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Performance Analysis Based on Axis Tracking of PV System

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Abstract: A solar resource assessment done to know the amount of solar radiation available at Indore showed that Indore receives about 5.17kWh/m^2/day. The financial analysis carried out using RETScreen through three different tracker axis mode as fixed axis, one axis and dual axis tracker revealed that at a grid connected solar PV dual axis tracker mode has 35% more output power from solar irradiation as compare to fixed axis system.Results of the analysis indicate that, the project when implemented will supply about 35% as compare to fixed axis tracker PV system. The project also stands the chance of saving about 606 tonnes of CO_2 which would have been emitted by a crude oil-fired thermal power plant generating the same amount of electricity.

Keywords: photovoltaic cell, inverter, Grid system

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I. Introduction

Grid-connected solar PV systems, though the fastest growing renewable energy technology in the world, have not been fully exploited in India; one of the reasons being the very high initial investment [1]. Prices of solar PV systems have however been on a decline for the past few years due to technological innovations which have led to improvements in cell efficiencies and the economies of scale resulting from increase in production. The main purpose of this paper is to present a technical and economic analysis of grid-connected solar photovoltaic power system for the Indore, Madhya Pradesh, India.

With the prevailing tariff conditions in the country, this project can be considered is not financially viable except with grants and capital subsidies. However, the other non-financial benefits like the greenhouse gas emissions savings can in the long run help mitigate the adverse effects of the climate change problem plaguing the entire earth. Indore currently doesn't have a feed-in tariff policy making it difficult for renewable energy projects to be implemented. However, there is a Renewable Energy Bill currently in parliament waiting to be passed into a law.

II. GRID-CONNECTED PV SYSTEM COMPONENTS

The design of grid-connected PV system, necessary components is PV cell, Inverter, load profile. This PV system configuration output power fulfills the required load demand of the design location [10-11].

A. PV System

The design location selected as Indore MP for PV system. This location has great potential of solar radiation.

The climate data location at latitude 27.7N and longitude 75.8 E. The daily solar radiation horizontally is 5.17Kwh/m^2/day of PV system design location. The detail information of solar radiation data, temperature heating, cooling etc. is shows in table 1[2]. The type of PV system is mono-Si - SPR-320E-WHT has 46 unit of array to satisfy the load demand. The efficiency of the PV array is 19.6%, nominal operating cell temperature and operating co-efficient are 0 0C and 0.38% respectively. The solar collector area is 75m2 and miscellaneous losses considered as 1%. The Maximum power point tracker (MPPT) method is used to measure maximum output power of solar PV array [4].

Table 1: Monthly solar data radiation

	Unit	Climate data location	Project location
Latitude	°N	22.7	22.7
Longitude	°E	75.8	75.8
Elevation	m	567	567
Heating design temperature	°C	10.4	
Cooling design temperature	°C	39.6	
Earth temperature amplitude	°C	20.7	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		18.2	48.9%	4.61	97.2	2.6	23.6	0	254
February		20.8	38.7%	5.35	97.0	3.1	27.6	0	302
March		26.0	27.2%	6.20	96.8	3.8	34.4	0	496
April		30.2	23.7%	6.65	96.5	4.7	38.4	0	606
May		32.5	32.3%	6.75	96.2	5.8	37.4	0	698
June		29.5	59.8%	5.54	96.0	6.1	32.4	0	585
July		26.1	80.0%	4.27	96.0	6.0	28.4	0	499
August		24.8	86.5%	3.83	96.2	5.4	27.6	0	459
September		25.5	77.3%	4.72	96.4	3.8	28.6	0	465
October		25.1	55.5%	5.17	96.8	2.2	28.9	0	468
November		22.0	48.1%	4.69	97.1	1.7	26.5	0	360
December		18.9	48.7%	4.32	97.3	2.1	23.2	0	276
Annual		25.0	52.3%	5.17	96.6	3.9	29.7	0	5,468
Measured at	m					10.0	0.0		

B. INVERTER

The charged of the inverter trust on the request it is usage for, the nature (waveform) of its output, its output capacity, and other integrated functions such as battery charging or gen set automatic starting. The inverters specification as Efficiency is 98%, Capacity is 15kW, and Miscellaneous losses is 0%. on-grid PV systems, the cost of inverters is in the $750/kW AC to $1,500/kW AC range, where bigger units are on the lower end of this range and smaller units on the higher end. A high-volume purchase of small units may bring the cost in the middle range. Note that some PV module manufacturers are offering "AC PV modules" for grid intertie systems. These modules have a short shape-in inverter. In this action, the user will not conclude an inverter cost here [5], [12].

