Economic evaluation of photovoltaic systems in Chaharmahal and Bakhtiari villages

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Abstract

The development of the country's villages is considered one of the most important and main of the government, for this reason, providing electricity to the villages is considered an important matter in order to achieve social justice. Chaharmahal and Bakhtiari province with high potential of solar energy is one of the provinces prone to use photovoltaic system to provide electricity to villages.

In this article, using economic evaluation indicators, two methods of electricity supply, one with photovoltaic system and the other as a nationwide network, are compared in the villages of Ab Be Kase and Shahryar Gorkanak of Kohrang County and at the end we will examine the results of economic indicators.

Keywords: solar energy, photovoltaic system, national electricity network, economic evaluation

1. Introduction :

Traditional energy sources and fossil fuels with population increase and unprincipled exploitation of these resources have forced mankind to use renewable resources. Among these sources of solar energy, as the largest source of renewable energy on the planet, it is considered a wonderful source of energy production. The amount of energy that reaches the earth every year is about 4 x 1024 joules. Sustainable energy supply in the country can be realized by using renewable energy such as solar energy for domestic use. In addition to saving costs, this supply can prevent the emission of greenhouse gases. This type of energy is more or less available in most parts of the world. It has many uses, such as providing electricity to rural areas. [1]

The global outlook report in 2009, which was published by the US Energy Information Administration, indicates an 80% increase in energy production by photovoltaic systems. According to the statistics published by Iran's Renewable Energy and Electricity Efficiency Organization (SATBA), the capacity of the photovoltaic system in the whole world has reached 70 GW, and Germany is the leader in the field of solar energy in the world with 38,250 MW[2]. Despite the problems of fuel supply and impassable routes in remote villages and the determination of governments to realize social justice and welfare, the use of photovoltaic systems is increasing day by day. In the implementation of the photovoltaic system, the question should be answered whether the use of solar energy improves development indicators such as economic savings, preventing time wastage, etc. in villages or not?

In this article, the design of the photovoltaic system in two villages of Ab Beh Kase and Shahryar Gorkanak from Kohrang County, Chaharmahal and Bakhtiari Provinces is discussed and the comparison and analysis of economic indicators with the method of electrification with the national grid is discussed. Thirdly, economic methods are discussed and at the end, data analysis and results are discussed.

2. Research background

Many researches and researches have been done in the field of electricity supply to villages using photovoltaic system both inside and outside the country, and in this article we mention some of these researches.

In ۲۰۰۵, Bahadrinejad and Farehmand (۲۰۰۵) did the design and economic analysis of the solar power system for an office building in Tehran. This building has an area of 120 square meters, which means that the use of solar system is economical. In the same year (2005), Kochzade studied the economic feasibility of solar power plants compared to diesel power plants in order to supply electricity to the central villages of Iran, and the results indicate that the photovoltaic system has a lower unit cost compared to other systems [3].

In 2009, Evans et al investigated different energy devices for indoor lighting in India. In this research, using the life cycle cost analysis method, the economic evaluation of energy distribution systems, including traditional systems and photovoltaic systems, has been conducted and they have come to the conclusion that modern solar systems are better options for providing lighting in rural areas. [4]

In 2009, in their study, Clark et al investigated the energy efficiency of buildings in two types of national electricity systems and solar energy. After the usual measurements, they came to the conclusion that the use of the photovoltaic system increases the energy efficiency of the building far compared to the case where the energy of the building was supplied without the use of renewable energy.[5]

In 2010, Chandraskar et al investigated and evaluated the photovoltaic system for providing electricity to villages in India. In this research, with the life cycle cost analysis method, they came to the conclusion that the photovoltaic system is very suitable and economical for providing electricity for domestic use in villages from economic aspects and environmental consequences.[6]

In 2011, Sheng Chang conducted Chandraskar's research for Taiwan. In this research, the advantages and obstacles of using the solar system to electrify the villages have been investigated. It was concluded that the market and investment incentives are factors influencing the installation of solar electric generators in Taiwan. [7]

3. Economic evaluation modeling:

In this article, modeling and economic methods such as:

1.3.NPV:

This method is used in economic calculations, the country's budget and micro and macro economic issues, trade and industry.

