Evaluation of economic advantage for produced electrical energy usage by solar cell in compression with steam power plant in home in Isfahan city

Abbas Ali Abounoori
Assistant Professor, Islamic Azad University central Tehran Branch.

Shahram Javadi
Assistant Professor, Islamic Azad University central Tehran Branch.

Hassan Ahmadi
Department of Economics, Islamic Azad University, central Tehran Branch., Iran.

Hadi Parhizi Gashti
Department of Economics, Islamic Azad University, central Tehran Branch., Iran.

ABSTRACT

The aim of this article is evaluation of economic advantage from using of solar energy (photovoltaic system) in compression with steam power plant in order to supply the electricity of Isfahan's household (2009 to 2011). For this reason, meanwhile the calculation of used electricity for each house in Isfahan city, the production cost for one kilo watt hour of electricity through two methods of steam power plant and photovoltaic system is estimated from the scale of equation's uniform annual cost. The result shows that application of photovoltaic system is inadvisable in Isfahan in now condition. It is considerable that due to increasing of electricity requirements and the limitation of fossil sources and the high pollution because of these sources, the usage of resulted energy from steam power plant hasn't economic justify in the not too distant future.

Keywords

New energies, solar energy, economic evaluation, photovoltaic system, steam power plant

1. INTRODUCTION

Daily lives of humans are dependent on energy's production and consumption. Along with technological advances and high levels of society's needs so trying to access new sources of energy was performed widely, because the primary sources of energy were not able to answer the demand amounts for different energy. The primary sources of fossil because of limitations and environmental pollutions could not supply all considered demands. So studying on the use of new energy such as eternal solar energy has been attention in recent years. Something that encourages everyone that to use of new energy are the limited reserves of fossil and adverse environmental effects also something that to avoid everyone from quick succession of new energy are their low efficiency in comparison with fossil energy is the its using high cost and their conversion also the unwillingly of industries and governments to support them. The main purpose of the present paper is the evaluation of economic advantage from solar energy with using of photovoltaic systems in comparison with steam power plant in order to supply the electricity of Isfahan's households.

2. Literature and research background

Solar energy is one of the most important new energy. Solar is atmosphere's energy source and outcome of its stored energy which are used in traditional and industry fuels also the coal which was the remains of forests fossil and animals for thousands years ago for its growing had essential require to sunlight. Other thermal and mechanical energy which their form is dependent to sunlight indirectly such as oil and its refined products, natural gas and other forms of chemical energy that have been created from the effect of sunlight on the body of living organisms in past periods.

According to scientific estimates although about 600 million years are passed of sun's life yet can use of its eternal energy about three million next years. Using of solar light and thermal energy has been much attention in order to electricity production. This phenomenon was discovered for the first time in 1839 and its most important step was production of pure silicon in the late 1940s. The first converter light into electricity was made of silicon semiconductor in Bell laboratory in 1954 then the process of converters' costs reduction and using of industry construction with high volume was performed in 1975.

Almost all solar energy with crossing of infinite space which is extensive in each direction will be lost before reaching to the ground only a small part of this energy is absorbed by earth and its atmosphere. Some factors are effective in intensity and the amount of solar radiation such as: Dust, water vapor, clouds and wind which reduced the intensity of solar radiation. Moreover the carbon dioxide, methane, oxygen and ozone in the air are absorbed the radiant energy from the sun. (Ahmadian 2002. 228)

Fortunately our country because of its geographical special position has high power in getting the solar energy. So with using of solar energy beside the benefit from this free energy and saving of fossil resources for future generations can reduce the environmental pollutions and provide the issue for achieving sustainable development in throughout the country.

