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Optimal Design of PV System in Passive Residential Building in Mediterranean Climate

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Abstract

Energy is a crucial element for prosperity and improving the standard of living. Fossil fuels are not an everlasting source of energy. However, the sun is the only eternally sustainable source of energy.

In this the present study, feasibility and reliability analyses of a PV grid-connected system are conducted in Mediterranean climate. MATLAB is used to model the energy system and examine its technical and economic performances. Life Cycle Cost (LCC) and Payback Period (PbP) criterion are also used to determine the optimum system design.

The present study shows that incorporating an optimum system of solar PV with a grid system (oriented at 26° from the horizontal) is feasible in Mediterranean region. It can reduce 6,075 kWh (83.7%) from the annual electricity bill. Moreover, LCC over a 30-year period is found to be US$ 19,524 while the PbP for the initial investment is 5.88 years. Furthermore, carbon dioxide emissions, associated with thermal power plants generated electricity, are expected to reduce by about 3.6 Tons annually. Thus, to move toward energy independence and energy security, favorable policies and incentives should be set to accelerate the use of such energy systems.

Keywords: *Energy; Grid-Connected; Optimization; Life Cycle Cost.*

1. Introduction

There are two global problems facing the scientific community; the first is the main source of energy, fossil fuels, is being rapidly exhausted. The second problem concerns the environment, where the combustion of hydrocarbon fuels has deteriorating effects on the environment. Therefore, there is an urgent need to use renewable energy instead of fossil fuels [1].

The total primary energy consumption was 7.979 M TOE in 2012, which cost around 6.52 Billion US Dollars (USD). Most of the energy used in buildings is in the form of electricity. Statistical studies showed that the residential sector consumed 43% of the total electricity consumption in Jordan in 2012 [2]. "On the other hand, Jordan has abundant supplies of solar energy, which is relatively high with an average daily solar radiation of 5.5 kWh/m^2. The average annual sunshine days are about 300 days. Thus, the need for passive and climatic design, energy efficiency measures, and utilizing renewable energy has emerged" [3].

Hammad *et al.* [4] presented a full description of a pilot photovoltaic station with thin-film modules on the Hashemite University campus. The pilot station is installed and tested as a canopy covering four car parking slots. The results showed that system efficiency is within the normal range for this type of tested technology in other countries.

Hybrid systems, such as wind/solar-Diesel, PV-Diesel with battery as a backup, are being used in urban and remote areas for uninterrupted power generation and meeting the energy demands in summer [5-9]. These studies recommended to use such system.

Solar Photovoltaic reduces the environmental impact of burning fossil fuels. The potential of using solar photovoltaic system for industrial processes was discussed by Iyappan *et al.* [10].

The hybrid power systems either as standalone or on-grid systems are more reliable and cheaper than single source energy systems [11, 12]. Moreover, it is showed in a number of studies that the hybrid power system could produce fewer greenhouse gases when compared with fossil-fuel conventional energy systems [11-13].

The main goal of the present study is to investigate the techno-economic viability of solar PV grid-connected energy system for a passive Jordanian household. A MATLAB code is written to simulate the hourly performance of a PV-grid interconnected system throughout the year. The simulation code is used to find the optimum size of the PV system at minimum Life Cycle

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Cost (LCC). In addition, optimum PV array tilt angle is determined by analyzing the optimum energy gain throughout the year. Finally, the amount of CO_2 emission reduction due to the optimization is calculated.

2. Design Parameters

PV system sizing and performance strongly depend on electrical demand and metrological variables such as solar energy and ambient temperature. Therefore, to optimize a PV system, extensive studies related to the metrological variables have to be done [14].

The selected building is a passive Jordanian building located in Amman, location of the building is shown in Figure 1.

Figure 1. Building Location

2.1. Metrological Data

Amman, the capital city of Jordan, has a mountainous topography and lies in the "global Sunbelt" at a latitude of 31.93° North and a longitude of 36° East. This location has abundant supplies of solar energy, with a relatively high average daily solar radiation. The annual sunshine is more than 300 days [15].The climate of Amman is predominantly of the Mediterranean type. It is marked by sharp seasonal variations in both temperature and precipitation. The climate can be cold to very cold in winter and warm to hot in summer. Summer starts around mid of May and winter starts around mid of November, with two short transitional periods in between (autumn and spring).

The yearly average temperature is 17.2°C, with lowest mean temperature of 3.6°C in January and highest mean temperature of 32.6°C in August. Figure 2 represents the hourly outdoor temperature profile all over the year [16].

The highest solar radiation is 7.56 kWh/m^2.day in June, while the lowest solar radiation is 2.71 kWh/m^2.day in December [16]. Figure 3 reflects that Amman has a very good solar energy potential, which makes PV systems a practical solution for this region.