One of the most standard methods for evaluating long-term investment projects is the NPV method. NPV is obtained from the difference in the present value of incoming and outgoing cash flow. If the NPV is greater than zero (NPV>0), the mentioned project has an economic justification, and if the NPV is less than zero (NPV <0), the mentioned project does not have an economic justification, and if the NPV is equal to zero (NPV=0), the implementation of the project is not we are different.

N $$NPV = \sum_{t=0}^{n} \frac{CFt}{(1+i)^t} = CF_0 + \frac{CF1}{(1+i)^1} + \dots\dots + \frac{CFn}{(1+i)^n} \quad (1)$$

In this regard, CF_0 is the initial investment, and CF_t is the cash received or paid at time t, and i is the discount or interest rate.

2.3. Internal rate of return (IRR): IRR is the rate that makes the project's present value (NPV) equal to zero. In other words, the internal rate of return can be considered as the maximum interest rate that the plan can pay and not be financially harmful. This rate has nothing to do with the prevailing interest rate in the capital market , that is why it is called the internal rate of return.

IRR> MARR ➡ project has economic justification

IRR<MARR ➡ project has no economic justification

IRR=MARR ➡ We are indifferent to the implementation of the project

$$\sum_{t=0}^{n} \frac{CFt}{(1+IRR)^t} = 0 \qquad , i=IRR \qquad (2)$$

3.3. Discounted Payback Period (DPP): The time it takes for the total present value of project receipts to cover the initial investment.

3.4. Profitability index (PI): It is obtained by dividing the total future cash flows by the initial investment.

If PI>1, then the project has economic justification.

4.Calculation of the present value of the total amount received annually from the solar photovoltaic system:

Bornstein in 2008, initially by calculating the value of a unit of solar photovoltaic electricity (Vt) and having wholesale electricity and the amount of losses in a period of 20 to 1 = t years, according to the following formulas, he was able to calculate the present value of the total amount received annually from the photovoltaic system get:

$$V_t\,(t) = W_t + 2\,\alpha Q_t\, W_t + \beta \qquad (4)$$

In this regard, Wt is the wholesale price and 2 αQt Wt is the reduction of line losses by replacing the photovoltaic system and Qt is the annual consumption for the entire household and β is the amount of absence of greenhouse gases.

The final amount of the system, which is obtained by increasing one unit of electricity produced by the central station, is expressed as follows:

$$\frac{dlt}{dQt} = 2\,\alpha\, Q_t \qquad (5)$$

In this relation, Lt is the loss of the system, which is defined as Lt = $\alpha\, Q_t^2$. α is a fixed number whose value is equal to:

$$\alpha = 0.15\,\frac{\sum_{t=1}^{T} Qt}{\sum_{t=1}^{T} \mathrm{Qt}\ 2} \qquad (6)$$

which $\sum_{t=1}^{T} Qt$ represents the total average annual consumption of 20 rural households during twenty years and $\sum_{t=1}^{T} Qt^2$ expression is 2 times the square power of the total average annual consumption of 20 rural households.

The following relationship is used to calculate the present value of the total amount received annually for the installation and operation of the solar photovoltaic system:

$$V_f = \sum_{t=1}^{T} £\, Vt\ Qt \qquad (7)$$

In this regard, Vt it is equal to the average annual consumption for all households in the village over twenty years, and $£$ discount factor is defined as follows:

$$= \frac{1}{(1+i)\ n}, \ n = t \ldots\ldots T \qquad (8)$$ £

In the above relationship, i is the real interest rate and because there is no specific interest rate in Iran's capital market, three interest rate scenarios with figures of 10%, 14% and 18% are considered.

It should be noted that the amount was obtained for one year, which is assumed to be constant for twenty years for convenience.