Due to increasing the importance of solar energy and existing difference opinions about being economical of its using the experts are done many studies about this subject that is interesting. In Liebenthal and et al 's study (1994), the electricity supplying to rural areas of the Pacific Islands by diesel and photovoltaic power plants has been evaluated from economic aspect. In this research that used of life cycle cost analysis method the electricity supplying to rural areas by mentioned tools was compared and the final cost of energy production is calculated by diesel and photovoltaic power plants. According to results of this study which is obtained based on experience of Pacific island countries, for electricity

supplying to rural areas with lower load capacity the electricity production by photovoltaic power plant will be cheaper than diesel plant. In Ahmad's research (1994) the costs for using of renewable energy (Thermal - solar, photovoltaic and Biomass) is calculated from present value and life cycle method. The results of the studies in this paper suggest that the costs of photovoltaic technology had descending process in fifteen last years (1994-1979) and this process will be continued up to 2020.But the cost of electricity production from thermal - solar and biomass technologies had various process. In Carlos and et al research (1998) which was performed in north of Brazil, they concluded that for supplying the electricity of rural below 100 households using of diesel and photovoltaic's combination power plant is good option and according to predicting the reduction of photovoltaic system components 'price in future then using of them will be justified from the economic aspect. In this research with using of present value model is calculated the electricity production costs through various methods of electricity Supplying. In Notton and et al research (1998), while using of life cycle costs analysis also calculated the cost of photovoltaic system's energy unit in two modes, supported and non-supported with auxiliary diesel engine and the system cost based on separation of its components is estimated. Lesourd (2002) in a research with this title "Solar photovoltaic systems: The economics of renewable resource" beside to obtain the cost of energy's unit of photovoltaic system from the life cycle cost's analysis method and its comparison with power plants 'unit cost of energy is studied on the advantages usage of photovoltaic power plant. In above research the cost of electricity production with photovoltaic system is estimated 25 cents for each kilowatt hour in 1997 which in comparison with the cost of electricity production which is 10 cents for per kilowatt hour of electricity, is higher. However, it is anticipated that due to advances in existing technology the cost of solar electricity will be reduced to half which according to this matter and also the ascending process of fuel global price so the usage of solar energy will be better and cheaper. Jurgen R. Olivier and et al (2007) studied on the economic advantage and technical use of solar energy in north of Africa in order to financial feasibility and foreign investment and savings trough reduction in the annual development program of diesel ships. So the average of radiation hour and radiation's degree in order to estimate the technical efficiency of solar electricity production systems with related data to area's energy demand estimation is extracted in order to its economic analysis. Estimates suggest that photovoltaic models can be used potentially instead of reducing the area's electricity although is not too cheap just can return its costs at the end of 25 years. Shababi and et al (1997), studied on a research with this title "Technical and economic evaluation of solar photovoltaic power plants in Iran" with calculation the amount of received mean energy with photovoltaic panels in sun-rich countries due to the amount of producible energy have calculated the initial investment costs, exploitation and power plant keeping and cost of electricity production with photovoltaic power plant with using of cost equilibrium energy. In the above article concludes that the most suitable areas for the construction of photovoltaic power plants is in the central south of country and the cost of electricity production with photovoltaic power plant is more than 400 for per kilowatt hour that in comparison with solar, thermal and fossil power plants is high significantly. Therefore, these power plants are recommended for remote areas with limited consumptions which their electricity supplying is very costly and difficult through the electricity networks.

3. Theoretical foundations and Research methodology

One of economic evaluation's methods for projects is the criterion for uniform annual cost equation. This way is solving the problems faster and easier in comparison to other ways when that the projects life is unequal. Based on this method the cost of producing kilowatt-hour electricity through photovoltaic systems and steam power plant is calculated as follows: First of all has estimated the system's costs and we divided the capital and current costs. We calculate the real interest rate and based on interest and inflation rate and with using of equation l then estimates the present value of current costs through equation 2 in during the lifetime of the project then the sum of obtained number with capital costs of project. Then we make the all costs as annually with using of equation 3 and we calculated the cost of a kilowatt hour of produced electricity by using of equation 4.