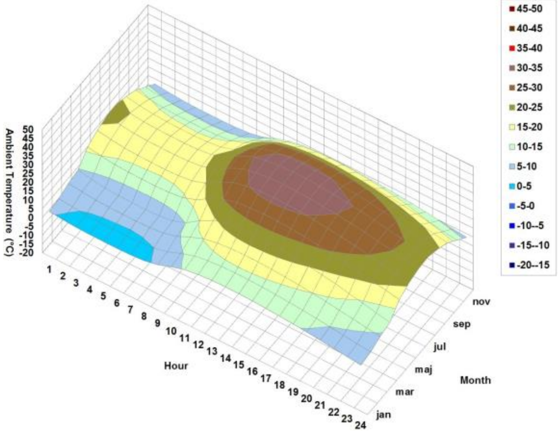

Figure 2. Outdoor Temperature Profile

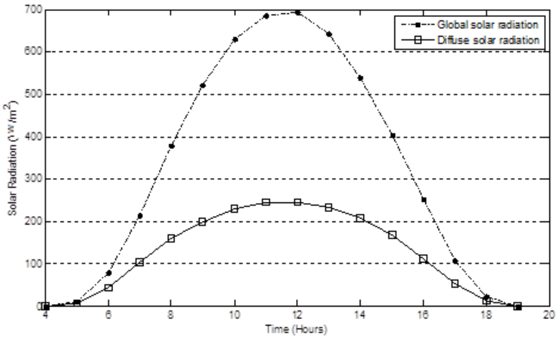

Figure 3. Average Daily Global and Diffuse Solar Radiations onto horizontal for Amman

2.2. Electric Demand

To begin sizing a PV system, the energy consumption is determined as indicated in Table 1, which lists most electrical devices and their daily consumption in a passive household in Amman. In the present study, the hourly demand is used in calculating the optimum size of the PV system. The simulated hourly demand profile has been simulated in MATLAB. It varies from one day to another throughout the year, since the energy consumption of a building varies according to the period of the year, the compartmental behavior and so on.

From Table 1, the total daily AC demand is about 20.4 kWh. Taking into consideration the efficiency of the inverter (94%), the daily DC demand is about 21.7 kWh. Furthermore, the peak AC power demand is about 10.95 kW.

Table 1. Household Appliances and Lighting Load

Demand	Power (W)	Total Peak (kW)	Usage (Hour/day)	kWh/day
Energy Saving Lamps × 15	11	0.165	7	1.155
TV set × 2	100	0.200	10	2.000
Satellite TV System × 2	15	0.030	10	0.300
Computer × 2	90	0.180	10	1.800
Refrigerator	150	0.150	10	1.500
Water Cooler/Heater	400	0.400	6	2.400
Hair dryer	1000	1.000	0.2	0.200
Iron	1500	1.500	0.5	0.107
Microwave	900	0.900	0.2	0.180
Water Heater	1200	1.200	1	1.200
Vacuum Cleaner	1000	1.000	0.3	0.129
Battery Charger × 4	2	0.008	0.5	0.004
Air Conditioning × 3	1005	3.014	3	9.043
Washing machine	1200	1.200	1	0.343
Total		10.947		20.361

2.3. PV System Design

The optimization of two PV system types has been discussed in the open literature; firstly, a stand-alone (off-grid) system [17-23], which is mostly used in remote areas as an isolated small power generation for essential electric power [24-33]. This system is shown in Figure 5;

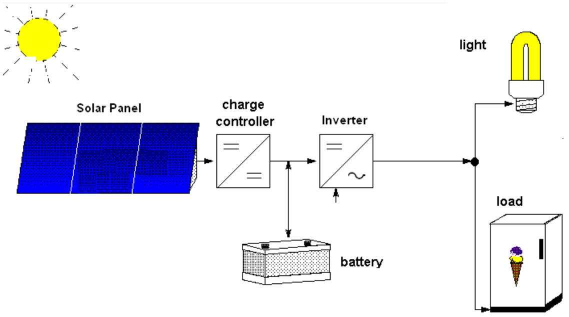

Figure 5. Stand-alone system Components

secondly, a grid-connected PV system [34-37], as shown in Figure 6. This system is used in areas with a grid system; energy storage facility can be removed, and instead, the grid system can be used as storage. PV energy storage system produces more energy than needed; the surplus energy is fed into the grid and, energy is taken from the grid when the PV system produces less energy than needed as outlined by Mondal and Islam [38].

A grid-connected PV system reduces the amount of purchased electricity from the utility each month. In addition, it reduces the capital cost of the system due to not using of batteries.

In the past, hybrid systems were selected as the prioritized choice for remote systems, especially at sites far away from conventional power system [39-42]. Nowadays, there is a trend to update an existing hybrid system for grid-connection applications [43].

In order to design a suitable grid-connected PV system a numerical method will be used. The numerical method is the most used method for sizing hybrid PV system [44]. This process starts by modeling the system using mathematical relations and then using a weather data and demand. Then, the calculation is performed. During the simulation, the amount of the generated energy each time step, usually a day or an hour, is predicted and compared with the demand. After that, the cost of each part of the system is calculated and based on the minimum LCC (capital cost, operating and maintains cost and salvage cost), the optimum system size is determined.