5. Calculation of the present value of the total amount received annually from the national network:

In 2008, Bornstein calculated the present value of the total amount received annually from the national electricity network by stating the fixed value of a unit of electricity delivered from the national electricity grid of the power plant (P). The value of a unit of electricity delivered from the national electricity network is expressed as follows:

(5)

$$P = \frac{1}{1-\emptyset} * \frac{\sum_{t=1}^{T} Qt\ Wt}{\sum_{t=1}^{T} Qt} \qquad (9)$$

In this regard, P is the fixed value of a unit of electricity delivered from the power plant's national power grid and 1-Ø is the amount of useful electricity available and $\sum_{t=1}^{T} Qt.Wt$ total value of electricity production from the power plant's power grid.

The total value of the annual amount received from the national electricity network is calculated from the following equation:

$$V_s = \sum_{t=1}^{T} \pounds\, P\, Qt \qquad (10)$$

In this regard, $\sum_{t=1}^{T} \pounds\, P$ expression is equal to the present value of a unit of electricity from the power plant and Qt is the annual consumption of the village.

In the end, the economic evaluation between the solar photovoltaic system and the national grid can be obtained as follows:

$$V_{diff} = V_f - V_s \qquad (11)$$

6. Data analysis:

The information of one day and night of a rural household in terms of kilowatt-hour consumption has been extracted as follows:

Table 1. The included energy consumption of each rural household in one day and night

Energy (W/h)	nsumption time	Power(W)	Description
630	7	5*18=90	Lighting
2000	10	۲۰۰	Refrigerator
600	6	۱۰۰	multimedia
400	2	۲۰۰	air conditioner
200	1	۲۰۰	Other uses

* In this table, the consumption of conventional village equipment has been extracted.

* The general lighting consumption for each household is 100 watts equivalent to 0.1 kilowatts.

6.1. Calculation of the solar system:

3830+100 = 3980 (w)

Total consumption $\longrightarrow$ P = 3930/5*0.9 = 874(W)

The number of panels $\longrightarrow$ N = 300/874 = 3

The chosen panel is the panel with specifications P=300 W, ISC=8.86 A, VOC=45.2 V, IM=8.37 A, and VMP=35.8 V.

Number of batteries: 3930 * 2 / 0.9 * 0.6 * 12 * 100 = 12

12 numbers, 12 volt 100 amp batteries are required.

Charge controller :8.86 * 1.3 = 11.5

3 number panels are closed in parallel and charge controller with VMP and ISC3 capacity is used.

Inverter selection: 790*1.3 = 1000 W

The cost rate of the photovoltaic system is as follows:

Table 2. Photovoltaic system cost rates

Total price (ria	Unit price (ri	Number	Description	Row
51000000	17000000	۳	Photovoltaic panel	1
192000000	16000000	۱۲	battery	2
12000000	12000000	۱	Charge controller	3
13000000	13000000	۱	inverter	4
5000000	5000000	۱	structure	5
273000000	63000000	۱۸	Total	6

According to the estimate of the consumption cost of one household in the village, which is 273000000 Rials, and the number of households in Ab Be Kase and Shahryar Gorkanak villages reaches 20 households, the total amount of households in the village is equal to:

20 * 273000000 = 5460000000(rials)

We consider the maintenance cost of the photovoltaic system equal to 1% of the total cost for each year, that is:

%1 * 5460000000 = 546000000(rials)

** Batteries and charging controller and inverter need maintenance and replacement from the 10th year onwards.

7. The result of the photovoltaic system:

The average annual consumption of the entire household in the villages is equal to 28689 kilowatt hours.The wholesale price of electricity (Wt) according to the tariffs of the Ministry of Energy is 1750 Rials per kilowatt hour in Chaharmahal and Bakhtiari provinces. According to the above information, the amount of α can be obtained as follows:

$$\alpha = 0.15 * \frac{\sum_{t=1}^{20} 28689}{\sum_{t=1}^{20} (28689)^2} = 0.005 \longrightarrow \frac{dlt}{dQt} = 2*1*0.005 = 0.01$$

To calculate the value of line losses, we multiply the final loss amount by the wholesale price of electricity per kilowatt hour in Chaharmahal and Bakhtiari province and we have:

$$\frac{dlt}{dQt} . W_t = W_t . 2\ \alpha\ Q_t = 0.01 * 1750 = 17.5$$

Preventing greenhouse gases in the environment is one of the benefits of using a solar photovoltaic system. To calculate the benefits of preventing the release of these gases, we refer to the balance sheet of the Ministry of Energy in 1994. The social cost of CO_2 gas per kilowatt hour is equal to β = 1500 rials.

