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Financial comparative analysis of SPV and SPT power plants for a village in Rajasthan

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Abstract- *A village Mansarkheri, situated in district Jaipur is selected and energy consumption data of the village is collected from electricity Distribution Company in 2014. On the basis of this data the energy consumption for year 2015, 2019 and 2024 is obtained by using linear regression forecasting. The annual energy required by the village Mansarkheri is found to be 638.25 MWh/annum, 821.27 MWh/annum and 1072.01 MWh/annum in year 2015, 2019 and 2024 respectively. According to these energy requirements, solar photovoltaic power plants of capacity 395.34 kW, 508.71 kW, 664.02 kW and solar parabolic trough power plants of capacities 312.61 kW 451.24 kW 641.88 kW are proposed and financially analyzed for year 2015, 2019 and 2024. Capital costs of SPV and SPT plants for year 2010 to 2014 are taken from order issued by central electricity regulatory commission and on the basis of these costs, capital cost for year 2015, 2019 and 2024 are calculated by using forecasting. Financial analysis has been done on the basis of four financial scenarios i.e. (i) pre tax (ii) post tax (iii) pre tax with equity (iv) post tax with equity. In each financial scenario, financial indicators are calculated which are, internal rate of return, simple payback period, discounted payback period at 10% and 15%, net present value at 10% and 15% discount rate. Levelized cost of energy and capital recovery factor are also calculated at different-different discount rates for year 2015, 2019 and 2024.*

Key words: Solar photovoltaic plant, solar parabolic trough plant, financial analysis, Electrical energy demand

1. INTRODUCTION

A village Mansarkheri situated in Bassi sub division of Jaipur district, at (latitude 26˚83'N, longitude 76˚05'E, altitude 351 m, is selected for the study. Energy demand of the village in year 2015, 2019 and 2024 are calculated and solar photovoltaic, solar parabolic trough power plants are proposed for which the financial indicators are calculated for the purpose of financial comparative analysis.

Chandel et al. [1] proposed and designed solar photovoltaic power plant to supply the electrical energy demand of the garment zone of Jaipur city, considering two cases i.e. (i) onsite option (ii) offsite option. In both the cases financial indicators are calculated and compared with each other. The internal rate of return (IRR), net present value (NPV) at 10% discount rate, simple pay-back period, discounted pay-back period at 10% discount rate and Levelized cost of energy at 10% discount rate are 11.88%, 119.52 million INR, 7.73 years, 15.53 years and 14.94 Rs. Per kWh for on-site power plant and 15.10%, 249.78 million INR, 6.19 years,10.14 years and 11.40 Rs. Per kWh for off-site power plant. **Agrawal et al.[2]**. Proposed and designed solar parabolic trough power plant to supply the electrical energy demand of the garment zone of Jaipur city, considering two cases i.e. (i) onsite option (ii) offsite option. In both the cases financial indicators are calculated and compared with each other. The internal rate of return (IRR), net present value (NPV) at 10% discount rate, simple pay-back period, discounted pay-back period at 10% discount rate and Levelized cost of energy at 10% discount rate are 19.21%, 372.77 million INR, 5 years, 7 years 4 months and 9.41 Rs. Per kWh for on-site power plant and 27.85%, 550.55 million INR, 3 years 6 months, 4 years 7 months and 6.89 Rs. Per kWh for off-site power plant. **Shimy [3]** carried out a study in order to find out site feasibility in Egypt for the 10 MW capacity power generation facility which is grid connected and also evaluated the power plant on the basis of techno-economical as well as environmental considerations. They also exercised in selection of most appropriate solar PV module for which the all available PV modules in the market are taken in to consideration. 29 sites are selected in Egypt for which the meteorological data are taken from NASA website and these data are further analyzed in order to extract the characteristics of important meteorological parameters like solar insolation, sunshine period, ambient temperature of air and humidity content in air. On the basis of these characteristics of meteorological parameters they examined the suitability as well as compatibility of PV modules in the meteorological conditions of Egypt. This project is analyzed by using RETScreen software. **Hongxing et al. [4]** proposed an optimally design model of hybrid energy generation system which includes solar system and wind system with the facility of battery storage. They identified the

configuration giving optimum performance and also ensured about the minimization of annualized cost of the system. This method suggested by this study is also practically applied at telecommunication relay station located in southeast China along the coast. In this telecommunication relay station this method and model is applied in order to fulfill the power required by it. The characteristics of both solar and wind are found to be acceptable.

