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Techno-Economic Feasibility of 5 kW_p Solar Tree Installed in Village Madar, Udaipur, Rajasthan

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ABSTRACT: A 5 kW_p solar tree was installed in the village Madar, Udaipur, Rajasthan. In this research techno economic feasibility of 5 kW_p solar tree was evaluated. Techno-economics evaluation of installed solar tree was calculated by using different economic parameters like net present value (NPW), benefit-cost ratio, payback period, and internal rate of return (IRR). The net present worth of installed system was found to be Rs. 950058.9, for 25 years assumed a life of solar tree. The internal rate of return of the solar tree was found to be 22% for 25 years. The benefit cost ratio was found to be 1.79 with the payback period of 2.92 years which is viable and feasible as well.

KEYWORDS: Solar tree, techno-economic, solar pv system, payback period.

I. INTRODUCTION

In comparison to other forms of renewable energy sources, solar energy is now one of the best alternatives for meeting future energy demand in terms of availability, economic viability, accessibility, various capacities, and efficient production Imam *et al.*, (2019). In India coal is the preferred fuel for electricity generation. Coal is abundant locally, while imported natural gas and oil prices have remained high, making coal-fired energy generation more economically appealing. India's electricity generation is heavily reliant on coal-fired thermal power plants, which emit massive amounts of greenhouse gases (GHGs) into the environment. A typical thermal power plant emits 980 g carbon dioxide (CO₂) (Sharma and Tiwari, 2013). By decreasing greenhouse gas emissions and global warming, the SPV plant has a good impact on the environment. In 2015, A 5 kW_pPV system is predicted to prevent 7031.9 kg CO₂, 8.9 kg SO₂, and 18.6 kg NO_x from entering the atmosphere (Yadav and Bajpai, 2018). The backup diesel generator is not a clean source of energy and has a very high operating cost. Solar energy is the greatest accessible carbon-neutral renewable energy source that can satisfy the country's energy demand, thus there is a tremendous need for a sustainable and clean source of energy. The recently developed idea of a solar tree has several benefits, including reducing CO₂ emissions and providing green energy.

II. RELATED WORK

Chandelet *et al.*, (2014) conducted a techno-economic analysis of a solar photovoltaic power plant for the garment zone of Jaipur city. The estimated energy demand of the garment zone for 2011 (2.21 MW) has been calculated, and a solar PV power plant with a capacity of 2.5 MW has been proposed, requiring approximately 13.14 acres of land. An off-site proposal for the power plant has also been considered and compared with the on-site option. The internal rate of return (IRR) for an on-site solar PV power plant is 11.88 %, with an NPV of 119.52 million INR at a 10 % discount rate, a simple payback period of 7.73 years, and a discounted payback period of 15.53 years, while the IRR for an off-site power plant is 15.10 %, with an NPV of 249.78 million INR, a simple payback period of 6.29 years, and a discounted payback. At a 10 % discount rate, the levelized cost of energy for on-site and off-site solar PV plants is Rs. 14.94 and Rs. 11.40 per kWh, respectively, and it was found quite attractive.

Ibrik (2020) assessed the techno-economic feasibility of an on-grid solar photovoltaic system in Palestine. This study analysed the outcomes of continuous data monitoring of a 41 kW_p solar PV system placed on the rooftop of An-Najah National University in Palestine. The system, which consists of 128 PV panels, a DC/AC inverter, and a grid-connected gross metre, was monitored for three years from 2016 to 2018. The net present value and simple payback period were calculated in this study. The net present value for the years 2016, 2017 and 2018 were 67859.94 US\$, 56668.68



US\$ and 55396.4 US\$ respectively. The simple payback period for the years 2016, 2017 and 2018 were 4.24 years, 4.35 years and 4.40 years respectively.

III. METHODOLOGY

The experimental investigation of a 5 kW_p solar tree was conducted at village Madar, Udaipur, Rajasthan, which is located at 24.7° North latitude and 73.61° East longitude and at an altitude of 634.0 m (2080.1 feet) above the mean sea level. For the 5 kW_p capacity system, total of 15 polycrystalline solar modules are attached. Each module's capacity is 335 W_p. The solar tree is the off-grid type that consists of solar modules, a power conditioning unit (PCU), 8 batteries, frame for modules and a power outlet.

Techno-economic feasibility of the solar tree was evaluated by calculating the following parameters (Panwaret *al.*, 2014).

- a) Net present worth
- b) Benefit-cost ratio
- c) Internal rate of return
- d) Payback period

i. Net present worth (NPW)

The simplest fundamental discounted cash flow metric of project worth is the Net Present Value. The NPW is calculated by subtracting the cost stream's total discounted current value from the benefit stream's total discounted current value. The installed system's NPW was determined using the formula provided.