C. LOAD

load profile is considered as central-grid & internal load. The proposed grid-connected PV system is usefull for both central-grid and off-grid system supply without batteries. Electricity load demand for design of solar photovoltaic system is on-grid (Central-grid & internal load) connected which utility supply system. On-grid applications cover both central-grid and isolated-grid systems without batteries [9]. The efficiency of grid connected system PV system is higher as contrast with isolated grid application on the grounds that if PV system yield is not satisfy the load requirement because of climate condition and so on no go down is accessible for supply system. The Peak load – annual is 3kW. The load profile of design location is shown in fig 1.

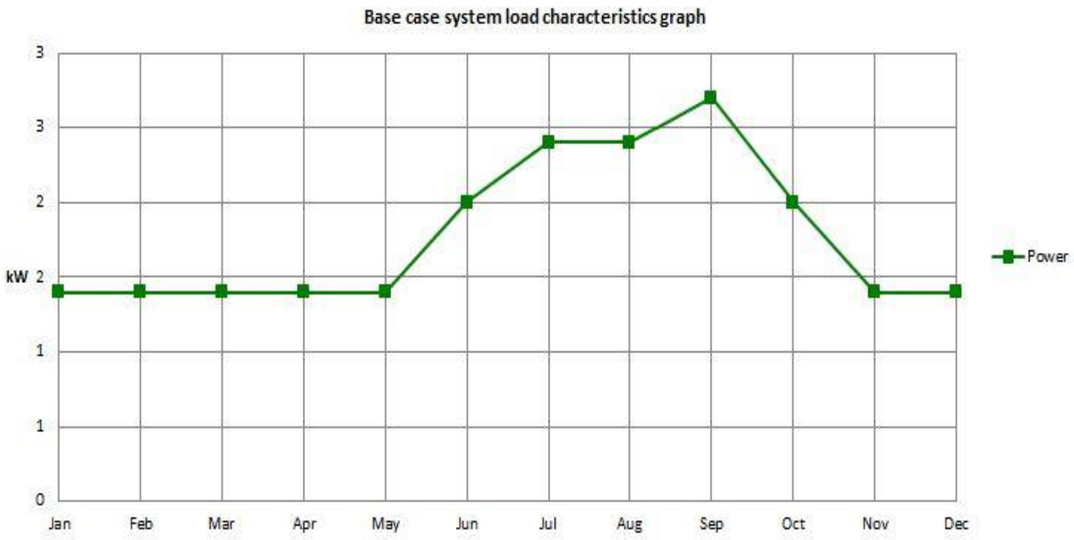

Fig.1. The load profile of design location

D. ENERGY MODEL

As part of the RETScreen Clean Energy Project Analysis Software, the Energy Model worksheet is used to evaluate the proposed case system. In this sheet the detail information of PV system components which are used for design a Grid connected system.

III. RESULTS AND DISCUSSION

The user selects the type of sun tracking device upon which the solar collector is mounted. The options from the drop-down list are: "Fixed," "One-axis," "Two-axis" and "Azimuth." If the solar collector is mounted on a fixed structure the user may select "Fixed." The remaining choices may be selected if the solar collector is mounted on a tracker. A tracker is a device supporting the solar collector which moves the collector in a prescribed way to minimise the angle of incidence of beam radiation on the collector's surface [6]. Hence incident beam radiation (i.e. solar energy collected) is maximized. Solar trackers may be classified as follows:

- **One-axis trackers** track the sun by rotating around an axis located in the plane of the collector. The axis can have any orientation but is usually horizontal east-west, horizontal north-south, or parallel to the earth's axis;
- **Azimuth trackers** have a fixed slope and rotate about a vertical axis; and
- **Two-axis trackers** always position their surface normal to the beams of the sun by rotating about two axes.