2. POPULATION AND ENERGY CONSUMPTION FORECASTING

Population data of year 1951 to 2011 are taken from census department and these data are forecasted in order to find population for the years up to 2024. The population data is tabulated in table-1. Per capita energy consumption data from 2010 to 2014 years are taken from electricity Distribution Company and these data has been forecasted in order to find per capita consumption data for years up to 2024. These electricity consumption data are tabulated in table-2.

Annual energy consumption is obtained by multiplying per capita energy consumption with population of the respective year. Capital cost for SPV plant for years 2010 to 2015 and for SPT plant for years 2012 to 2015 are tabulated in table-3 and table-4 respectively. These costs have been taken from the order issued by central electricity regulatory commission. On the basis of these costs, capital cost for SPV plant and SPT plant for year 2019 and 2024 are calculated. Capital cost of spv plant is estimated as 818.84 Rs.lakh/MW and 866.39 Rs.lakh/MW for year 2019 and 2024 respectively. Capital cost of SPT plant is obtained as 1101.50 Rs.lakh/MW and 1012.03 Rs.lakh/MW for year 2019 and 2024 respectively. According to these capital costs, project cost of SPV plants and SPT plants for year 2015,2019 and 2024 have been calculated and tabulated in table-5 and table-6respectively.[6], [7], [8], [9], [10], [11], [12], [13]

Table-4: Capital Cost for SPT Power plant in Rs. Lakh/MW for years 2012-2015

S.No.	Particulars/Years	2012	2013	2014	2015
1	Collector	572.00	528.00	528.00	528.00
2	Storage	234.00	216.00	216.00	216.00
3	Contingencies	156.00	144.00	144.00	144.00
4	Electricity generation	130.00	120.00	120.00	120.00
5	Consultancy	78.00	72.00	72.00	72.00
6	Balance of plant	52.00	48.00	48.00	48.00
7	Heat exchangers	39.00	36.00	36.00	36.00
8	Structures	20.06	20.50	20.88	21.25
9	Land	10.03	10.25	10.44	10.63
10	Total capital cost	1291.09	1194.75	1195.31	1195.88

Table-6: Project cost of SPT plants in Rs. Lakh/MW

S.No.	Particulars/Years	SPT 2015	SPT 2019	SPT 2024
1	Collector cost	165.06	218.40	283.31
2	Storage cost	67.52	89.35	115.90
3	Contingencies cost	45.02	59.56	77.27
4	Electricity generation cost	37.51	49.64	64.39
5	Consultancy cost	22.51	29.78	38.63
6	Balance of plant cost	15.01	19.85	25.76
7	Heat exchangers cost	11.25	14.89	19.32
8	Structures cost	6.64	10.38	16.69
9	Land cost	3.32	5.19	8.34
10	Capital cost	373.84	497.04	649.60
11	Capital cost with 30% subsidy	261.69	347.93	454.72

3. FINANCIAL ANALYSIS

In this section SPV and SPT power plants are financially evaluated on the basis of four scenarios i.e. (i) pre tax (ii) post tax (iii) pre tax with equity (iv) post tax with equity. In each financial scenario, financial indicators are calculated which are, internal rate of return, simple payback period, discounted payback period at 10% and 15%, net present value at 10% and 15% discount rate.

3.1 Financial assumptions

The financial analysis is carried out as per some standard financial assumptions which are tabulated in table-7.

