



Effect of non-technical factors on the electricity cost of the photovoltaic (PV) systems

Ahmad Zahedi*, Joe Hallenstain

*Solar Energy Applications Research Group,
Department of Electrical and Computer Systems Engineering, Monash University,
Wellington Road, Clayton, Vic. 3168, Australia
Fax +61 3 9905-3454; email: zahedi@eng.monash.edu.au*

Abstract

There is an extensive range of applications where the photovoltaic (PV) systems are already viewed as the best and economical option for electricity supply. These systems are usually stand-alone, and exploit the following advantages of PV electricity: (i) there are no fuel costs or fuel supply problems; (ii) the equipment can usually operate unattended; (iii) it is very reliable and requires little maintenance. These advantages make solar PV to be seen as the greatest opportunity of electricity generation for billions of people throughout the world without electricity. However, there are some barriers hindering growth of this sector as the high cost of photovoltaic systems is capital intensive. The objective of this contribution to the conference is to present the results of a study conducted on the effects of non-technical factors on the capital and electricity costs of PV systems. In our research group we have developed a numerical method for calculating the electricity cost (considering time value of money) of the solar photovoltaic energy systems, which includes grid-connected, stand-alone and hybrid system. One of the features of this method is that it allows program user to investigate the effects of non-technical factors on the electricity cost of renewable sources.

1. Introduction

There are many applications where the PV systems are the most economical option for electricity supply. However, there are some technical

and non-technical barriers hindering development of solar photovoltaic systems.

Areas in which non-technical barriers exist are

- Lack of awareness
- By the community
- New technology
- Seen as untested and risky
- Leading to high cost

*Corresponding author.

The main applications of solar photovoltaic energy systems for the purpose of electricity generation are

- Grid-connected
- Stand-alone, and
- PV Hybrid system.

The latter combines PV array with a conventional electricity generating unit such as diesel generator. Solar photovoltaic energy systems have many advantages. They are modular and silent, they have no moving parts, they require low maintenance, and produce no emissions. However, they have a relatively high capital and electricity cost. Fig. 1 shows the range of cost of PV electricity in comparison with the other types of renewable energy and technologies.

Australia like much other overseas country has developed a Photovoltaic Rebate Program for PV systems installed on residential and community buildings. This financial support makes installation of grid-connected PV systems more affordable and consequently reduces the PV electricity price to a competitive level.

Although fuel of solar PV generators is free, but price of PV electricity is far above the price of electricity from conventional fossil fuel power plants. And also PV electricity is the most expensive amongst the other renewable electricity prices. This has been clearly shown in Fig. 1.

This high capital cost is affected by some technical factors such as efficiency, technology, reliability, location, orientation, tilt, as well as some non-technical factors, which are often overlooked.

Non-technical factors are classified as

- Awareness, attitudes and acceptance of customers and energy providers
- Financing
- Research and development
- Demonstration and marketing
- Regulatory measures
- Market-based factors
- Electricity infrastructure factors

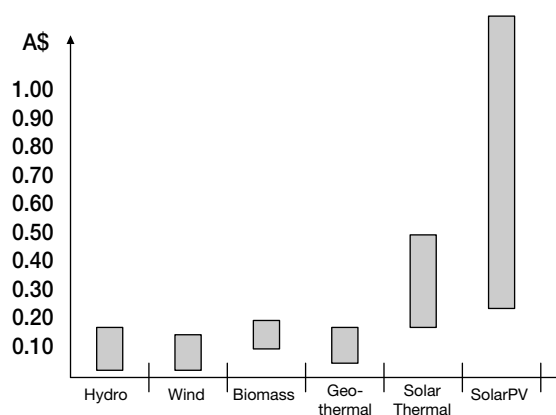


Fig. 1. Comparative electricity costs of renewable energies.

With regards to the financing, installation of solar PV systems require a large amount of upfront capital and it is more difficult to attract finance and to compete with electricity from conventional power plants.

In this approach we tried to minimize the cost of hybrid power system by optimizing the size of PV system and investigate the effect of some non-technical factors on these costs. In order to make sure that this does not result in poor performance of the system we have tried to predict the performance of the system.

In our research group we have developed a program, which has many features including size optimization, cost calculation and performance prediction of any type of solar PV system. This program also enables us to see the effect of non-technical factors such as interest rate, discount rate, mortgage rate, etc. on the capital and electricity cost of the solar PV system under investigation.