In this proposed case three different type of tracker as One-axis trackers, one-axis trackers and Two-axis trackers is used for obtaining maximum power output from solar PV system.

Analysis is followed by outcomes of the sensitivity analysis. Prefeasibility analysis of grid connected PV system for location Indore, Madhya Pradesh, INDIA evaluated through the RETSCREEN software. The software gives the result in form of net present value (NPV), internal rate of return (IRR), Simple payback, Equity payback, Annual life cycle savings, Benefit-Cost (B-C) ratio and GHG reduction cost. RETSCREEN software also performs risk and sensitive analysis.

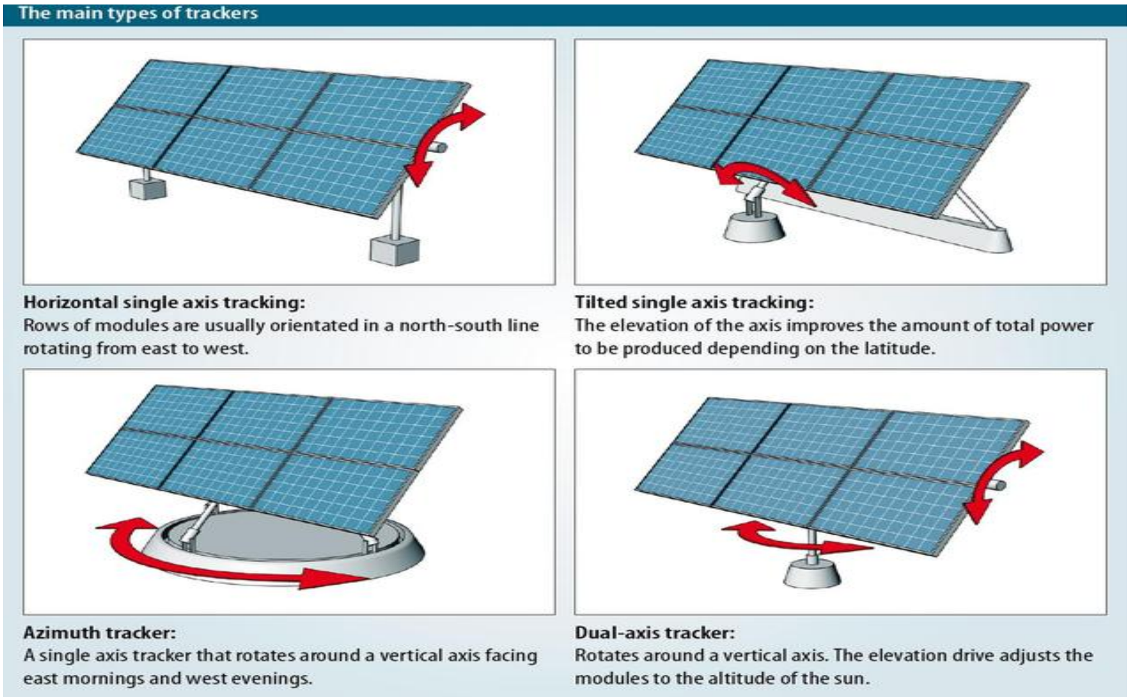

Fig. 2. Type of solar tracker [6]

A. Cumulative cash flow

The model calculates the cumulative cash flows, which represent the net pre-tax flows accumulated from year 0. The net pre-tax cash flows are the yearly net flows of cash for the project before income tax. It represents the estimated sum of cash that will be paid or received each year during the entire life of the project. Note that the equity is assumed to occur at the end of year 0 and that year 1 is the first year of operation of the project. Annual costs, savings and income, which reflect amounts valid for year 0, are thus escalated one year in order to determine the actual costs and savings and income incurred during the first year of operation (i.e. year 1). The yearly cash flow and cumulative cash flow of fixed, one axis and two axis is shown in fig. 3 (a), (b), (c) and table .2.

