A Study of a Grid-connected PV Household System in Amman and the Effect of the Incentive Tariff on the Economic Feasibility

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Abstract

Jordan state is very rich in renewable resources especially in solar energy, which indicates the potential for installing grid connected Photovoltaic system, but the initial costs of the photovoltaic systems are still very high. This paper present a simulation of a residential household powered by a 2 kW grid connected PV system with a 2 kW inverter situated in Amman the production cost is $ 0.228/ kWh, which is high, the system is then compared with an identical system but with the European renewable energy incentives, the Italian incentives are applied to the system, which resulted in a very competitive and feasible system with a payback period of less than ten years.

1. Introduction

Jordan is a non-oil-producing country and imports 96% of the energy used. As a consequence, energy imports accounts for roughly 22% of the GDP. The population's growth rate is high; about 2.3% per year. This causes the demand on energy sources, mainly oil products to increase rapidly. Implementation of renewable energy resources such as solar energy, will lead to economical, social and environmental benefits [1].

Jordan on the other hand is very rich in renewable resources especially in solar energy, which indicates the potential for installing grid connected Photovoltaic systems. Extensive research was made in this field, Anagreh et al [1], presented an investigation of the solar energy potential for seven sites in Jordan and concluded that Jordan has a great solar energy potential which motivates the utilization of stand-alone or grid-connected solar energy systems. Mondal et al [2] studied the potential and viability of grid connected of 1 MW using RET screen simulation software for 14 widespread locations in Bangladesh and showed the favorable condition for the development of the PV systems in Bangladesh. Li et al [3], presented a study of a grid-connected PV system in Hong Kong, and showed that the energy payback period was estimated to be 8.9 years.

Y. Udea et al [4], performed an analysis of various system configurations and orientations of grid-connected PV systems and showed the effect of the orientation and model of PV panels on the total energy yield. G. Mulder et al [5], presented a study of grid-connected PV systems for residential houses with energy storage, and studied the relation between storage size and energy flow to the grid in Belgium, while J. De La Hoz et al [6], performed an technical and economic analysis of grid-connected systems in Spain during the period 1998-2008, and intended to explain the evolution by focusing on the key growth factors and drivers embedded in the legal, economic and technical framework of the PV energy policy.

Sopian et al [7], studied the optimization of a stand-alone PV hybrid system for a household in Malaysia using HOMER simulation software, and showed that the least expensive system is composed of a 2 kW PV and 1 kW wind turbine. Numerous studies were conducted on the subject [8-10].

This paper presents an analysis for a grid-connected photovoltaic system for a residential house in Amman, the capital of Jordan, and energy production costs and incomes are compared with the European incentives for renewable energy, the Italian incentives in specific under the legislation called "Conto Energia" [11], the system configuration is simulated using the Hybrid Optimization Model for Electric Renewable (HOMER).

2. Site characteristics

Amman is the capital and largest city of Jordan. It is the country's political, cultural and commercial centre and one of the oldest continuously inhabited cities in the world [12], it is located on latitude 31°56′59″ N and longitude 35°55′58″E, it is populated by 2,800,000 (2010 data) [13], Spring is brief, mild and lasts a little more than a month, from April to mid May, with rain during the morning and the afternoons.

High temperatures are around 14 °C (57 °F) and lows are a little less than 7 °C (45 °F) and several times going near 0 °C (32 °F) causing several freezes. Snow has been known to fall mildly in the city during the spring, sometimes with severe storms rarely happening during the season. Amman has long summers starting from late May to early October. Summer's high temperatures range from 25 °C (77 °F) to 33 °C (91 °F), usually with very low humidity and frequent cool breezes. Most summers are rain-free with cloudless skies during the noon period, Autumn is usually mild, and lasts from October to late November or mid-December and The winter in Amman is long and cold, usually starting in late November and continuing to mid-April. Figure 1 shows Amman location.

Figure 1: Amman location

2.1 Solar irradiation

Amman has very high potential of solar energy with an annual average irradiation of 5.5, annual solar irradiation data was obtained from [1, 14 and 15]. Figure 2 shows the average monthly solar radiation and clearness factor. Data is shown in table 1.