We would like to present the results obtained from this program for a hybrid power system, which has been designed with optimum size to supply electricity for a remote located facilities, which requires an average of 18 kW h of electricity per day.

Configuration of the system under investigation has been shown in Fig. 2. The system consists of

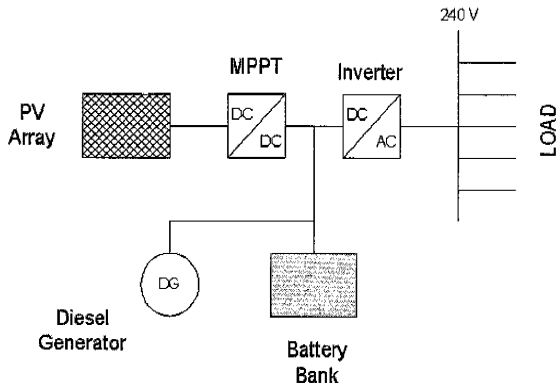


Fig. 2. The single line diagram of the PV hybrid system.

a solar array, a battery bank to support the array, a generator set for charging the batteries and a control system. An important factor in designing a PV hybrid PV system is optimizing the size of components in the system. In sizing the components we use an accurate methodology to avoid wasting PV electricity. For sizing the PV array in a hybrid system we use the average of sun radiation data of summer. When sizing procedure is

complete we can predict the performance of the system by using a numerical method. The prediction gives us idea that the components in the hybrid system are not oversized and also are not undersized but optimal sized. Both under-sizing and over-sizing are undesirable. Over-sizing makes the system more expensive, while under-sizing makes the system unreliable.

Table 1 shows sizing results while Table 2 shows the variation of electricity cost with interest rate on the money borrowed from a financial institution. In Table 2 two separate cases are compared. Case one is when cost of installation of PV hybrid system is not subsidized and case two is when the installation is subsidized by the Government. When money is available and in not borrowed from bank and no financial support is received from the Government the cost of electricity is A\$2.27/kW h as indicated in Table 1 (RHS of the last row).

The size of each component in this system depends on the kW h/day required by the load as well as the amount of sun energy received by solar array.

Table 1
Sizing results

Latitude	Longitude	PSHrs/ year	Spring	Summer	Falls	Winter	Ann-ave.	World ave.	PSH (Cal.)	Life time
37.53	143.72	1657.0	5.6	6.8	3.5	1.9	4.5	5.75	6.8	25
B. Eff.	Inv. Eff.	PV-Eff.	Wiring Eff.	Depth of discharge	PV siz- factor	Bat. siz- factor	kW h/ Liter	Usage (kWhrs)/ Day	Size in kW	No. of No SUN
0.85	0.90	0.95	0.98	0.80	1.0	1.0	0.7	18	3.74	5
PV (\$/ Wp)	Inverter size (kW)	Inverter cost (\$/kW)	O&M/kW /year	Inflation rate	Discount rate	Mortgage rate	Factor (X)	Present worth	Bat.cost	DG cost/kW
10.0	3.93	3000	100	0.03	0.1	0–10%	0.936	12.678	150	1000
P_{max} (W)	V_{mp} (V)	I_{mp} (I)	V_{oc} (V)	I_{sc} (I)	Fill factor	%DG	Voltage	Voltage	Voltage	Fuel cost \$/L
80	17	4.71	21.1	5.13	0.74	0.5	12V? Or	24V	48	1.00
Demand/ year	PV&DG/ year	PV/year	DG/year	% by PV	% by DG	Angle factor				Elect. cost \$/kW h
6570	6879	3749	3130	57	48	0.85				2.27

Table 2
AGO (Australian Greenhouse Office) provides financial support

	AGO No subsidies	AGO subsidies A\$7,500
Interest rate (%)	0.00	0.00
ANN-PMT	7565	7265
Electricity cost \$/kWh	1.15	1.11
Interest rate (%)	1.00	1.00
ANN-PMT	8587	8246
Electricity cost \$/kW h	1.31	1.26
Interest rate (%)	3.00	3.00
ANN-PMT	10860	10429
Electricity cost \$/kW h	1.65	1.59
Interest rate (%)	5.00	5.00
ANN-PMT	13418	12885
Electricity cost \$/kW h	2.04	1.96
Interest rate (%)	7.00	7.00
ANN-PMT	16227	15584
Electricity cost \$/kW h	2.47	2.37
Interest rate (%)	8.00	8.00
ANN-PMT	17715	17013
Electricity cost \$/kW h	2.70	2.59
Interest rate (%)	10.00	10.00
ANN-PMT	20834	20007
Electricity cost \$/kW h	3.17	3.05

The variation of electricity cost as a function of mortgage rate on the loan borrowed for installation of PV system has been shown in Figs. 3 and 4. Fig. 3 shows this variation for the case that the Government does not provide financial support, while Fig. 4 shows this variation for the case that the Government provides financial support.