$$i = \frac{1+r}{1+p} - 1 \quad (1)$$

$$PV[C(O\&M)] = C(O\&M) \times \frac{(1+i)^n - 1}{i(1+i)^n} \quad (2)$$

$$EUAC = AC \times \frac{i(1+i)^n}{(1+i)^n - 1} \quad (3)$$

$$C(U) = \frac{EUAC}{E} \quad (4)$$

Where:
i: Real interest rate
P: Inflation rate
r: Interest rate
C (O&M): Current costs
AC: Present value of all project costs
EUAC: Monotonous annual cost
C (U): Production cost of electricity per kilowatt hour
n: Project's lifetime

$\frac{(1+i)^n - 1}{i(1+i)^n}$: Capital recycling coefficient

$\frac{i(1+i)^n}{(1+i)^n - 1}$: The current coefficient of annual installments

E: Kilowatt hours of annual production electricity

3. 1 Technical calculation of photovoltaic system

The average amount of solar radiation on the unit level according to watt hours on square meter during the day in the

country is considered about 6500 W square meter. Based on the information of company which was the manufacturer of photovoltaic modules in Iran (Shahid Ghandi Communication Cable Company) and according to required energy for per household and the amount of sun hours (PSH) also losses of photovoltaic systems accessories (10%), inverter system (10%), storage system (10%), synchronization coefficient for all types of usage (6%), nominal power of panels (45 Watt) can calculate the number of needed photovoltaic panels for every home. Also for storing the produced energy with panel and its usage at night or cloudy days is used of lead - acid battery made in country(Yazdani Rad, 1998,123), which according to the amount of daily produced energy with panels and the number of cloudy days(Maximum consecutive cloudy days) can calculate the batteries' capacity.

According to don calculations the needed of net energy for per household is calculated 12608 wh/day. But according to technical experts 10% of consumption amount will be added to total consumption of per household for compensating the energy losses in the panel and connector cable (Khosh Akhlagh and et al 2005, 182).Consequently needed impure energy for supplying the daily electricity of a house is about 13868.8 watt hours in per day which for ease of calculation is considered about 14,000 watt hours in day.

3.2 Designing of Photovoltaic System

E_S: Radiant energy from the sun on unit level according to watt hours on square meter during the day, its average value in the country is considered about 6500 watts on square meter during the day.

E_t: Required electrical energy for a day based on the watt hours and its amount in this research is about 14,000 watt hours in a day.

η p.v: Efficiency (11%)

S_{pv}: The dimensions of photovoltaic panels based on square meter (0.5 square meters).

N_{pv}: Number of photovoltaic panels

D_{bac}: Number of consecutive cloudy days (3 Days) and DOD% residual minimum capacity in storage system and battery's bank supporter. (0.4)

E_{bac}: Storage amount according to total cloudy day based on watt hour battery bank.

Ah_{bat} AndN_{bat}: Number of needed batteries and capacity of battery bank according to ampere hours.

V_{bat} : Battery's voltage according to volt (12 volt).

C_{bat}: Capacity of selected battery based on ampere hours (100 AH).

Equations:

$$E_{bac} = E_t \left(wh\right) * D_{bac} + DOD\% \quad (5)$$

$$Ah_{bat} = \frac{E_t \left(wh\right) * D_{abc} + DOD\%}{V_{bat}(v)} \quad (6)$$

$$N_{bat} = \frac{Ah_{bat}}{C_{bat}} \quad (7)$$

$$N_{p.v} = \frac{E_t + E_{bac} * 0.07}{\eta_{pv} * E_s * S_{pv}} \quad (8)$$

With using of equation 5 we will have:

$$E_{bac} = E_t \left(wh\right) * D_{bac} + DOD\% = 14000 * 3 + 0/4 = 47600 \left(wh\right)$$

Battery Bank

The capacity of battery bank and the number of needed batteries are calculated respectively from equation 6 and 7:

$$Ah_{bat} = \frac{E_t \left(wh\right) * D_{abc} + DOD\%}{V_{bat}(v)} = \frac{47600}{12} \cong 3967 \left(Ah\right)$$