With these words, the value of a unit of electricity from the solar photovoltaic system (Vt) for one kilowatt hour is equal to:

$$V_t (t) = W_t + 2\ \alpha Q_t\ W_t + \beta \longrightarrow 1750 + 17.5 + 1500 = 3267$$

Considering that the average annual consumption of villages is equal to 28689 kilowatt hours, multiply this amount by the value of one unit of electricity from the solar photovoltaic system (Vt) and the result is the amount of income from the solar photovoltaic system at the end of the year. comes means we have:

Earnings at the end of each year= 3267 * 28689 = 93726963(rials)

8. Investment and development cost of the nationwide network:

According to the work order received from the electricity distribution company of Chaharmahal and Bakhtiari province, the cost of building and installing equipment to supply electricity to the villages of Ab Be Kase and Shahryar Gor Kanak is 6300000000 Rials. The variable costs during the operation period are as follows:

8.1. Annual maintenance cost: The maintenance cost is obtained by multiplying the average annual consumption of the entire household in the villages by the wholesale price of electricity. That is, we have:

28689 * 1750 = 502057500 (rials)

8 .2 . Cost of line losses:

The cost of line losses is as described in the following table:

Author's calcu		The average amount of total water consumpt the villages of Beh Kase and Shahryar Gorkanak in kilowatt
balance shee		Internal uses of the powe
balance shee		Transmission and distribution network
Author's calcu	kwh	The social cost of environmental pollutants produced by the powe
Author's calcu	437	The amount of electricity wasted from the production process to consumption
Ministry Of I		Wholesale price of electricity in Chaharmahal and Bakhtiari province (
Author's calcu	766	The value of wasted electricity from the production process to consumption (

In the above table, the amount of annual electricity produced by the power plant for all households in the villages (kWh) is obtained as follows:

$\frac{1}{1-\gamma} * \frac{1}{1-\emptyset}$ * electricity consumption of the village

In the above relationship, γ is the amount of internal consumption of the power plant, which is equal to 2.9%, and Ø is the amount of losses of the transmission and distribution network, which is 12.1%.

To calculate the amount of wasted electricity from the production process to consumption (kilowatt hours), if we subtract the annual amount of electricity produced by the power plant for all households in the villages from the average consumption of all villages, the amount of wasted electricity is obtained, that is:

Amount of electricity wasted from the production process to consumption (kWh)= 33067-28689 =4368

The value of wasted electricity from Raita, the wholesale price of electricity in Chaharmahal and Bakhtiari province is obtained in the amount of wasted electricity, that is:

Value of wasted electricity from the production process to consumption (Rials)= 1750* 4378 = 76615000

8.3. The social cost of environmental pollutants produced by the power plant:

The social cost of pollutants in the balance sheet of the Ministry of Energy in 1994 is equal to 1500 Rials per kilowatt, so we have:

Social cost of environmental pollutants produced by the power plant= β * 33067 1۵۰0*33067 = 49600500(Rials)

9. Annual income from the power plant:

The value of a unit of electricity delivered from the national electricity network is expressed as follows:

$$P = \frac{1}{1-\emptyset} \cdot \frac{\sum_{t=1}^{T} Qt\,Wt}{\sum_{t=1}^{T} Qt} \longrightarrow \frac{1}{1-12.1\%} \cdot \frac{\sum_{t=1}^{20} 33067 * 1750}{\sum_{t=1}^{T20} 33067} = 1991$$

Therefore, if we multiply the annual consumption of villages (28,689 kilowatt hours) by the value of a delivered electricity unit, the annual income from the power plant is obtained, that is:

Annual income from the power plant= 1991 * 28689 = 57119799 (Rials)

10-Evaluation and economic comparison of the photovoltaic system with the national network:

If the difference in the present value of the electricity provided by the installation and operation of the solar photovoltaic system (Vf) during the time t to T is calculated from the present value of the electricity provided by the power plant (Vs) during the time t to T, the amount of usefulness of The solar photovoltaic system is as follows:

$V_{diff} = V_f - V_s$

Table.4. Comparison of the present value received from the photovoltaic system and the national grid (amounts in Rials)

Difference in the present value received from the photovoltaic system and the national electricity grid	National electricity network	Solar photovoltaic system	Real interest rate	Description
۱۵۳۶۳۳۱۶۱	۲۳۳۸۰۷۳۲	۳۸۶۷۲۰۴۸۲	۱۰%	first scenario
۱۱۱۶۷۱۹۵۹	۱۶۵۸۴۲۲۰	۲۷۷۵۱۴۱۶۰	۱۴%	second scenario
۱۹۳۳۴۰۴۷	۱۱۷۲۶۳۷۶	۱۳۶۵۹۷۸۱۲	۱۸%	third scenario

Source: researcher's calculations

According to the above table, we find that the difference in the present value received from the photovoltaic system and the national grid has become positive, that is, the present value of the amount received from the solar photovoltaic system is greater than the present value of the amount received from the national grid, which indicates the advantage of using the system. It is photovoltaic.

To calculate the net present value (NPV), it is very important to allocate subsidies for the implementation and installation of national network equipment. The current economic situation of the country makes it clear that the amount of money that the government pays to the Ministry of Energy as a subsidy for the implementation of electrification projects causes disruptions in the provision of government services. In the current research, it is assumed that the government is exempted from subsidy allocation, according to the calculations in the table below, we can easily find that the net present value (NPV) of the national electricity grid is not included in the net present value (NPV) of the photovoltaic system. The government subsidy is more, which has caused the net present value difference (NPV) of the photovoltaic system to be negative with the national grid, which indicates that the project is not economically profitable, so the power distribution companies are in charge of building and killing the grid. Electricity suffers a significant loss in the absence of government subsidies. But if the government subsidy is paid for the construction of nationwide networks, the projects will become profitable, which will create a financial burden on the shoulders of the governments. With these interpretations, it can be seen that the photovoltaic system is very economical and its use is reasonable.

Table.5. Comparison of the net present value (NPV) of the photovoltaic system with the national grid in case of no subsidy allocation (Rials)

The net present value (NPV) difference of the photovoltaic system with the national grid	National electricity network	solar photovoltaic system	real interest rate	Description
-1900327489	۷۷۱۱۸۹۷۵۶	۵۸۱۱۵۶۴۰	۱۰%	first scenario
-1942042142	۷۶۴۵۴۷۵۶۱	۵۷۰۳۴۳۳۴	۱۴%	second scenario
-2006615469	۷۵۸۲۳۷۶۰۷	۵۵۷۵۷۶۰۶	۱۸%	third scenario

Source: researcher's calculations

The profitability index of the project is shown in the table below

Table 6: Comparison of the profitability index (PI) of the solar photovoltaic system with the national electricity grid

National electricity network	solar photovoltaic system	real interest rate	Description
۲/۰۱	۲/۰۶	۱۰%	Profitability index in the first scenario
۱/۹۶	۲/۰۴	۱۴%	Profitability index in the second scenario
۱	۱/۸	۱۸%	Profitability index in the third scenario

Source: researcher's calculations

According to the above table, the profitability index in the photovoltaic system is much higher than the national network. The profitability index in the third scenario belonging to the national grid has reached a numerical value of 1, which is against the definition of the profitability index (a project is profitable that has a profitability index greater than 1), which itself expresses the advantage of using the photovoltaic system.

11. Conclusion

In this research, two methods of expanding the national electricity grid and the photovoltaic system were compared using economic evaluation indicators. The results indicate that in the absence of government subsidies for the development of the national electricity network, the implementation of electrification projects is not economical. In fact, it can be said that the initial and variable cost in the national electricity grid is much higher than the photovoltaic system, which gives very little income to the investor. But if the government wants to implement these plans in the villages for the sake of social justice, it should allocate subsidies to this sector, it is exactly against the economic policies in the country's 20-year vision. Therefore, in remote and nomadic villages, which Chaharmahal and Bakhtiari provinces are no exception, the use of solar photovoltaic systems is suggested to provide their energy needs.

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