Table-7: Financial assumptions

S.No.	Parameters	Value
1	Analysis period	25 years
2	O & M cost	2.20%
3	Escalation in O & M cost	5.72%
4	REC benefits	3500 INR/MWh
5	Tax	4% after 10 years
6	Debt fraction	70%
7	Equity fraction	30%
8	Interest rate	10%
9	Depreciation	5.83% for first 12 years, 1.54% afterwards

3.2 financial indicators

Financial indicators for SPV and SPT plants i.e. internal rate of return, simple payback period, discounted payback period at 10% and 15%, net present value at 10% and 15% discount rate are calculated and tabulated in table-8 for comparative analysis. All these financial

Table-1: Population forecasting [5]

Year	1951	1961	1971	1981	1991	2001	2011	2015	2019	2024
Population	891	985	1233	1525	2177	2834	3662	3474	3659	3891

Table-2: Per capita energy consumption in kWh of village Mansarkheri

Year	Feb	Apr	Jun	Aug	Oct	Dec	Annual per capita(kWh)	Population	Annual Consumption(MWh)
2010	17.72	20.86	23.92	29.38	16.98	24.50	133.37	3243	432.48
2011	22.78	22.98	18.99	23.85	23.94	19.76	132.29	3289	435.10
2012	18.79	17.20	27.75	28.94	36.90	33.04	162.64	3335	542.44
2013	25.97	30.86	32.63	29.04	28.33	23.51	170.34	3382	576.01
2014	28.91	17.95	32.37	24.31	32.58	29.61	165.74	3428	568.14
2015	30.51	22.59	36.29	25.62	38.42	30.27	183.71	3474	638.25
2019	40.74	23.42	48.12	23.64	52.66	35.86	224.44	3659	821.27
2024	53.54	24.45	63.09	21.17	70.45	42.84	275.54	3891	1072.01

Table-3: Capital Cost for SPV Power plant in Rs. Lakh/MW for years 2010-2015

S.No.	Particulars/Years	2010	2011	2012	2013	2014	2015
1	PV Modules Cost	915	833	494	344.50	334.00	332.35
2	Land Cost	5	15	16	16.80	18.00	25.00
3	Civil and General Works Cost	90	95	90	94.50	50.00	50.00
4	Mounting Structures Cost	80	105	100	105.00	40.00	50.00
5	Power Conditioning Unit Cost	180	160	98	60.00	50.00	45.00
6	Evacuation Cost up to Inter-connection Point (Cables and Transformers) Cost	85	90	100	105.00	60.00	55.00
7	Preliminary and Pre-Operative Expenses including IDC and contingency Cost	165	144	80	80.00	60.00	48.50
8	Capital Cost	1520	1442	978	805.8	612	605.85

Table 10: LCOE analysis of SPT plant for 2015, 2019 and 2024

LCOE for 25 years									
Discount rate		6%	7%	8%	9%	10%	11%	12%	15%
Capital Recovery Factor		0.0782	0.0858	0.0937	0.1018	0.1102	0.1187	0.1275	0.1547
Capital Recovery Factor + O&M		0.0982	0.1058	0.1137	0.1218	0.1302	0.1387	0.1475	0.1747
Year	Installed cost (INR/ kW)	LCOE(INR/kWh)							
2015	119587.50	**4.22**	**4.49**	**4.76**	**5.05**	**5.35**	**5.65**	**5.96**	**6.92**
2019	110150.00	**3.94**	**4.19**	**4.45**	**4.71**	**4.98**	**5.26**	**5.55**	**6.43**
2024	101203.13	**3.68**	**3.91**	**4.15**	**4.39**	**4.64**	**4.90**	**5.16**	**5.97**

Table-9: LCOE analysis of SPV plant for year 2015, 2019 and 2024

LCOE for 25 years									
Discount rate		6%	7%	8%	9%	10%	11%	12%	15%
Capital Recovery Factor		0.0782	0.0858	0.0937	0.1018	0.1102	0.1187	0.1275	0.1547
Capital Recovery Factor + O&M		0.0982	0.1058	0.1137	0.1218	0.1302	0.1387	0.1475	0.1747
Year	Installed cost (INR/ kW)	LCOE(INR/kWh)							
2015	78010.00	**3.01**	**3.18**	**3.36**	**3.55**	**3.75**	**3.94**	**4.15**	**4.77**
2019	81883.00	**3.12**	**3.30**	**3.50**	**3.69**	**3.89**	**4.10**	**4.31**	**4.97**
2024	86639.00	**3.26**	**3.45**	**3.66**	**3.86**	**4.08**	**4.30**	**4.52**	**5.22**

