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Feasibility study of using 2kWp residential PV system comparing with 2.5kVA gasoline generator (Case study: Baghdad city)

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Abstract
The economic analysis is the most important parameter in the engineering projects. The current research aims to propose economic and financial analysis in order to assess the feasibility for a 2kWp designed PV system with a battery capacity of 500Ah for each residential consumer of Baghdad city in Iraq comparing with a 2.5kVA gasoline generator and thus calculating the total expected revenue from the use of PV system against using conventional electricity generation sources (gasoline generator). The economical evaluations in this work clarified that the life cycle cost of the conventional source (gasoline generator) is approximately doubled the life cycle cost of the PV system for a 2kWp system capacity. This result indicates that the using of PV system for residential sector in Baghdad city is feasible when compared with conventional electricity source.

Keywords: PV: Cost; Economic; Analysis; Baghdad; Feasible; Gasoline generator; Payback; Benefits.

1. Introduction

Electricity sector in Iraq has faced many troubles and fences which have a great effect on the development and upgrading of this sector. Such problems involve the increasing of the electrical load demand after 2003 and appearance of peak loads causing the electricity generation deficit. Various factors have led to this situation, such as the international blockade on Iraq, limited investments, consecutive wars, security issues and others [1].
All previous parameters caused a load shedding in the electrical grid and this shortage of electricity makes people meeting those requirements through traditional means of electric power generation such as large diesel generators, small diesel generators and gasoline generators. There are certain drawbacks for power generation through conventional resources. Some of these drawbacks are the environmental effects involve combustion products that causing global problems such as the greenhouse effect and pollution which are posing great danger for the entire life on our planet. As well as to the environmental reasons, the lack of the crude oil sources such as gasoline or natural gas causing oil crises. Therefore, it is necessary to shift our focus from conventional resources to non-polluting renewable energy sources such as PV systems and wind energy systems [2, 3]. Therefore, this study is presented to assess the feasibility of using renewable

energy resource represented by solar energy versus conventional energy source represented by gasoline generator for residential consumer of Baghdad city.
The essential parameters of engineering decisions is economics. So, the price of the photovoltaic system and its installation are important factors in the economics of PV systems. These include the prices of PV modules, storage batteries and balance of system. From the economical point of view, PV energy systems differ from conventional energy systems in such that they have high initial cost, very low operating and maintenance costs because there is no fuel cost (fuel free) and replacement costs are low. While the traditional energy resources (such as gasoline generator) featured in very high running cost which represented by fuel with operation and maintenance costs [4, 5].
Some of researchers have been focused on the economic evaluations and calculations for solar energy systems in the last ten years. From literatures, M. M. Mahmoud and I. H. Ibrik, [6] presented three energy supply alternatives for a remote village in Palestine represented in PV system, diesel generator and electric grid. The design of these systems and the associated costs of their utilization are illustrated. The results showed that, utilizing of PV systems for rural electrification in Palestine is economically more feasible than using diesel generators or extension of the high voltage electric grid. A. Batman, et al., [7] introduced a study to determine solar power generation potential and its impact on peak demand in Istanbul, Turkey. Measured data with technical and commercial parameters were used to perform the calculations. Different tariffs such as time-of-use was considered in this study. K. K. Jagtap, et al., [8] studied the feasibility of wind-solar PV hybrid energy system for domestic loads in the Maharashtra state, India.

2. Economic model for PV system

The life-cycle cost (LCC) of a solar PV system is given by [4]:

$$LCC = C_o + O\&M_{PV} + R_{PV} \tag{1}$$

where, C_o: The initial capital cost, which is the summation cost of each part of the photovoltaic system, i.e. photovoltaic array, inverter, storage batteries, electric control and battery charger as well as electric cables, packaging, transportation and installation (C_o=PV array + Batteries + BOS). $O\&M_{PV}$: The operation and maintenance costs. R_{PV} : Total replacement cost, which includes the battery replacement over the system lifetime and BOS.
The annually photovoltaic generation cost is equal to the annually PV production (kWh) multiplied by the price of electricity unit ($/kWh). This is an important factor to calculate the payback period (The time required for an investment to recover its initial cost). The payback period (PBP) is calculated [4, 9],

$$PBP = \frac{LCC}{Q \times e} \tag{2}$$

where, e : The price of electricity unit ($/kWh). Q : Annually actual production (kWh) from PV system, is calculated from,

$$Actual\ PV\ production = 5\ hours \times 350\ days \times size\ of\ system \tag{3}$$

where the number five represents the hours of actual production in each day during the year, and 350 days because a 15 days for rest and maintenance purposes. With a 2kWp PV system, the annually actual production is equal 3500 kWh. The annually generation cost can be obtained from,

$$Annually\_generation\_\cos t = e \times Q \tag{4}$$

The benefits from selling the solar energy produced from a 2kWp PV system during a 20 years life-cycle can be calculated as follows,

$$Benefits = (Annually\_generation\_\cos t \times 20 years) - LCC \tag{5}$$

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3. Results and discussion

In this work, the economic analysis will be present for a 2kWp PV system and 500Ah storage system for each consumer in residential sector of Baghdad city and based on the obtained design results of references [3, 10] as which are illustrated in Table 1.