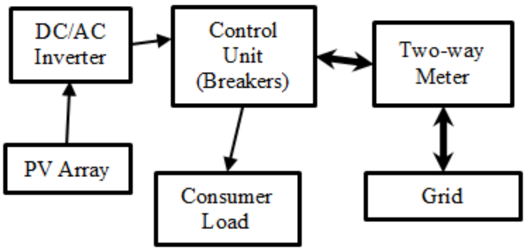

Figure 6. Block diagram of PV grid-connected system

2.3.1. PV Array Sizing

A mono-crystalline silicon PV module is selected in a different situation in order to find the optimum position, and to avoid shade. The module specification is listed in Table 2.

Table 2. Technical specification of PV module under nominal operating cell temperature [45]

Parameter		**Specification**
Nominal maximum power		300 Wp
Voltage at nominal power		36.58 V
Current at nominal power		8.21 A
Open-circuit voltage		45.36 V
Short-circuit current		8.78 A
Efficiency, η_{PV}		15.4 %
Operating module temperature		-40 to +85°C
Temperature coefficients:	Pmax	-0.41 %/°C
	Voc	-2.11 mV/cell°/C
	Isc	4.62 mA/cell/°C
Dimension		1965 mm × 990 mm × 45 mm

The number of panels is determined according to energy demand and its initial cost. The optimum number of panel is designed using MATLAB based on simulated hourly demand.

The hourly energy taken from the grid (E_{Grid}) in kWh is calculated taking into consideration the inverter efficiency (η_{inverter}) of 94%. In addition to losses due to system components, and high normal operating PV cell temperature, which are represented by a typical Safety Factor (S.F) of about 20%, thus,

$$E_{Grid} = E_{Demand} - E_{PV} \tag{1}$$

where, E_{PV} is the total energy generated from the PV array (kWh), $E_{Demand}$is the demand seen by the PV array (kWh) and it is calculated based on Figure 5 as follow:

$$E_{Demand} = \sum \frac{\text{Simulated Hourly Demand} \times \text{S.F}}{\eta_{\text{inverter}}} \tag{2}$$

It can be noticed from equation (1) that the energy taken from the grid could be positive or negative or zero. A negative value indicates an excess PV energy that is fed to the grid. Furthermore, the net energy taken from the grid is used in calculating the energy bill at the end of each month.

2.3.2. Inverter Sizing

The inverter input voltage is 12 V, so the total AC Ampere hours per day (Ah/day) used by AC demand is

$$\text{Total Ah/day used by AC Demand} = \frac{\text{Total AC Demand}}{\text{Inverter Input Voltage}} \tag{3}$$

3. Optimal Sizing Of PV Tilt Angle

The tracking system is a mechanical device used to maximize the solar energy intake by changing the tilt angle of PV panels as the sun sweeps across the sky automatically. Using tracking systems is costly, as they require energy for their operation and are not always applicable [46]. Therefore, it is often practical to orient the solar collector at an optimum tilt angle and correct the tilt angle manually from time to time. Thus, hourly, daily, monthly, seasonal or yearly changing the tilt angle for a PV system could be more feasible than applying an active sun tracker. It is reported in the literature that, in the northern hemisphere, the optimum orientation is south facing, and the optimum tilt angle depends only on the location latitude. Researchers did not define any value for the optimum tilt angle. The open research shows that there is a wide range of optimum tilt angle for precise locations as recommended by different researchers [47-56].

In general, solar radiation data are described in terms of incident global solar radiation, solar energy is one of the combinations of the global, direct (beam), diffuses, and ground reflected solar energy. To calculate the solar energy on a tilted surface, the solar energy on a horizontal surface and geometrical models are considered. The following equation describes solar energy components on a tilted surface mathematically [57]:

$$G_{TLT} = (G - D)R_B + DR_D + G\rho R_R \tag{4}$$

where G_{TLT} is the solar radiation on a tilted surface (kWh/m2). G and D are the ground solar radiation (kWh/m2) and the diffuse solar radiation (kWh/m2), respectively. ρ is the Albedo ground reflection, which equals around 0.3 for a ground similar to Amman [58]. R_B,R_D, and R_R are radiation coefficients.

$$R_B = \frac{\cos(L-\beta)\cos\delta\cos\omega_{SS} + \sin(L-\beta)\sin\delta}{\cos L\cos\delta\cos\omega_{SS} + \sin L\sin\delta} \tag{5}$$

where L is the location latitude (rad), β is the tilt angle (rad), and ω_{ss} is the hour angle (rad).

The declination angle (δ) is calculated from [58]:

$$\delta = 23.45\sin\left(360\,\frac{284+n}{365}\right) \tag{6}$$

where n is the day number in the year ($n = 1{:}365$)

The amount of reflected solar energy on a tilted surface, R_R, can be calculated as [57]:

$$R_R = \frac{1-\cos\beta}{2} \tag{7}$$

The geometric factor R_D is defined as the ratio of the diffuse solar energy on the tilted surface to that on the horizontal surface at any time. Many solar models, classified as isotropic and anisotropic, have been used to estimate R_D. Isotropic solar models are based on the hypothesis that isotropic radiation has the same intensity regardless of the direction of measurement, and an isotropic field exerts the same action regardless of how the test particle is oriented. One of the most famous isotropic diffuse solar models is the Liu and Jordan model [59] with R_D being formulated as:

$$R_D = \frac{1+\cos\beta}{2} \tag{8}$$

By substituting Eqs. (5, 7, 8) into Eq. (4) a mathematical model can be obtained, based on the Liu and Jordan model, for calculating the optimum tilt angle. A code is written by using multidimensional arrays and MATLAB's built-in functions to find optimum tilt angle. Fig.7 shows the algorithm for calculating the optimum tilt angle, numbers in brackets show array sizes.