Table-5: Project cost of SPV plants

S.No.	Particulars/Years	SPV 2015	SPV 2019	SPV 2024
1	PV Modules Cost	131.39	155.96	183.40
2	Land Cost	9.88	17.97	33.07
3	Civil and General Works Cost	37.26	50.08	67.92
4	Mounting Structures Cost	45.46	69.95	107.59
5	Power Conditioning Unit Cost	17.79	22.89	29.88
6	Evacuation Cost up to Inter-connection Point (Cables and Transformers) Cost	47.44	75.03	121.24
7	Preliminary and Pre-Operative Expenses including IDC and contingency Cost	19.17	24.67	32.20
8	Capital Cost	**308.40**	**416.55**	**575.30**
9	Capital cost with 30% capital subsidy	**215.88**	**291.58**	**402.71**

Table-8: Financial indicators of SPV and SPT plants

Case	Without subsidy						With subsidy					
Year	2015		2019		2024		2015		2019		2024	
Plant	SPV	SPT	SPV	SPT	SPV	SPT	SPV	SPT	SPV	SPT	SPV	SPT
Pre Tax												
NPV @ 10 %	3.61	-0.87	2.24	-2.95	-0.69	-3.82	12.02	9.32	17.10	13.48	19.75	17.53
NPV @ 15 %	-4.56	-9.33	-7.96	-13.63	-13.59	-17.79	3.49	0.42	5.09	1.13	4.38	1.42
IRR in %	11.82	9.64	10.85	9.06	9.80	9.07	18.36	15.33	18.55	15.66	17.22	15.63
Simple payback period (years)	7.39	8.76	7.88	9.13	8.46	9.13	5.08	6.02	5.10	5.97	5.44	5.98
payback period (years) @ 10%	15.36	Never	18.71	Never	Never	Never	7.60	9.93	7.60	9.75	8.22	9.78
payback period (years) @ 15%	Never	Never	Never	Never	Never	Never	10.91	20.67	10.84	18.56	13.01	18.72
Post Tax												
NPV @ 10 %	3.31	-1.19	1.86	-3.35	-1.16	-4.34	11.70	8.98	16.64	13.01	19.18	16.91
NPV @ 15 %	-4.70	-9.48	-8.14	-13.82	-13.82	-18.04	3.34	0.26	4.88	0.91	4.10	1.12
IRR in %	11.69	9.49	10.71	8.92	9.67	8.93	18.24	15.20	18.44	15.54	17.11	15.51
Simple payback period (years)	7.39	8.76	7.88	9.13	8.46	9.13	5.08	6.02	5.10	5.97	5.44	5.98
payback period (years) @ 10%	15.63	Never	19.30	Never	Never	Never	7.60	9.93	7.60	9.75	8.36	9.78
payback period (years) @ 15%	Never	Never	Never	Never	Never	Never	10.94	21.86	10.87	19.26	13.16	19.45
Pre Tax Equity												
NPV @ 10 %	3.61	-0.87	2.24	-2.95	-0.69	-3.82	12.02	9.32	17.10	13.48	19.75	17.53
NPV @ 15 %	-0.72	-4.68	-2.78	-7.44	-6.43	-9.71	6.17	3.67	8.72	5.46	9.39	7.08
IRR in %	13.84	9.29	11.74	8.22	9.61	8.24	31.29	22.32	31.38	22.96	27.55	22.89
Simple payback period (years)	10.19	13.97	12.60	14.63	13.64	14.62	3.10	4.62	3.14	4.55	3.61	4.57
Payback period (years) @ 10%	15.36	Never	18.71	Never	Never	Never	3.94	6.73	3.98	6.54	4.77	6.57
payback period (years) @ 15%	Never	Never	Never	Never	Never	Never	4.59	9.30	4.64	8.78	5.76	8.85
Post Tax Equity												
NPV @ 10 %	3.31	-1.19	1.86	-3.35	-1.16	-4.34	11.70	8.98	16.64	13.01	19.18	16.91
NPV @ 15 %	-0.86	-4.83	-2.96	-7.63	-6.66	-9.96	6.02	3.52	8.50	5.24	9.12	6.78
IRR in %	13.59	9.01	11.48	7.94	9.34	7.96	31.17	22.14	31.26	22.77	27.39	22.70
Simple payback period (years)	10.24	14.11	12.69	14.80	13.77	14.79	3.10	4.62	3.14	4.55	3.61	4.57
payback period (years) @ 10%	15.63	Never	19.30	Never	Never	Never	3.94	6.73	3.98	6.54	4.77	6.57
payback period (years) @ 15%	Never	Never	Never	Never	Never	Never	4.59	9.30	4.64	8.78	5.76	8.85