In PV system, the assumptions for economic estimations in this work are illustrated in Table 2. These assumptions are according to the market costs and as references [4, 9, 11].

The obtained results based on the previous table and Eq. 1 for this system are illustrated in Table 3.

Table 1. Design parameters and specifications of the PV system and storage system [3, 10].

Parameter	Value
System size	2 kWp
Nominal power of Panel	327 W
Panel area	1.6 m²
Panel efficiency (η_R)	20 %
Number of panels	6
System surface area (S_{PVG})	10 m²
System losses	20 %
Temp coefficient (β_P)	–0.38 % / °C
Cell type	Monocrystalline
Operating temperature	-40 °C to +85 °C
Peak load period	(18-23) PM
Nightly peak load period (E_L)	2.4 kWh
System efficiencies (BOS)	85 %
Deep of discharge (*DOD*)	50 %
Battery storage (*S*)	6 kWh
Battery voltage	12 V
Number of batteries	5
Ampere-hours of each battery	100 Ah
Total ampere-hours required	500 Ah

Table 2. The economic assumptions for PV system according to [4, 9, 11].

Parameter	Assumption
Price of solar energy	0.85 $/Wp
Price of battery	1.7 $/Ah
BOS (inverter, charger, wires)	5% of PV array cost
Operation and Maintenance ($O\&M_{PV}$)	2% of initial cost (C_o)
Life-cycle of the system	20 years
Replacement Parameters(R_{PV})	BOS each 10 year Batteries each 8 year

Table 3. The costs of PV system.

PV array Cost (2 kWp)	= 2000 Wp× 0.85 $/Wp = 1700 $
Group of Batteries (500Ah)	= 1.7 $/Ah × 500 Ah = 850 $
BOS cost	= 0.05 × 1700 $ = 85 $
Initial cost (C_o) = PV array + Batteries + BOS	= 1700 $ + 850 $ + 85 $ = 2635 $
$O\&M_{PV}$ cost	= 0.02 × 2635 $ = 53 $/Annual
Replacement cost (R_{PV})	BOS = 85 $ per ten years Batteries = 850 $ per eight years
Life-cycle cost (*LCC*) = $C_o + O\&M_{PV} + R_{PV}$	= 2635 $ + (53$ × 20 year) + 85 $ + (2× 850 $) = 5480 $

Due to the very low running cost and high initial cost for PV systems comparing to conventional sources cost, it is necessary to compare the above results with a traditional electricity source such gasoline generator. The assumptions for economic evaluations according to the market are illustrated in Table 4.

Table 4. The economic assumptions of gasoline generator versus PV system.

Generator type	PV system	Gasoline
Generator size	2 kWp	2.5 kVA (2kW)
Generator price	2635 $	200 $
Fuel price	Free	0.38 $/liter
Fuel consumption	—	0.5 liter/hour
Replacement	—	Each four years
Annually maintenance cost	46 $	75% of initial cost=150 $
Annually fuel consumption	—	038$/liter × 0.5liter/hr × 350day × 5hrs=332.5 $ per year
Life – cycle after	20 years	=200 + (200 × 4) + (150 × 20) + (332.5 × 20) = 10650 $

For comparison purposes, the life cycle cost of PV system (2 kWp PV system) is 5480$, while the life cycle cost of the conventional source (gasoline) is 10650$ which is approximately double the life cycle cost of the PV system, because the running cost (fuel cost, replacement cost and maintenance cost) for traditional electricity source is very high, while the fuel cost of PV system is free. It is concluded that the solar cells application for residential sector in Baghdad city is feasible, competitive and beneficial when compared with conventional electricity sources such as gasoline or diesel generator

If it is assumed that a 2kWp photovoltaic system is implemented as a project by utility company which sells this energy to the costumer and it is required to compute the payback period and the incomes during the life-cycle, the total cost of generation according to the unit price of electricity ($/kWh) during the year is illustrated in Table 5. For a 2 kWp PV system, the annually generation equals to 3500 kWh as discussed using Eq. 3. So, the generation cost can be calculated by multiplying the price of electricity unit by annually actual generation based on Eq. 4.

Table 5. Cost of generation for PV system.