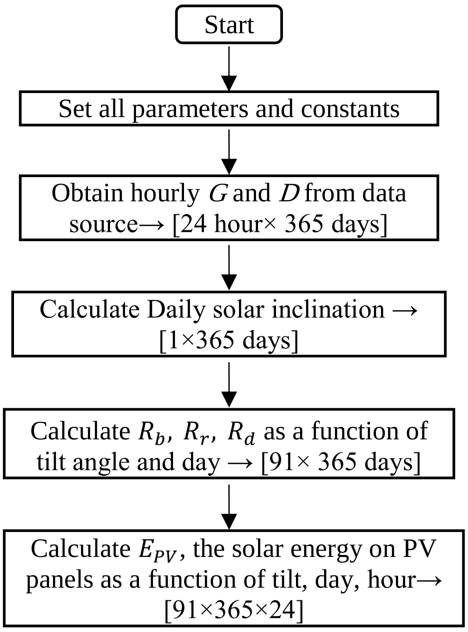

Figure 7. Tilted Solar Radiation Flow Chart

The MATLAB code calculates the tilted solar radiation as a function of hour, day, and tilt angle ($0° < \beta < 90°$), having a 24 by 365 matrix. Then, the optimum tilted solar radiation with respect to tilt the angle is set to design a PV system accordingly.

4. Life Cycle Cost Analysis

Today, the life span of a typical PV system reaches 30 years. In order to observe the financial benefits of the PV on-grid system, a 30-year life-cycle-analysis is performed. With a grid connected PV system that does not include batteries, the electric energy fed to the grid and that consumed from the grid are taken into account.

The following equation describes the Life Cycle Cost (LCC) function for the PV system (Duffie and Beckman):

$$LCC = C_{PV}\left[1 + (f_{O.M} \times PWF) - \left(f_{salv}\left(\frac{1+i}{1+r}\right)^{N}\right)\right] + (C_{Grid} \times PWF) \qquad (9)$$

where C_{PV} is the initial cost of the PV system, $f_{O.M}$ is the operation and maintenance factor set at 5% of the capital cost,f_{salv} is the salvage factor set at 6% of the capital cost (according to local figures).

According to Jordanian market, the inflation rate,r, in fuel prices is around 8.9%, and the interest rate, i, is about 6.25% [60], N is the life span, PWF is the Present Worth Factor calculated according to the following equation:

$$PWF = \frac{1+i}{r-i}\left[1 - \left(\frac{1+i}{1+r}\right)^{N}\right] \qquad (10)$$

C_{Grid} is the annual grid electricity cost, assuming a monthly billing system. Current electricity prices in Jordan are calculated monthly based on a slab tariff as shown in Table 3.

Table 3. Slab Tariff [61]

	Energy Consumption (kWh/Month)	Tariff (US cent/kWh)
Slab 1	0-160	46
Slab 2	161-300	101
Slab 3	301-500	121
Slab 4	501-600	161
Slab 5	601-750	199
Slab 6	751-1000	237
Slab 7	>1000	331

In the present study, the optimum area of a PV array is found by determining the minimum LCC of the PV system. A MATLAB program is used to calculate the LCC of PV systems ranging from 1 to 16 panels. The minimum LCC corresponds to the optimum number of PV panels. The program is described by the flow diagram shown in Figure 8, where the brackets indicate the matrix sizes.

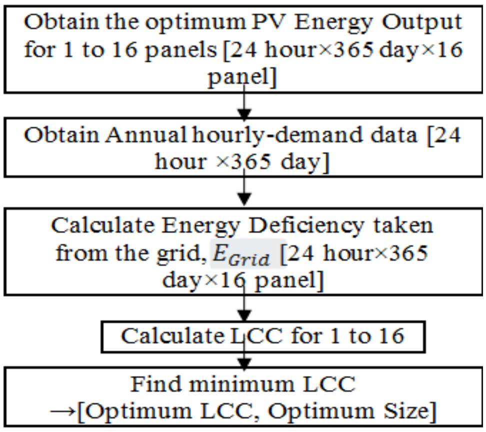

Figure 8. LCC Flow Chart

The Payback Period (PbP) is the length of time it takes for an initial investment to be repaid out of the net cash inflows from the project [62]. At the end of PbP, the system has paid for the initial investment and any revenue produced thereafter is pure gain. Thus, PbP in years is equal to:

$$\mathrm{PbP} = \frac{\text{Initial Cost of PV system}}{\text{Annual Saving of PV system}} \qquad (11)$$

5. Results

5.1. Optimal Sizing Of PV Tilt Angle

The magnitude of the solar radiation can be increased by a simple manipulation of the the panel tilt angle. To decide which angle is the optimum at the selected location, the monthly solar radiation, as a function of the tilt angle ($0° < \beta < 90°$), is simulated and plotted in Figure 9.