indicators are calculated in two cases i.e. (i) without subsidy (ii) with 30% capital subsidy if provided by government.

4. LCOE ANALYSIS

Levelized cost of electricity and capital recovery factor at different-different discount rates has been calculated for SPV and SPT plants and tabulated in table-9 and Table-10 respectively.

5. CONCLUSION

In this study a village Mansarkheri is selected and the electricity demand of the village is estimated for years 2015, 2019 and 2024. Now to supply the electricity demands of year 2015, 2019 and 2024, SPV and SPT power plants are proposed. Following conclusions can be drawn from the study.

Energy demand: The annual energy required by the village Mansarkheri is 638.25 MWh/year, 821.27 MWh/year and 1072.01 MWh/year in year 2015, 2019 and 2024 respectively.

Plant capacity: To supply this energy demand SPV plants of capacity 395.34 kW, 508.71 kW, 664.02 kW and SPT plants of capacity 312.61 kW, 451.24 kW, and 641.88 kW are proposed and analysed in year 2015, 2019 and 2024 respectively.

Capital cost of SPV plant: The capital cost of SPV power plant is 780.10 RS.Lakh/MW, 818.83 RS.Lakh/MW and 866.39 RS.Lakh/MW in year 2015, 2019 and 2024 respectively.

Project cost of SPV plant: SPV power plant project cost for village Mansarkheri are calculated as 308.40 Rs.Lakh, 416.55 Rs.Lakh, 575.30 Rs.Lakh for without subsidy and 215.88 Rs.Lakh, 291.58 Rs.Lakh, 402.71 Rs.Lakh with 30% capital subsidy in year 2015, 2019 and 2024 respectively.

Levelized cost of electricity (LCOE): LCOE is calculated for SPV plant and SPT power plant by considering different discount rates i.e. 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14% and 15%. As the discount rate is increasing from 6% towards 15%, LCOE is also increasing in both the cases i.e. for SPV plants and SPT power plants in every year.

Financial indicators: The IRR is found to be higher in case of pre-tax scenario as compared with the IRR in Post-tax scenario and the pay-back period is found to be lesser in case of pre-tax scenario as compared with the pay-back period in Post-tax scenario. Similarly IRR is found to be higher in case of pre-tax with equity scenario as compared with the IRR in Post-tax with equity scenario and the pay-back period is found to be lesser in case of pre-tax with equity scenario as compared with the pay-back period in Post-tax with equity scenario

Capital cost of SPT plant: The capital cost of SPT power plant is 1195.88, RS.Lakh/MW, 1101.50 RS.Lakh/MW and 1012.03 RS.Lakh/MW in year 2015, 2019 and 2024 respectively.

Project cost of SPT plant: SPT project cost for village Mansarkheri are calculated as 373.84 Rs.Lakh, 497.04 Rs.Lakh, 649.60 Rs.Lakh for without subsidy and 261.69 Rs.Lakh, 347.93 Rs.Lakh, 454.72 Rs.Lakh with 30% capital subsidy in year 2015, 2019 and 2024 respectively.

Major findings: It is found that the capital cost, simple payback period, discounted payback periods at 10% and 15% discount rate and LCOE are less and IRR is more for SPV power plant as compared with SPT plant in every year and in all cases.

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