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Real Evaluation of the Economic Parameters of a Solar Power Plant in Chaharmahal and Bakhtiari Province

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Abstract

Solar energy is one of the most important types of renewable energy in Iran. Solar systems are more acceptable in Iran due to their availability. There are development models and software for the purpose of economic calculations, but one should choose a model that, in addition, does not have limitations in solar system models whose results are not related to accurate and large tens. Also, due to the complexity of the results of some software (such as Homer), the analysis of these results requires special knowledge and expertise. The selected model must be in accordance with the specific needs of the project and be customized with unique conditions. Therefore, the above items can be counted as the difference between the selected model for solar economy calculations in this article with previous studies and relevant software. In this article, the economic indicators of a 400 Kw power plant in Iran are discussed. Regarding the investments in this sector, we have examined all the costs of the construction of the power plant and we evaluate and make economic calculations using the main analysis and profit analysis techniques. Computer results have been evaluated with 25% and 30% discount and 40% inflation. The capital return rate of this power plant is 25.09% and the payback period of this power plant is 9 years. NPV with a 25% discount in the ninth year is 845.35 million Rials and with a 30% discount rate, it is 26809.88 million Rials. Also, the internal rate of return is calculated as IRR = 25.08%.

Keywords: Economic Evaluation, Net Present Value (NPV), Renewable Energy, Photovoltaic.

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1. INTRODUCTION

Traditional energy sources and fossil fuels with population increase and unprincipled exploitation of these resources have forced mankind to use renewable resources [1]. Although many alternative energy sources are available, due to easy access, free maintenance, and zero pollution, many investors and countries of the world have been attracted to use of solar energy in their project plans [2]. Developing countries are faced with the challenge of facing high energy demand [3,4]. These countries are required to achieve the goals in all UN policies by 2030 [5]. Investors are always looking for ways to maximize their investment since the energy economy is essential for the investor, so the analysis of economic parameters is very necessary. Economic analysis requires the calculation of all costs, benefits, and related cash flows. Therefore, investors evaluate sustainability and feasibility conditions for investing in photovoltaic systems by using various key economic performance indicators such as internal rate of return, VPV, investment return period (IRR), LCOE, leveled energy cost measure, etc. [6,7,8]. A lot of research has been done in the field of economic evaluation of solar power plants. Most of the results are based on Homer software. For example, in 2022, a study was conducted on the technical-economic analysis of the renewable energy system with Homer software, and the cost of energy (COE) decreased from 0.060 dollars per kilowatt hour to 0.0446 dollars per kilowatt hour [9].
In 2020, V. Motjoadi conducted an economic analysis of a Pv-based microgrid using Homer software, and the research result was NPC=1.48 and COE=$1330 [10]. In 2021, a study was conducted on the economic analysis of the Pv-based RE hybrid system. Researchers calculated COE using Homer software. the results indicate the cost-effectiveness of the proposed system and COE=0.214 dollars per kilowatt hour [11].

A study on comparative economic analysis of various types of hybrid systems in 2024 has been conducted. Using Homer software, the researchers calculated the net present cost of various hybrid systems. The net cost is 1.5368 and the cost of energy (COE) is 0.155 dollars per kilowatt hour [12].

As seen in the above studies, in order to evaluate the economic parameters of the solar power plant with different software and algorithms, they do not consider all aspects of the costs related to the power plant. Considering the importance of fixed and variable costs in the calculation and economic evaluation of the power plant, the aforementioned study has focused on all costs and calculating parameters based on the real inflation rate of Iran. This article is a complete reference for the design and economic evaluation of the solar power plant. The structure of the article is as follows: in the first part, the research method and important economic projects of the solar power plant will be discussed, and in the second part, the design of the 400KW solar power plant will be discussed, and in the third part, the calculation of the costs of the construction of power plants and sectors will be discussed. It will come to an end. We analyze data and draw conclusions.