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \dots\dots\dots(1)$$

Where,

- C_t = Cost in each year
- B_t = Benefit in each year
- t = 1, 2, 3.....n (years)
- i = Discount rate, %

ii. Benefit-cost ratio

The benefit-cost ratio is calculated by dividing the present value of the benefit stream by the present value of the cost stream. For the measure of project value, the benefit-cost ratio is a formal project acceptance criterion that should be one or greater. The benefit-cost ratio can be calculated using the following formula:

$$\text{Benefit cost ratio} = \frac{\text{Total Benefit}}{\text{Capital Cost}} \dots\dots\dots(2)$$

$$\text{Benefit cost ratio} = \frac{\sum_{t=1}^{t=n} B_t}{\sum_{t=1}^{t=n} C_t}$$

iii. Internal rate of return (IRR)

The IRR is closely related to the NPV, which calculates the actual rate of return on the initial investment. It is the discount rate (weighted average cost of capital) at which the project's net present value (NPV) is exactly zero, and it may be calculated using the method below.

$$\sum_{t=1}^{t=n} \frac{(B_t - C_t)}{(1+i)^t} = 0 \dots\dots\dots(3)$$

iv. Payback period (PP)

The payback period, which is defined as the time it takes to recover an investment's capital cost, is another method for analysing project feasibility. The project is viable if the payback period is less than the project lifetime; otherwise, it is not. The payback period (PP) of the installed system was determined using the following formula.

$$\text{Payback Period} = \frac{\text{Total Investment}}{\text{Net Profit}} \dots\dots\dots(4)$$

IV. EXPERIMENTAL RESULTS

The techno economics analysis was carried out on the assumptions given below. The benefit-cost ratio was found to be 1.79 with a payback period of 2.92 years and an IRR of 22%. It can be inferred that the developed system is technically as well as economically feasible.

1. The life of the installed system is 25 years (n).
2. The discount rate is considered to be 10%.
3. The annual repair and maintenance cost is considered to be 5% of the total capital cost.
4. The working days of the system are 330 days per year.
5. The cost of the system is ₹ 450000.
6. Solar tree can generate electricity per day 17.57 kWh.

The installed system was compared with 5 hp diesel-based electric generator for techno-economic analysis.

1. CO₂ emission from diesel to generate 1kWh electricity = 0.58 kg.
2. The Fuel required to operated 5kVA diesel-based electric generator = 1 litre/hr.
3. Fuel consumption of electric generator to generate 1 kWh energy = 0.4 litre.
4. As per above data time required for the diesel generator to generate 17.57 kWh energy = 7.028 hr

Table 1 Cash flow analysis for installed system of solar tree

Total Investment (A)	4,50,000	₹
Repair and Maintenance @5% of A	22,500	₹/year
Discount rate @10% of A	45,000	₹/year
Cost of production (B)	67,500	₹/year
Profitability		
Annual saving on diesel @₹ 94 per year	2,17,140	₹/year
CO ₂ emission = (0.58 kg per kWh × 17.57 kWh × 330 days) = 3.36 tons/year Carbon trading rate = 3.36 × 17 × 77.95 = ₹ 4601.79 (USD = ₹ 77.95 as of June 2022)	4452.50	₹/year
Total profit (C)	2,21,592.50	₹/year
Net annual saving (D = C-B)	1,54,092.50	₹/year
Net present worth (NPW)	94874.61	₹ for 25 years
Benefit-cost ratio	1.79	
Payback period (A/D)	2.92	Years

Net present worth (NPW)

The NPW for the solar tree was calculated on the current investment and the interest rate assumed for the system and profit in each year. The life of the solar tree is 25 years. The NPW for the solar tree was Rs 950058.9. The NPW of the solar tree was calculated for 25 years is shown in table 2.

Table 2 Net Present Worth of solar tree

Year	Discount rate (a)	Net annual savings (b)	Present value (ab)
0	1	-450000	-450000
1	0.90909	1,54,092.50	1400084.17
2	0.82645	1,54,092.50	127349.25
3	0.75131	1,54,092.50	115772.04
4	0.68301	1,54,092.50	105247.31
5	0.62092	1,54,092.50	95679.37
6	0.56447	1,54,092.50	86981.25

7	0.51316	1,54.092.50	79073.86
8	0.46651	1,54.092.50	71885.33
9	0.4241	1,54.092.50	6535030
10	0.38554	1,54.092.50	59409.36
11	0.35049	1,54.092.50	54008.65
12	0.31863	1,54.092.50	49098.65
13	0.28966	1,54.092.50	44635.13
14	0.26333	1,54.092.50	40577.40
15	0.23939	1,54.092.50	36888.54
16	0.21763	1,54.092.50	33535.04
17	0.19784	1,54.092.50	30486.40
18	0.17986	1,54.092.50	27714.91
19	0.16351	1,54.092.50	25195.37
20	0.14864	1,54.092.50	22904.88
21	0.13513	1,54.092.50	20822.62
22	0.12285	1,54.092.50	18929.65
23	0.11168	1,54.092.50	172208.78
24	0.10153	1,54.092.50	15644.34
25	0.0923	1,54.092.50	14222.13
NPW			948704.61 ₹

Table 3 Economic analysis of solar tree

Sr. No.	Economic indicator	Value
1	Net Present Worth	948704.61 ₹
2	Benefit-cost ratio	1.79
3	Payback period	2.92 year
4	Internal rate of return	22%

V. CONCLUSIONS

1. The net present worth of installed system was found to be Rs. 948704.61, for 25 years assumed a life of solar tree.
2. The installed solar tree was found economically feasible as the invested capital can be recovered in 2.92 years of working operation with the benefit-cost ratio of 1.79.
3. The installed solar tree was determined to be economically viable as, with a benefit-cost ratio of the invested capital may be returned in 2.92 years of working operation.
4. The internal rate of return of the solar tree was found to be 22% for 25 years.
5. For a period of 25 years, the solar tree's internal rate of return was found to be 22%.

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