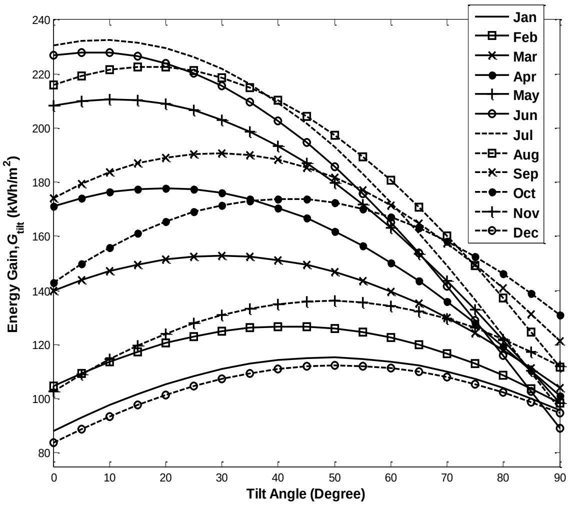

Figure 9. Monthly solar radiation gain vs. tilt angle

Figure 9 shows that the hot months (May – Aug.) have a small optimum tilt angles while the cold months (Jan – April and Sep. – Dec.) have a large optimum tilt angle. This is due to the location of the sun; in hot months, the sun is located at the highest point in the horizon where in cold months the sun is located at the lowest point. In this study, the gain obtained by adjusting the tilt angle of a PV panel is investigated for monthly, quarterly, biannual and annual (fixed) periods in order to determine the optimum tilt angle and solar energy yield. The monthly adjustment assumed that the tilt angle is changed from month to month twelve times a year. The quarterly adjustment considers that the PV panel tilt angle is adjusted seasonally four times annually, whereas the biannual adjustment assumes that Amman has two climate seasons, so the tilt angle is adjusted twice a year. The annual adjustment means that the system will be sloped at fixed tilt angle during the lifetime of the PV system. The results are listed in Tables 4, 5, and 6 for monthly, quarterly, and bi-annual adjustment, respectively.

Table 4. Monthly optimum tilt angle

Month	β degree	G_{TLT} kWh/m^2	G_0 kWh/m^2	Energy Gain %
Jan.	49	115.3	88.1	30.9
Feb.	42	126.8	104.7	21.2
Mar.	30	152.9	139.9	9.2
Apr.	20	177.9	171.2	3.9
May	11	210.7	208.2	1.2
June	7	228.0	226.8	0.5
July	9	232.4	230.4	0.9
Aug.	17	222.7	215.9	3.2
Sep.	29	190.8	174.2	9.5
Oct.	41	173.9	143.0	21.7
Nov.	49	136.2	102.8	32.6
Dec.	51	112.3	83.9	33.9
	Total	2080	1889	10.1

Table 4 represents the optimization results of a monthly solar radiation on both slanted panel (G_{TLT}) and horizontal panel (G_0). The results show that the monthly tilt angle value varies between 7° – 51°. The maximum tilt angle value is on December while the minimum tilt angle value occurs on June. The energy gain is increased on December by an amount of 33.9 % as compared with a horizontal panel. Moreover, the energy gain is increased by only 0.5 % on May. On the other hand, as an overall result, an increase of 10.1 % in the energy gain, as compared to the horizontal panel, is achieved by applying the monthly tilt angle adjustment.

Table 5 shows that the optimum tilt angle is 14° and 15° in the period of (21/03–21/06) and (22/6-21/9), respectively. Meanwhile, it is 44° for the period 22/09–21/12, and it is one degree less in the period of 22/12 – 20/3. However, the quarterly tilt angle optimization leads to an energy gain of 9.6 % as compared with PV horizontal panel.

Table 5. Quarterly optimum tilt angle

Period	β degree	G_{TLT} kWh/m^2	G_0 kWh/m^2	Energy Gain %
21/3-21/6	14	600.8	589.3	2.0
22/06-21/09	15	660.1	643.6	2.6
22/09-21/12	44	434.4	347.8	24.9
22/12-20/3	43	375.2	308.3	21.7
	Total	2071	1889	9.6

Table 6 represents that the slanting of the PV panel at 15° in the period of 21 March to 21 September and 43° for the period 22 September to 20 March, gains the energy by 9.6% as compared to the horizontal surface.

Table 6. Bi-annual optimum tilt angle

Period	β degree	G_{TLT} kWh/m^2	G_0 kWh/m^2	Energy Gain %
21/3-21/9	15	1260.8	1232.8	2.3
22/09-20/3	43	809.6	656.1	23.4
	Total	2070.4	1888.9	9.6

Both Table 5 and Table 6 show an interesting result, the overall energy gain either for quarterly or biannual strategies optimum tilt angle is the same. In addition, Table 6 shows that energy gain in the period of 22 September to 20 March is higher than the energy gain in the period of 21 March to 21 September by 90% (about ten times).