2. RESEARCH METHODOLOGY

Engineering economics includes a set of

methods and techniques that are used to evaluate, analyze, and optimize engineering projects and decisions. The revenge of engineering economics methods is dependent on factors that can be different depending on the nature of the project, the goals of the organization, and the existing constraints. Criteria and criteria for choosing the appropriate methods of engineering economics can include the type and complexity of the project, the purpose and objectives of the project, the cost and time required, the financial and economic scale of the project, and the sustainability and long-term effects of the project. Some calculation methods of engineering economy are:

- Net Present Value (NPV)
- Internal rate of return (IRR)
- Benefit-cost ratio (B/C)
- Breakeven Point – BEP
- Inflation

2.1. Net Present Value (NPV) Measure

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a specified period of time. This criterion tries to find a balance between investment payments and income from investment implementation by considering the time adjustment of money. The evaluation of this balance is compared to the standard interest rate that the plan management has determined in advance for investment and use of funds. This interest is called "minimum absorbable interest" or "cost of capital".

Considering that the main goal of this project is to increase profitability and also due to the uncertainty of the project that requires sensitivity analysis and risk management, this method has been used.

$$PV = \sum_{t=0}^{n} \frac{CF_t}{(1+i)^t} = CF_0 + \sum_{t=0}^{n} \frac{CF_1}{(1+i)^1} + \ldots + \sum_{t=0}^{n} \frac{CF_n}{(1+i)^n} \quad (1)$$

In the above relationship, CF0 is the initial investment, CFt is the cash received or paid at time t, and i is the discount rate.

IF: NPV=> Project selection

$IF: NPV = 0$=>Indifference to choosing or not choosing the project

$IF: NPV < 0$=> Failure to select a project [13].

2.2. Internal Rate of Return (IRR)

IRR is the rate that makes the project's net 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. It should not be financially harmful. According to the absorption rate (MARR), it is possible to decide on the economic viability of the project as follows.

IRR $> MARR =>$ The project has economic justification.

IRR $< MARR =>$ The project has no economic justification

IRR = MARR=> We are indifferent to the implementation of the project [14]

$$\sum_{t=0}^{n} \frac{CFt}{(1+\mathrm{IRR})^t} = 0 \text{ و } i = IRR \quad (2)$$

2.3. Benefit-Cost Ratio (B/C)

One of the economic indicators for project evaluation is the ratio of benefits to costs or benefits to costs (B/C). This ratio is equal to the result of dividing the present value of the project's benefits by the present value of its costs. If this ratio is greater than one, it means that the plan is economic, and if it is smaller than one, it means that the plan is uneconomical [15].

Due to the fact that the project includes social, environmental, and public sector goals and it is necessary to compare several different options in order to achieve the best answer, we use this method in the economic analysis of the project.

$$\text{Benefit} - \text{costratio} = \frac{\text{Pv of Expected Benefit}}{\text{Pv of Expected Costs}} \quad (3)$$

2.4. Breakeven Point – BEP

The break-even point is the point where total sales equal costs. That is, at that point, the net profit of the company becomes zero. In fact, it is a term that shows the relationship between the amount of production of an economic project, in which the amount of expenses is equal to the income, and the project at this level of production neither gains nor loses. If the production is more than the break-even point, the project will be profitable, otherwise it will be unprofitable.

$$\text{Breakeven Point – BEP} = \frac{F}{P-V} \quad (4)$$

In the above formula F is fixed costs, P is sales price and, V is variable costs.

The percentage of sales the Breakeven Point – BEP is calculated as follows:

$$\text{BEP} = \frac{Fixed\ cost}{Total\ sales - Variable\ cost} \quad (5)$$

Considering that the project has fixed and variable costs and the management of these costs leads to profitability, therefore this method is used in the economic analysis of the project.

2.5. Inflation

Inflation means a continuous increase in the general price level of goods and services in a society for a certain period of time. To measure the inflation rate, one year is considered as the base year. They measure the price increase according to it. The general formula for calculating inflation is as follows:

$$\text{T} = \frac{\text{CPI}_\text{p} - \text{CPI}_\text{b}}{\text{CPI}_\text{b}} \quad (6)$$

In the formula, CPIp is the index of goods and services at the current time and CPIb is the CPI index of the base period. To calculate the CPI index, Laspierre's formula is used as follows:

$$I_{t,0} = \frac{\sum_{i=1}^{n} p_{t,i} q_{0,i}}{\sum_{i=1}^{n} p_{0,i} q_{0,i}} \times 100 \quad (7)$$

Pt is the price of the desired product at time t and P0 and q0 are the price of the desired product at time zero or the base year [17].