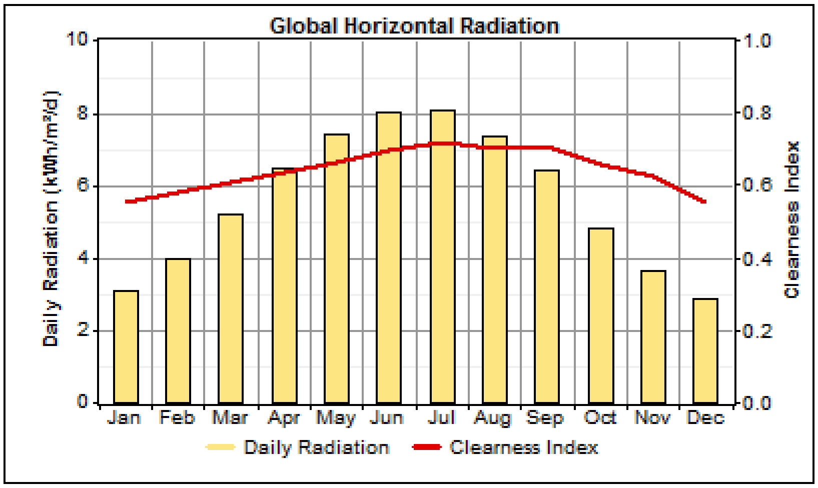

Figure 2: Amman solar radiation and clearness index.

Month	Clearness index	Daily radiation [kWh/m^2/d
January	0.552	3.090
February	0.581	3.990
March	0.608	5.200
April	0.637	6.450
May	0.664	7.380
June	0.696	7.990
July	0.716	8.060
August	0.701	7.330
September	0.706	6.400
October	0.656	4.820
November	0.625	3.670
December	0.551	2.860
Average	0.654	5.6

Table 1: solar radiation and clearness index data for Amman[14].

As shown in figure 2 and table 1 the months with highest solar radiation are may through September with an average solar radiation of 6.4 - 8.06 kWh/ m^2/ d which indicates a very high potential for PV systems.

The clearness index is a measure of the clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth. It is a dimensionless number between 0 and 1, defined as the surface radiation divided by the extraterrestrial radiation. The clearness index has a high value under clear, sunny conditions, and a low value under cloudy conditions [16].

3. The load profile

The load was obtained for a typical house in Amman and energy usage data was obtained from the electrical bills over a year; figure 3 shows the average monthly load profile, while figure 4 shows the seasonal profile for the load.

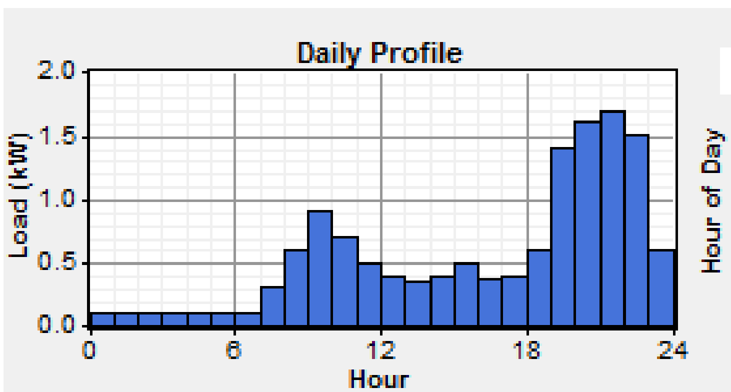

Figure 3: average load profile.

The load profile has a minor peak in the morning period with the peak at 9:00 and the total peak in the evening at 20:00.

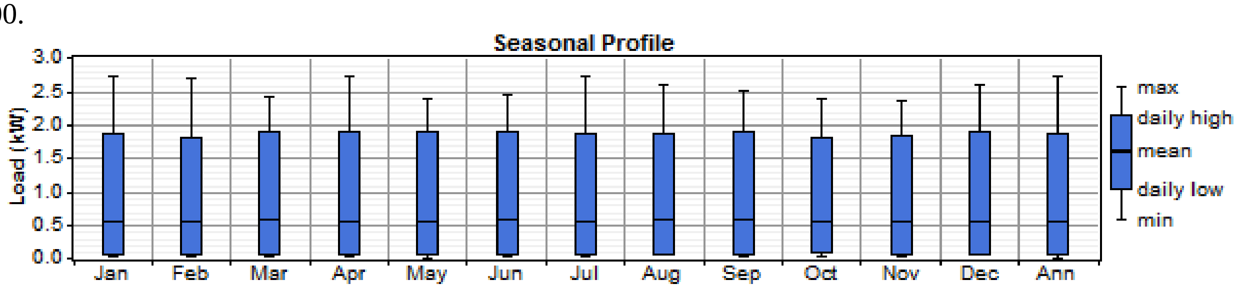

Figure 4: seasonal load profile.