The solar energy gain per each fixed tilt angle for the whole year is shown in Figure 10. The optimum tilt angle is found out to be 26°. The solar energy gain is equal to 2028 kWh/m^2. This increases the solar energy by 7.4%, as compared to the solar energy gain collected by a horizontal surface.

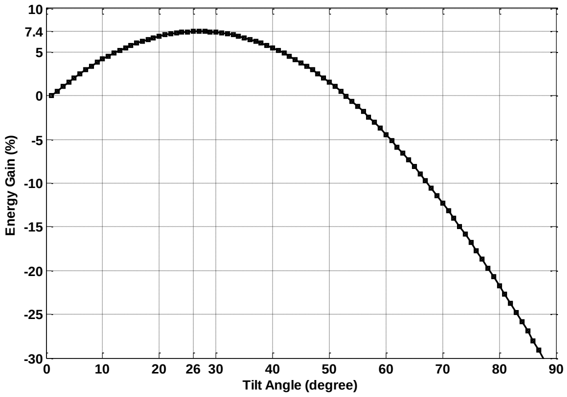

Figure 10. Energy gain according to varying tilt angle

From the previous results, it is clear that the monthly adjustment of tilt angle is the best strategy with an energy gain of 10.1% followed by the quarterly and the biannual techniques. The worst strategy of tilt angle adjustment is an annual (fixed) tilt angle whereas the energy gain value for this strategy is about 7.4%.

It is worth noting that for offline remote household, an adjustment system would have an enormous impact on the solar system efficiency. However, it is apparent that a monthly tilt angle adjustment has a negligible gain compared to the adjustment system cost and maintenance. Therefore, slanting the PV panels by 26° (latitude -6°) for the whole year time is the optimum, which increases the solar energy yield by 7.4%.

5.2. Optimal Sizing of PV System

In order to make the PV systems more feasible, a grid-connected PV system is considered. This system offers users both economic and environmental advantages. Where utility power is available, users can use a grid-connected PV system to supply a portion of the power they need while using utility-generated power at night and on very cloudy days.

For a monthly billing system, Figure 11 shows the amount of energy obtained from the grid each month as the number of PV panels is varied from 1 to 16. The monthly auxiliary energy needed from the grid is indirectly

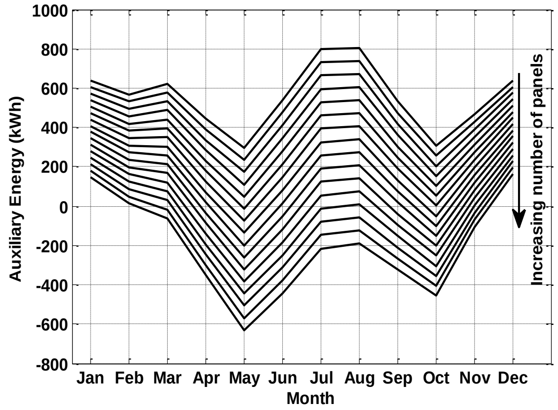

Figure 11. Monthly Auxiliary Energy needed from the grid versus number of panels

Figure 12 shows the grid energy use and the annual percent energy savings, system cost, and LCC as a function of the number of PV panels. Using LCC analysis, the optimum number of PV panels with the specifications in Table 2 is found to be ten panels. The total cost of the optimum PV system is US$ 4,056, while the life cycle cost over a 30-year period is determined to be US$ 19,524.

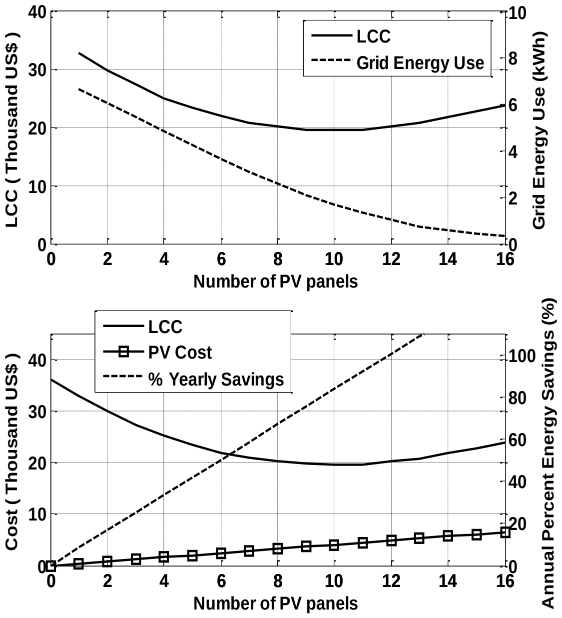

Figure 12. LCC Analysis for different PV System sizes

The electricity generated by the PV-grid energy system and the corresponding electricity consumed by the users (when the cost of PV is US$ 1,352 per kWp and global solar radiation is 5.5 kWh/m^2/day) is shown in Table 7. The total electricity produced by the energy system is 7,261 kWh/year which comprises of 6,075 kWh/year (83.7%) from the solar PV and 1,186 kWh/ year (16.3%) from the grid.

