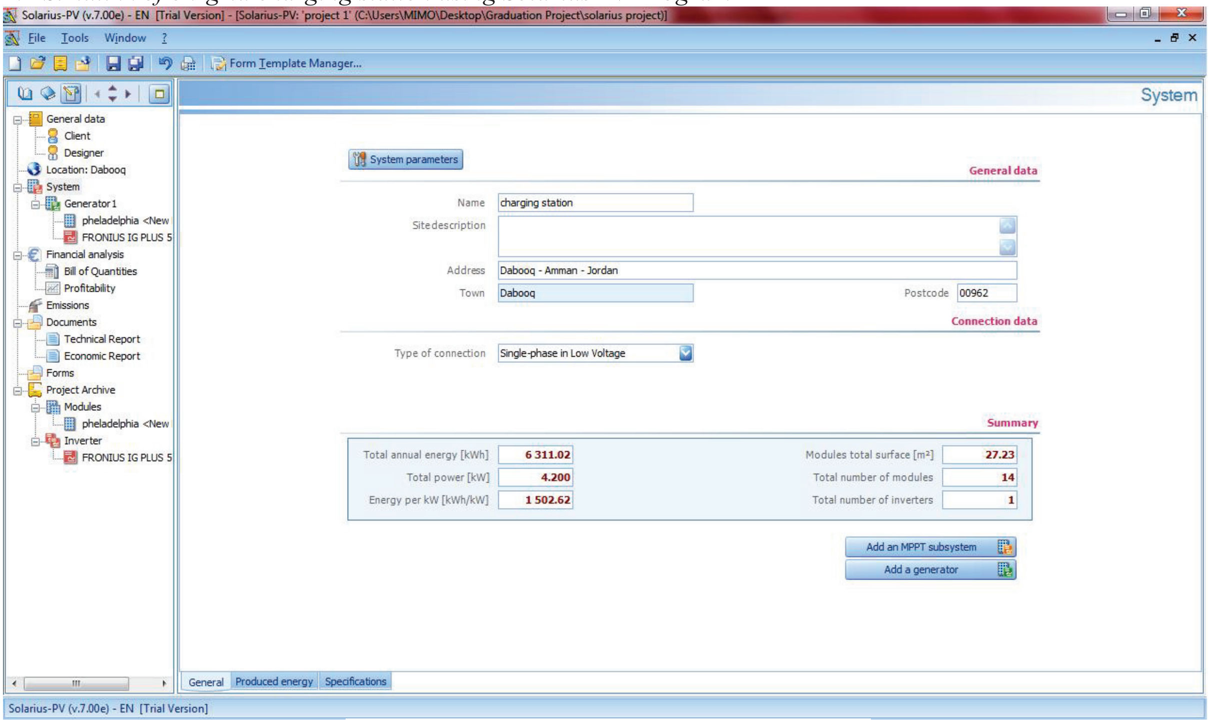

Figure. 7 The main workspace of the peogramme

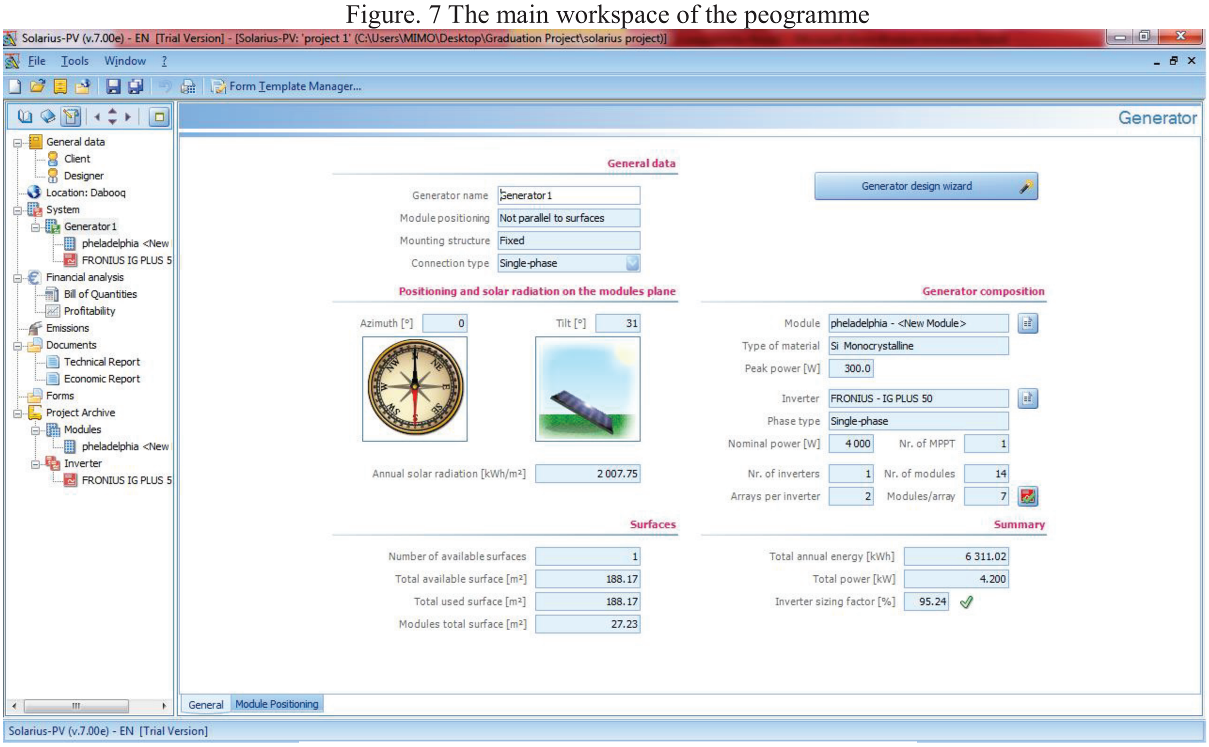

Figure. 8 The best tilt angle and the results of calculations

- This program gives a technical report and an economic one for the results of the calculations and the available data that was provided to it.

3. Conclusions

The current study tends to protect the environment by discussing electric vehicles under Jordanian climate. It was found that the cost and the **JD/km** for the electric car in comparison with conventional car that our car is not only protects the environment, it is also economical. It is true that the initial cost high, but during the 8 years we don't have to pay for oil which makes the study is more economical.

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