Capacity of the battery bank

$$N_{bat} = \frac{Ah_{bat}}{C_{bat}} = \frac{3967}{100} = 39/67 \cong 40$$

Number of batteries

The numbers of panel from equation 8 is:

$$N_{p.v} = \frac{E_t + E_{bac} * 0.07}{\eta_{pv} * E_s * S_{pv}} = \frac{14000 + 47600 \times 0/07}{0/11 \times 6500 \times 0/5} \cong 49$$

3.3 Economic calculation of photovoltaic system

Purchase cost, installation and exploitation of photovoltaic system is including of investment costs (Primary) and operational costs. System's useful life is 20 years. For producing 14 kilowatt hours of electricity through photovoltaic systems for a sample houses in Isfahan city, needed equipment and the equipment cost there is in table 1 as estimation form:

Table 1. The needed equipment and equipment's cost

Row	Equipment	NO	Unit	Unit price()	Total cost()
1	Panel 45 Watt	49	Device	1800000	88200000
2	Structure	3	Device	2200000	6600000
3	Controller charge 24 volt 40 amp hour	2	Device	3400000	6800000
4	Battery 12 volt 100 amp hour	40	Cell	2800000	112000000
5	Inverter 5kw	1	Device	40000000	40000000
6	Accessories (Including wires, cables and other accessories)	-	-	30000000	30000000

7	Installation	-	-	30000000	30000000
	Total sum				313600000

Total cost includes needed equipment, design, installation will be about 313600000. According to experts' comment from complex manufacturer of optical fiber, 0.5 % of capital costs are estimated as operating costs and current annual cost of a photovoltaic system (Jabar, 2004, 22).

C (O&M) =313600000 * 0.5% =1568000

According to this subject that obtained income is the produced electricity here and its value should be used in calculations. According to imposed free tariff by department of energy we will attention to its value so the amount of annual electricity cost savings for a house was calculated 4406400.

Summary of costs and income can be seen on the table 2:

Description	The cost of a kilowatt-hour in a day during the year()	The cost of 14 kilowatt-hour in a day during the year()
The initial investment cost	4500000	*63000000
Operation cost (Except Fuel)	55000	770000
Fuel cost	175	175*14*365=894250
The cost of transmission and distribution	237	237*14*365=1211070

The summary of costs and income in photovoltaic system ()

Table 2. The summary of costs and income in photovoltaic system ()

T	Cost	Income	Net profit
0	313600000+1568000	4406400	-2838400
1	1568000	4406400	2838400
2	1568000	4406400	2838400

$$i=\frac{1+r}{1+p}-1=\frac{1.17}{1.21}-1\cong -0.033$$

3	1568000	4406400	2838400
4	1568000	4406400	2838400
5	1568000	4406400	2838400
….	….	….	….
20	1568000	4406400	2838400

Assuming an average interest rate 17 percent and inflation rate of 21 percent then we will calculate the real interest rates with helping of following formula:

The present value of current cost is equal to:

$$NPV[C(O\&M)]=1568000\times 29.0952=456212736$$

The sum of present value from total costs will be equal:

$$AC=313600000+1568000+456212736=3607892736$$

Now with using the below formula make the present value of total costs as annually:

$$EUAC=AC\times\frac{i(1+i)^n}{(1+i)^n-1}=3607892736\times 0.0344\cong 1241115101$$

With using of below formula the unit cost of produced electricity's energy from photovoltaic system is obtained:

$$C(U)=\frac{EUAC}{E}=\frac{1241115101}{14\times 365}\cong 2428.8$$

On KWh

3.4 Economic calculation of steam power plant

About the steam power plant the initial investment cost for each kWh is 4500000 and exploitation cost is 55000, construction period of five years and the useful life is 30 years. So can summarize the production, transmission and distribution cost from per kilowatt hour of electricity as table 3:

Table 3. Cost of production, transmission and distribution of electricity

*Number 63000000 is the future value of the initial investment during the construction (5 years) which is given zero years.