Unit price of electricity (cent/kWh)	Generation cost ($/Annual)
8	= 0.08 $/kWh × 3500 kWh = 280
10	= 0.1 $/kWh × 3500 kWh = 350
12	= 0.12 $/kWh × 3500 kWh = 420

The payback period for unit price of 8 cent/kWh is shown in Figure 1. For this case, the benefits are in the last year and equal to 120$ using Eq. 5 and the payback period started in twentieth year using Eq. 2. Also, it is clear that there are an increment cost in the eighth year. This is due to replacement costs after each eight years for batteries.

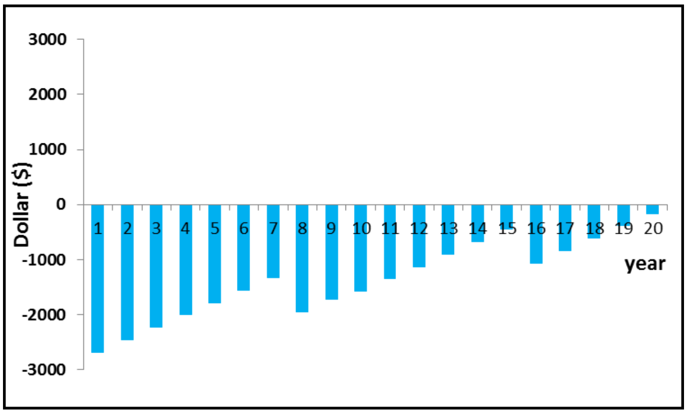

Figure 1. Pay-back period if the unit price 8 cent/kWh.

In case of 10 cent/kWh unit price, the payback period is shown in Figure 2. It is obvious that the benefits started in the thirteenth year and is equal to 1520$ using Eq. 5.
While in case of 12 cent/kWh unit price, the payback period is as shown in Figure 3. It is observed that the benefits started in the eleventh year and equals to 2920$ using Eq. 5.

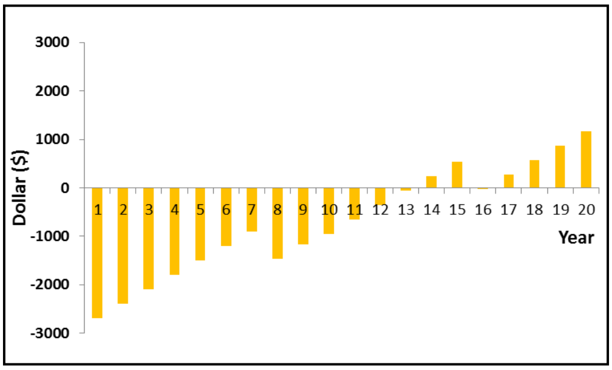

Figure 2. Pay-back period if the unit price 10 cent/kWh.

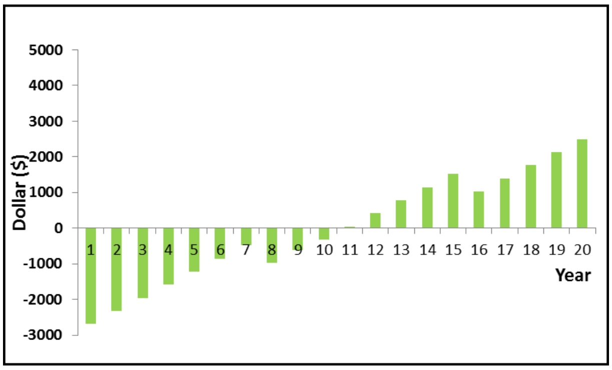

Figure 3. Pay-back period if the unit price 12 cent/kWh.

4. Conclusion

The economic calculations of PV system was analyzed for including initial cost, life-cycle cost, annual income and pay-back period. The main objective of this study is to evaluate the feasibility of using solar cells instead of traditional methods (such as gasoline generator) to generate electricity because PV systems have very low running cost and high capital cost while the conventional sources have a high running cost which represented in fuel cost and replacement cost. The life-cycle cost of PV system is 5480$, while the life-cycle cost of conventional source (gasoline) is 10650$, which is approximately double the life cycle cost of PV system, and from the economical viewpoint, the PV system is cheaper than the conventional one. This is due to the fuel free of the PV system and high running cost of gasoline generator. If the electricity price is 12 cent/kWh, the pay-back period of a PV system would be in the ninth year with a benefit of 2920$.
It is concluded that the using of solar cells for residential sector in Baghdad city instead of conventional electricity source such as gasoline or diesel generator is feasible. Also, PV systems provide clean and green energy during the solar generation because there is no harmful greenhouse gas emissions, so, solar energy is environmentally friendly energy.

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