Table 7. Electricity generated by the solar

	Annual Production kWh	%
Solar PV	6,075	83.7
Grid purchases	1,186	16.3
Total	7,261	100

Figure 13 represents the LCC reduction as a function of a number of PV panels as compared with energy cost from grid, calculated as follow:

$$\mathrm{LCC}\ \% = \frac{\mathrm{LCC(1{:}16)]} - \text{Energy cost from grid}*\mathrm{PWF}}{\text{Energy cost from grid}*\mathrm{PWF}} \times 100 \quad (12)$$

From this figure, it is determined that the minimum LCC occurs for a 10-panel solar system.

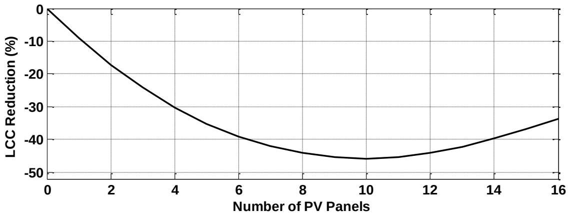

Figure 13. LCC reduction as a function of the number of PV panels

The relationship between the payback period and the number of panels is linear, as shown in Figure 14. The payback period for an optimum sized system is 5.88 years.

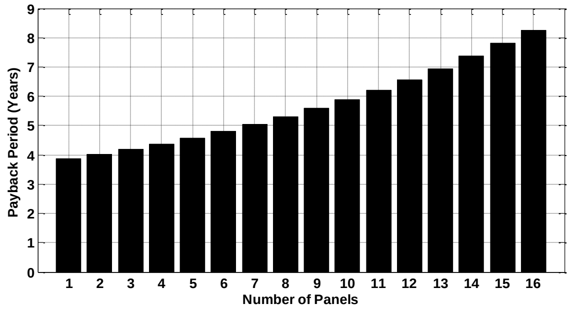

Figure 14. Payback period analysis for different PV System

The monthly average electric energy produced by the PV array is presented in Figure 15. The monthly and seasonal variations in electricity produced by PV system and the grid contribution can be observed from this figure. This is due to the variability in the monthly global solar radiation. The maximum monthly energy generated by the solar PV is about 675 kWh in July, and the minimum is about 315 kWh in December.

The monthly energy purchased from and sold to the grid is presented in Table 8. It can be seen from this table that the quantity of the electricity purchased varies from 179 kWh in May, when the load is low and the PV produced a relatively high amount of electricity, to 519 kWh in August when the load rises sharply due to the increased usage of AC in the hottest month of the summer. Similar variations in the electricity sold to the grid can also be observed from this table.

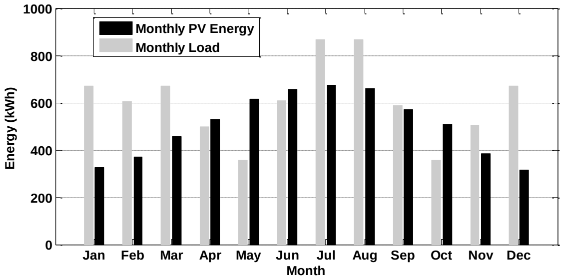

Figure 15. Monthly distribution of the electricity produced by the energy system

Table 8. Monthly distribution of the electricity produced by the energy system with optimum parameters

Month	Energy Purchased (kWh)	Energy Sold (kWh)
Jan.	472	128
Feb.	396	161
Mar.	422	210
Apr.	290	325
May	176	436
June	329	380
July	503	313
Aug.	519	313
Sep.	362	344
Oct.	220	371
Nov.	346	224
Dec.	490	133
Annual	4,525	3,339

Figure 16 shows the performance of the proposed system throughout the year. a snapshot showing zoomed in details of a 4-day period between the 50th and the 53rd day of the year is shown in Figure 17.

In addition to its economic savings, the PV system's main purpose is to protect the environment; the annual savings after installing a PV system for the chosen demand is around 6,075 kWh. In addition, the PV system will reduce around 3.6 Tons of CO_2 emissions annually [63].