Load data showed that the average daily energy consumption is 13.5 kWh and the peak demand is 2.74 kW which is typical for an average house in Amman. It is shown in figure 4 that the highest energy consumption occurs in the months of July and January and that’s because they are the hottest and coldest months.

4. System configuration

The system is composed of 2 kW PV system with the cost of $4000 per kilowatt peak and a grid connected inverter of 2 kW capacity with the cost of $850 per kilowatt figure 5 shows the system configuration of the HOMER program, the system is designed to have a life time of 20 years so the PV panels will not be replaced.

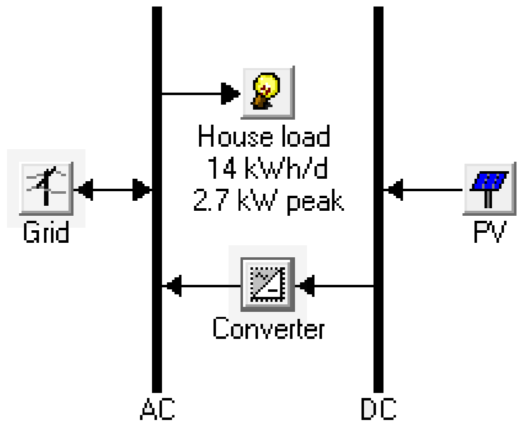

Figure 5: system configuration.

Table 2 shows a summary of the costs of each component, as shown in table 2 the PV panels does not need any maintenance and operation cost which is an advantage of the PV systems, it is also clear that the main issue for the PV systems is the high initial cost.

Component	Initial capital ($US)[17]	Replacement cost ($US/year)	Operation and maintenance cost ($US)	Salvage cost ($US)
2 kW PV panels	8000	0	0	0
2 kW inverter	1700	50	0	-215

Table 2: Costs of components.

The cost of electrical energy is taken to be 0.08 $/kWh for purchase and 0.05 $/kWh for sale back, for comparison the same system with the same resources and load will be used but with the calculation of the renewable energy incentives.

The Italian renewable energy incentive law [11] states that the electric energy produce by the photovoltaic system has the right to receive an incentive tariff depending on the level of the integration of the system to the edifice structure and on the output power.

In our case every kWh produced from the moment of installation to 20 years of lifetime it will be granted an incentive tariff of $ 0.58, which is a great help to the economic feasibility of the project.

5. Results and discussion

After running the data through HOMER the optimal results data for the system in Amman is shown in table 3.

Component	**Production** (kWh/yr)	**Fraction**
PV array	3,804	56%
Grid purchases	2,962	44%
Total	6,766	100%
Load	Consumption	Fraction
AC primary load	4,891	74%
Grid sales	1,685	26%
Total	6,576	100%
Converter	losses	Fraction
Inverter	190	2.8 %

Table 3: Electrical simulation data.

As seen in table 3 the renewable energy fraction is 56% of the total energy produced, the initial capital cost for the system is very high $ 9,700, and the total net present cost is $ 10,962 the production cost is $ 0.228/kWh which is high compared to the conventional energy sources, so if environmental benefits are not counted the system is not feasible.

A comparison for the system incomes with the incentives and without is shown in table 4. The great advantage of the incentives can be seen from the data of table 4, the annual income of the incentive granted system is of $ 2444.57 which means that the system pays back in less than ten years and the law states that incentives are given for 20 years from the installation of the project which gives other 10 years of pure income

Source of income	Quantity kWh/yr	System with incentives income $/yr	System without incentives income $/yr
PV production	3804	2206	0
Energy Not Purchased	1929	154.32	154.2
Energy sell back	1685	84.25	84.25
Total annual		2444.57	238.57

Table 4: Income comparison of system with incentives and without.

6. Conclusion

A residential house in Amman powered by a system composed of 2 kW grid connected PV panels with a 2 kW inverter is simulated using HOMER, the resources data was obtained by the NASA surface meteorology for solar energy and from the Solar and Wind Energy Resource Assessment (SWERA), the load profile was built using typical energy consumption in Jordan, the simulation results showed that the system production cost is $ 0.228/kWh which is quite high compared with conventional energy, but with the introduction of the Italian incentive tariff for comparison the income resulted highly feasible and competitive, which indicates the need for a Jordanian law makers that promotes the use of renewable energy through the country.

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