Quantitative inflation has properties that help improve transparency, measurability, and economic comparability. These features help investors make their financial decisions and monetary policies in order to choose the right project for profitable investment. Therefore, in this project, we consider inflation quantitatively.

3. INVESTMENT COSTS

3.1. Fixed Cost

Fixed costs do not change as service increases or decreases. The independence of the fixed cost from the output of the production units is the main and fundamental condition of the fixed cost. The list of fixed investment costs is as follows:

- The cost of obtaining permits
- The cost of machinery and facilities
- Purchase of land
- Provision of office equipment
- Building construction and landscaping

-Wage cost [18].

3.2. Variable Cost

Unlike fixed costs, variable costs depend on output. That is, the higher the output of a project, the higher the variable costs.

The list of variable costs is as follows:

- The cost of purchasing raw materials and equipment
- Cost of energy consumption
- Maintenance cost

The formula for calculating fixed and variable costs is as follows:

$$C_T = (F_c)_T + (V_c)_T$$

where (Fc)T is the fixed cost, (Vc)T is the variable cost, and CT is the total cost [19].

Table 1. ***Power plant equipment under study.***

row	Type of machinery and equipment	Number	Unit price (Rial)	Price (million Rial)
1	30 kW polycrystalline solar pane	14	5500000000	77000
2	structure	1	8000000000	8000
3	DC, Ac electrical panel	1	6400000000	6400
4	Solar panel connector	14	280000000	3920
5	Inverter 1 MW	1	6500000000	6500
6	Surge protector	1	500000000	500
7	Meter with CT	1	850000000	850
8	DC high voltage ground power cable	100	9000000	900
9	Medium voltage ground power cable AC	100	7000000	700
10	lightning rod	1	30000000	30
11	copper earth wire	10	1900000	19
12	copper plate	14000	2970000	41580
13	Other equipment	1	900000000	900
14	Installation cost (10%)	1	13898000000	13898
	Total			161197

*https://www.satba.gov.ir (1403 price list)

Variable costs are of particular importance in the economic calculations of solar power plants. These costs have a decisive role in the economic analysis and decision to invest in these types of power plants. These costs have a direct effect on the calculation of Breakeven Point -BEP, Internal rate of return (IRR), impact on profitability and impact on the final price. Therefore, it is very important to consider these costs in the economic calculations of the solar power plant.

4. PHOTOVOLTAIC SYSTEM DESIGN

It will take 5000 square meters of land to build this photovoltaic system. The solar panels are connected in series and according to the calculations, 14 polycrystalline solar panels of 30 kW and one Iforty of 1 MW are needed. The equipment of the 400 kW photovoltaic system is as described in Table 1.

5. CALCULATION OF POWER PLANT CONSTRUCTION COSTS

5.1. Landscaping

Table 2. ***Cost of Landscaping.***

Description	Area (m^2)	unit price (Rial)	total cost Million Rial
Leveling	5000	1500000	7500
Fencing	400	4500000	1800
Create an access road	1000	4000000	4000
Total			13300

*https://www.mrud.ir/ (1403 price list)

5.2. Construction

Table 3. ***Cost of Construction.***

Description	building type	Area (m^2)	unit price (Rial)	total cost Million Rial
Facilities	To maintain the equipment	30	100000000	3000
Guarding	Guard building for protection	20	100000000	2000
Total			5000	

*https://www.mporg.ir , *https://www.mrud.ir/ (1403 price list)

5.3. Raw Material

Table 4. ***Cost Raw material.***

name of the raw materials	Annual consumption	unit	Unit price (Rial)	Total cost Million (Rial)
Consumables and spare parts	1	-	1000000000	1000
Other consumables	1	-	100000000	100
Total				1100