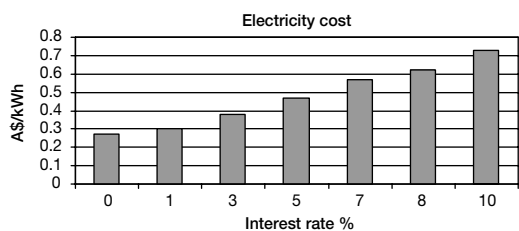


Fig. 3. Electricity cost vs. mortgage rate on loan for installation of PV system. No financial support from government.

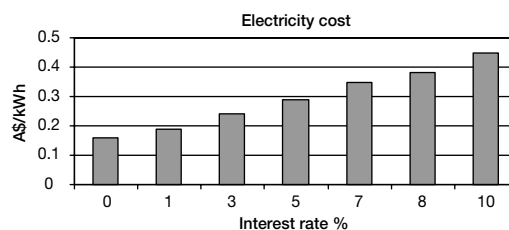


Fig. 4. Electricity cost vs. mortgage rate on loan for installation of PV system. Financial support from government.

2. Performance prediction

In order to make sure that the system, for which we have conducted the optimum sizing, is able to supply reliable electricity for the load, we have performed computer simulation for the purpose of performance prediction. As battery

Table 3

Number of hours per day in each month that the diesel generator has to operate

Hrs in Jan.	Hrs in Feb.	Hrs in March	Hrs in Apr.	Hrs in May	Hrs in June	Hrs in July	Hrs in Aug.	Hrs in Sep.	Hrs in Oct.	Hrs in Nov.	Hrs in Dec.
1	1	2	3	4	4	5	4	4	1	1	1

bank is the weakest component in the PV hybrid power system, we have chosen the state of charge (SOC) of batteries as a measure for performance prediction. Fig. 5 shows the SOC of battery bank over one year. As this figure shows in winter time (the least sunny season) the depth of discharge is just above 60%.

Table 3 shows the number of hours per day in each month that the diesel generator has to operate to ensure that batteries remain in healthy conditions and the load receives the electricity needed.

3. Conclusions and remarks

This paper has presented the fact that the non-technical factors such as correct sizing, inflation rate, discount rate and mortgage rate have strong effects on the capital and electricity cost of PV hybrid power systems. The correct sizing is important part of designing a hybrid system. Over-sizing the system makes it more expensive and will result

in wasting electricity, while under-sizing makes the system unreliable. Therefore optimum sizing is very important. Optimum sizing is important because it ensures minimum capital and electricity cost. In this investigation we have assumed that the PV array generates in summer the same amount of energy which is needed by the load in a typical in a summer day. Usage of diesel generator will be minimum summer. In the other seasons PV array generates less electricity, therefore usage of diesel generator will be more. This arrangement offers all the benefits of PV systems with respect to low operation and maintenance costs, and also ensures that PV electricity is not wasted. This paper has also presented a method for performance prediction of PV system. Performance prediction is an important part of any system design.

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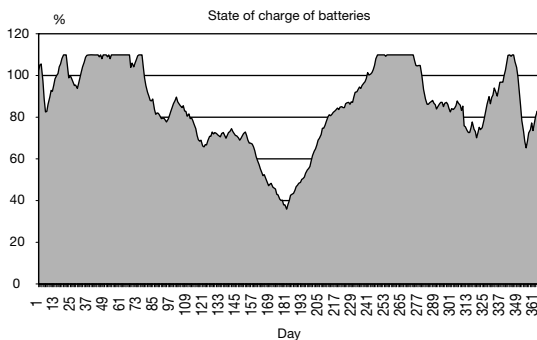


Fig. 5. State of charge of the battery bank.