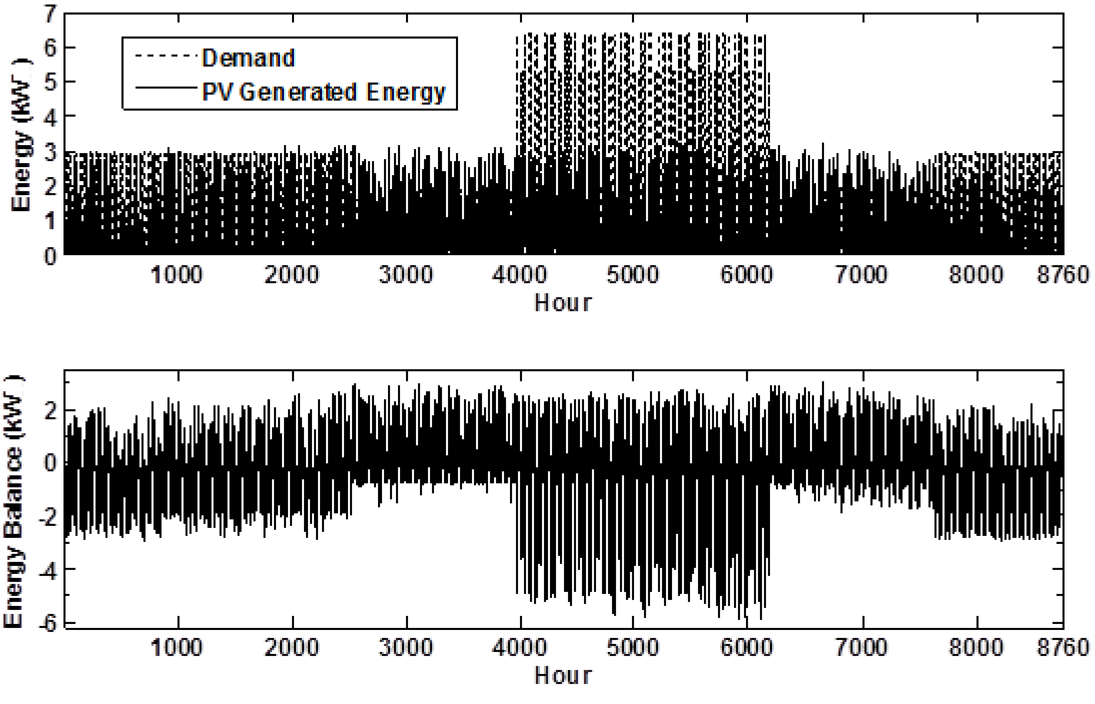

Figure 16. Designed system performance

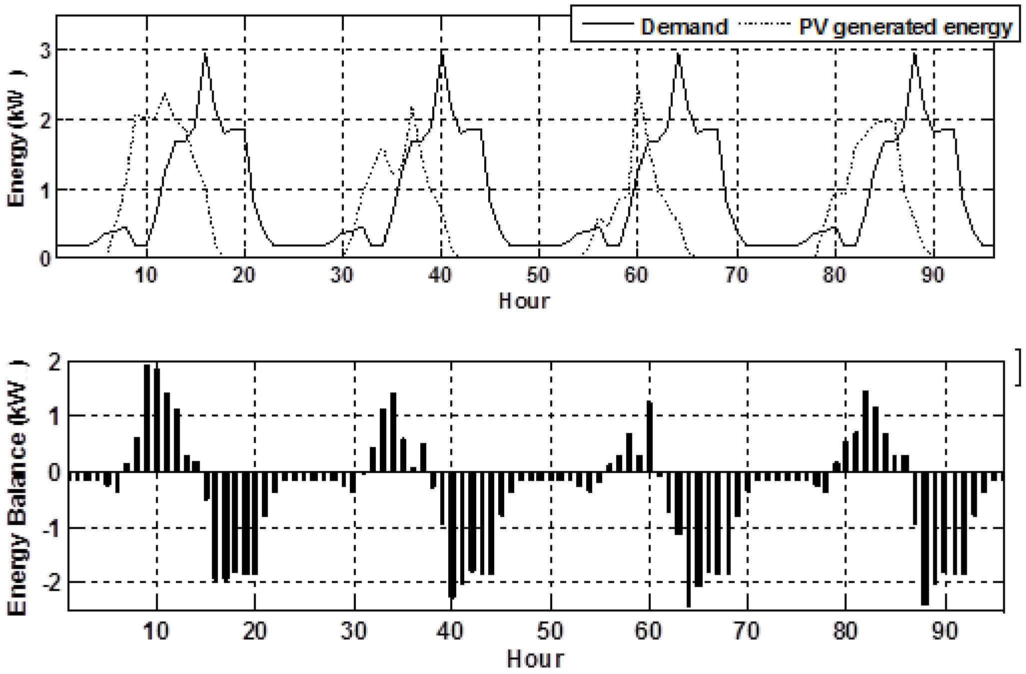

Figure 17. Four-day sample of hourly performance of the proposed system

6. Conclusion

As part of electrical energy can be produced by renewable means, and while the principal advantage of PV is the production of environment, it is a good chance to use alternative energy options before the supply of fossil fuels is depleted, and the damage to the environment is irreversible. The presented results are quite detailed and include, besides the optimum PV panel tilt angle, the simulation and the optimum sizing of the system in Mediterranean climate. It also presents a cost analysis of several years, and the system's behavior on an hourly basis.

With the rapid population growth and the increase in the various economic activities, more energy is consumed; to identify the impacts of the amount of saving, the macroeconomic analysis should be considered. Once only 100 houses in Jordan generate electricity by solar systems, around 607.5 MWh will be saved annually, and about 360 Tons of CO_2 emissions will be reduced. As PWF at 6.25% interest rate and inflation rate of 8.9% after 30 years, the total saving in the energy bill, during 30-years, is about US$ 3.4 million that will strengthen the local economy. Once the output of the present research is expanded to all the Mediterranean region, a superior economic and environmental benefits will be achieved.

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