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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; ongrid 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):

Month	Daily radiation (KWh m ⁻ ² day ⁻¹) on horizontal surface	Monthly Averaged Daylight Hours (hours)	Daily radiation for tilt 31° (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
Мау	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
L	Avg = 5.27	Avg = 12, 133	Avg =5.44

The first of the f	Table	1.	Radiation	data	for	Amman,	Khalda	City.
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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.

$$miles/kwh = \frac{100miles}{24kwh} = 4.166miles/kwh$$
(1)
Total kwh/day = $\frac{52.0834}{4.1667} = 12.5$ kwh/day (2)

Efficiency $(\eta) = \text{wiring } \eta x \text{ inverter } \eta x \text{ batteries } \eta x \text{ Dry factor}$ $(\eta) = 0.98 \ge 0.96 \ge 0.9 \ge 0.762$

Number of modules on series = $\frac{\text{inverter input voltage}}{1 + 1 + 1}$ module nominal voltage

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

Number of modules on Parallel

kwh/day

$$= \frac{1}{nominal \ module \ current \ x \ \eta \ x \ system \ voltage \ x \ LDSR}$$

$$=\frac{12.5 \ x \ 10^3}{8.21 \ x \ 0.762 \ x \ (2 \ x \ 30.46) x 3.75} = 8.777 \ \simeq 9 \ modules$$

Total number of modules=2 x9 = *18 modules*

Total output power = $18 \times 250 = 4500$ 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

(4)

(3)

Capacity of charge controller
$$= \frac{Power of PV}{System Voltage} = \frac{4500}{2 x 30.46} = 73.867 A$$
 (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
 $= 4500 x 3.75 x 0.762 = 12858.75 Wh/day$
Ah $= \frac{Wh (watt hour corrected load) x Nd (autonmy days)}{DOD (Deapth Of Discharge)x system voltage}$ (6)
Nd = -0.48 x LDSR + 4.58 = 2.78 \approx 3 days.
Ah $= \frac{12858.75 x 3}{0.7 x (2x30.46)} = 904.69 Ah$
• If we use 12 volt, 200Ah lead acid battery ;
number of series battaries $= \frac{inverter nominal voltage}{battery voltage} = \frac{48}{12} = 4 battaries$ (7)
number of Parallel battaries $= \frac{Ah of the system}{Ah of battery} = \frac{904.69}{200} = 4.523 \approx 5 battaries$ (8)
Total number of batteries = 4 x 5 = 20 batteries
• The Economic Feasibility (Table 2):
Table 2. Off-Gird Economic Feasibility

Tuble 2. On Ghu Leonomie reasonity				
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 8 th year	261.124 \$	-	5222.48 \$	
Charge Controller at 10 th	366.583 \$	-	366.583 \$	
year				
Inverter at 10 th year	728.144 \$	-	728.144 \$	
Total Cost	-	17662.202 \$	23979.409 \$	
		12575.487 JD	17073.34 JD	

 $PW = C_o \ge 0.9545^N$ 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:

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

Total miles per day =
$$\frac{375}{30} \times 4.1667 = 52.08 \, mile/day$$
 (9)

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

Efficiency $(\eta) = \text{wiring } \eta x \text{ inverter } \eta x \text{ Dry factor } \eta$

 $(\eta) = 0.98 \ge 0.943 \ge 0.9 = 0.832$ inverter input voltage Number of modules on series = module nominal voltage (11) $=\frac{250}{36.58}=6.834\simeq 7$ modules Number of modules on Parallel kwh/day nominal module current $x \eta x$ system voltage x LDSR 12.5×10^3 $\overline{8.21 \ x \ 0.832 \ x(7 \ x \ 36.58 \)x \ 3.75} = 1.905 \simeq 2 \ modules$ (12)Total number of modules=2 x7 = 14 modules Total output power = $14 \times 300 = 4200$ watt Minimum Output Power of array $(10-years) = 4200 \times 0.9 = 3780$ 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 = $20.76 \times 8 = 2020.64 \text{ JD}$

• The 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 10 th 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:

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

1.4 Conclusions:

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

	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.	-	2020.64 JD/8year	-
JD			
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

5)



Figure. 2 The subsystem contents in PV module modeling

This model was done by using the following equation:

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

Where,

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

 \dot{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.

$$Iph = [Isc + K1(Tc - Tref)]\lambda$$
Where,
(1)

 I_{SC} : is the cell's short-circuit current at a 25 $\,{}^{\circ}\!\mathrm{C}$.

K₁: 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/m²].

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

$$\operatorname{Irs} = \frac{\operatorname{Irs}}{\exp\left(\frac{q \operatorname{Voc}}{\operatorname{NSKTcA}}\right) - 1}$$
(17)

The results were as the following







• As we note that the peak power increase when the insolation level 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

Solarius-PV (v.7.00e) - EN [Tria	I Version] - [Solarius-PV: 'project 1' (C:\Users\MIMO\Desktop\G	Graduation Project/solarius project)]	
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General data	ប្រឹ System parameters	G	eneral data
Generator 1	Name	charging station	
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Bill of Quantities	Address	Dabooq - Amman - Jordan	
Profitability	Town	Dabooq Postcode 009	52
Emissions		Conn	ection data
Forms Project Archive Modules	Type of connection	Single-phase in Low Voltage	
pheladelphia <new< th=""><th></th><th></th><th>Summary</th></new<>			Summary
FRONIUS IG PLUS 5	Total annual energy [kWh]	6 311.02 Modules total surface [m ²]	27.23
	Total power [kW]	4.200 Total number of modules	14
	Energy per kW [kWh/kW]	1 502.62 Total number of inverters	1
		Add an MPPT subsystem Add a generator	
< <u> </u>	General Produced energy Specifications		
Solarius-PV (v.7.00e) - EN [Trial V	ersion1		



Solarius-PV (v.7.00e) - EN [Trial Version] - [Solarius-PV: 'project 1' (C:\Users\MIMO\E	Desktop\Graduation Project\solarius project)]		-
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	tion type Single-phase		
Financial analysis Positioni Bill of Quantities Positioni	ng and solar radiation on the modules plane	Generator composition	
Emissions Azimuth [°]	0 Tilt [°] 31	Module pheladelphia - <new module=""></new>	
Documents		Type of material Si Monocrystalline	
Escencia Report		Peak power [W] 300.0	
Forms		Inverter FRONIUS - IG PLUS 50	
Modules		Phase type Single-phase	
pheladelphia <new< td=""><td></td><td>Nominal power [W] 4 000 Nr. of MPPT 1</td><td></td></new<>		Nominal power [W] 4 000 Nr. of MPPT 1	
ERONTUS TO PLUS 5 Annual solar ra	diation [kWh/m ²] 2007.75	Nr. of inverters 1 Nr. of modules 14	
		Arrays per inverter 2 Modules/array 7	
	Surfaces	Summary	
Number of a	available surfaces 1	Total annual energy [kWh] 6 311.02	
Total avail	able surface [m ²] 188.17	Total power [kW] 4.200	
Total u	used surface [m²] 188.17	Inverter sizing factor [%] 95.24	
Modules	total surface [m ²] 27.23		
General Module Positioning			-
Solarius-DV (v 7 00e) - EN [Trial Version]			

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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