Now according to this subject that in country's energy sector the external costs are the costs that are imposed to society and the environment because of production, transmission, conversion and energy consumption but has not any affect on the price of goods or services and the lack of attention to environmental costs of electricity production will cause the destructive impact on used resources and as actuating force leads the electricity production system to instability also seems that the estimation of environmental costs and considering the final cost of electricity production on it, is necessary.

In table 4 we see the amount of greenhouse and polluting gases' emissions from the steam power plant's sector. In tables 5 and 6 the social costs of energy and steam power plant are mentioned respectively .Actually this costs are describe the environmental damages because of electricity production that society should pay it for returning to the initial state.

Table 4. The amount of greenhouse and polluting gases' emissions in the steam power plant's sector in 2009 (Ton)

The type of power plant N2O	Department of steam energy
No_x	240257
SO_2	556467
SO_3	2293
CO	138136
SPM	13136
CO_2	71305980
CH_4	1769
	297

Table 5. Social costs of energy separately pollutants gas/ greenhouse based on the prices of 2002 (Thousand on ton).

The type of gas	Cost *
No_x	4800
SO_2	14600
SO_3	.
CO	1500
SPM	34400
CO_2	80
CH_4	1680
N2O	.

. Values are not available
* According to the World Bank study and Environmental Protection Agency

Table 6. Social costs of emissions and greenhouse from steam power plant in 2009(Thousand)

1153233600	No_x
8124418200	SO_2
.	SO_3
207204000	CO
451878400	SPM
5704478400	CO_2
2971920	CH_4
.	N2O

So the sum of social costs of emissions and greenhouse of steam power plant in 2009 will be about 15644184520 thousand. According to this subject that production of electric generators' produced energy from country steam power plants (Energy Department) is 92252600 in this year, consequently we have:

$$\frac{15644184520}{92252600} \cong 170;$$

Social cost of kilowatt hour produced electricity from steam power plants in 2009.

So the social costs of production 14 kilowatt hours of electricity in day during the year are:

170×14×365=868700

The summary of costs and income can be seen on the table 7:

Table 7: Summary of costs and income in steam power plants ()

Net profit	Income	Cost	t
-63000000	0	63000000	0
662380	4406400	3744020	1
662380	4406400	3744020	2
662380	4406400	3744020	3
662380	4406400	3744020	4
662380	4406400	3744020	5
662380	4406400	3744020	6
…	…	…	…
662380	4406400	3744020	30

Assuming an average interest rate 17 percent and inflation rate of 21 percent then we will calculate the real interest rates with the help of following formula:

$$i = \frac{1+r}{1+p} - 1 = \frac{1.17}{1.21} - 1 \cong -0.033$$

Present value of current costs is:

$$NPV[C(O\&M)] = 3744020 \times 52.875 = 197965057.5$$

The sum of total costs 'present value is:

$$AC = 63000000 + 197965057.5 = 260965057.5$$

Now with using of below formula make the present value of total costs as annually:

$$EUAC = AC \times \frac{i(1+i)^n}{(1+i)^n - 1} = 260965057.5 \times 0.019 \cong 4958336.1$$

With using of below formula the unit cost (A kilowatt-hour) of produced electricity from the steam power plant is obtained:

$$C(U) = \frac{EUAC}{E} = \frac{49583361}{5110} \cong 970.3$$

Rail on KWh

4. Conclusions and Suggestions

There is the summary of obtained results:

$C(U)_{PV} = 2428.8$ On kWh

$C(U)_{sp} = 970.3$ On kWh

So the cost production of electricity 's one kilowatt hour in steam power plant (970.3 on kWh)is less than the electricity production cost in photovoltaic power plant(2428.8 on kWh) so according to this subject steam power plant is in priority. Of course some issues such as limited reserves of fossil, environmental destructive effects of their consumption also the importance of electrical security the governments and industries' broad and immediate support will be clear. It should be mentioned that now our researchers are tried to make the panels with cheaper prices and greater return which seems that using of photovoltaic systems will be possible with economic advantage in the not too distant future.

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