*https://www.satba.gov.ir, https://www.mporg.ir/(1403 price list)

Table 5. ***Cost of repairs and maintenance.***

Description	Asset value (million rials)	Percent	Annual maintenance cost (Million rial)
Landscaping	13300	2	266
Building	5000	2	100
Equipment	161197	5	8059.85
Facilities	500	10	50
Means of transportation	0	10	0
Total			8475.85

* https://www.mporg.ir/

Table 6. ***Cost of repairs and maintenance.***

Description	Amount (Million Rial)
Land	0
Landscaping	13300
Building	5000
Equipment	161197
Facilities	500
Means of transportation	0
office supplies	359.994
Unpredicted (1% of items above)	9017.8497
Million Rial in total	189374.84

Table 7. ***Cost before operation.***

Description	Amount (Million Rial)
Costs of preparing a plan, consulting for obtaining a license, the right to register bank contracts (2% of the capital cost)	3787.50
Total	3787.50

5.4. Estimating the cost of repairs and maintenance

Maintenance costs include: landscaping, building, machinery, and facilities. According to the lifespan and functionality of each of the mentioned items, we consider a percentage of the total costs of each for maintenance on an annual basis.

5.5. Cost Before Operation

The pre-operation cost includes 2% of the capital cost, which is calculated as follows:

Pre-operation costs + capital cost = fixed capital
3787.50+189374.84=193162.34

5.6. Working Capital Estimation

The cost of working capital includes the purchase of raw materials, which is expressed as follows:

million rials of capital in circulation in the first year of operation = 458.33 * %70 = 320.83

5.7. Partnership with the Bank

Considering that there is support for investors in the public and government sectors, therefore, we consider the percentage of investor and government sector participation similar to the instructions of the Renewable Energy and Electricity Utilization Organization (Satba) as follows:

Table 8. ***Working capital estimation.***

Title	Description	Amount (Million Rial)
raw materials	One month of raw materials	458.33
Total		458.33

Table 9. ***Partnership with the bank.***

Description	Applicant's share		Banking facilities		Total (Million Rial)
	Amount	Percent	Amount	Percent	
fixed capital	19316.23	10	173846.11	90	193162.34
capital in circulation	45.83	10	412.50	90	458.33
Total investment	19362.07		174258.61		193620.67

Table 10. ***Depreciation cost after implementation.***

Description	Asset value (million rial)	Percent	annual depreciation cost (Million Rial)
Landscaping	13300	5	665
Building	5000	5	250
Equipment	161197	10	16119.7
Facilities	500	10	50
Means of transportation	0	10	0
office supplies	359.994	20	71.9988
unexpected	9017.8497	0	0
Total			17156.70

5.9. Annual production cost

Table 11. ***Annual production cost.***

Description	Amount
Cost of raw materials	1100
Energy cost (water, electricity, fuel)	0
Cost of repairs and maintenance	8475.85
Cost of salaries and wages	0
Depreciation cost	17156.70
Unforeseen cost of production (1% of high items)	267.33
Administrative and sales fee (1% of above items)	270
Cost of financial facilities (5% of the fixed capital loan amount)	8692.31
Depreciation cost before operation (10% of the costs before operation)	378.75
Training and insurance fee (2% of sales)	408.80
Total	36749.73

5.8. Depreciation Cost After Implementation

Due to the fact that the cost is evenly and equally distributed during its useful life and a certain amount of the cost of the asset is calculated as depreciation every year, it can be said that we consider depreciation linearly.

6. CONCLUSION

The main goal of this article is the economic analysis of a 400 KW power plant in Chaharmahal and Bakhtiari province. According to the calculations, the NPV of the power plant has been positive since the ninth year and it can be said that it has an economic value. Also, according to the calculation of IRR (IRR = 25.08%), this value can be justified and indicates that the power plant has economic justification. According to the table of current costs of the power plant over 10 years and the amount of profit and loss, the investment return period is estimated to be nine years, and the amount of profit over 10 years is 348,812.341 Rials.

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