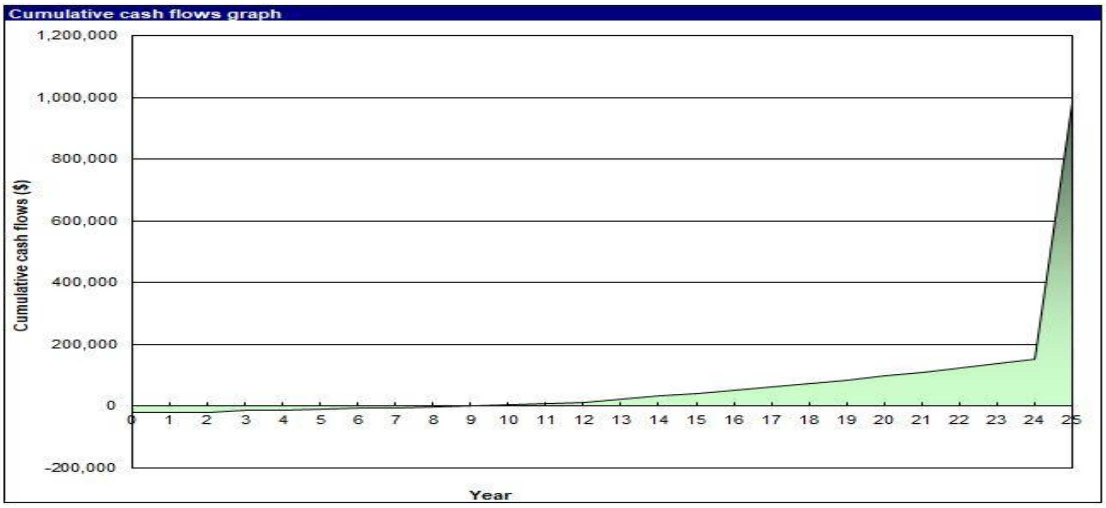

Fig 3. (a)

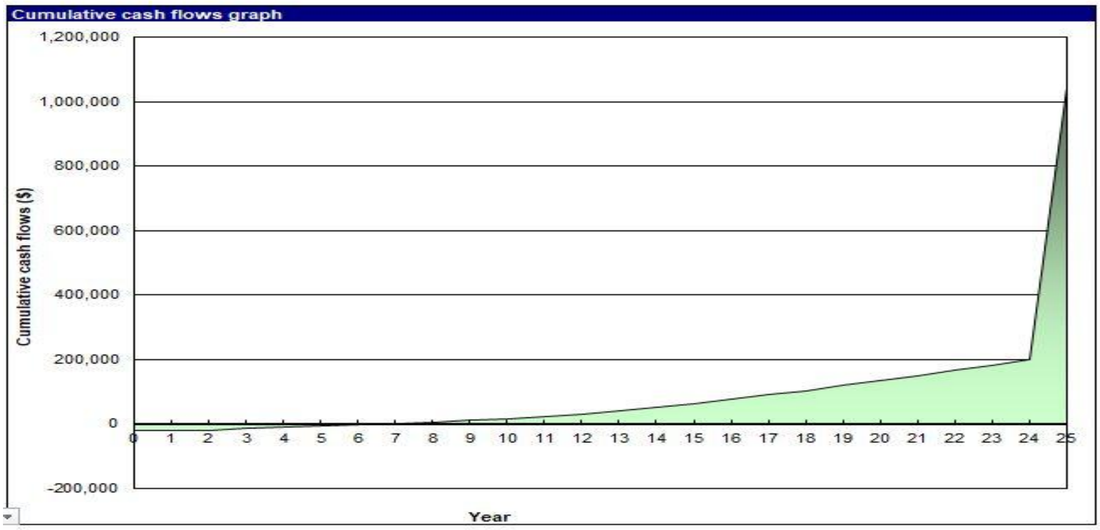

Fig 3 (b)

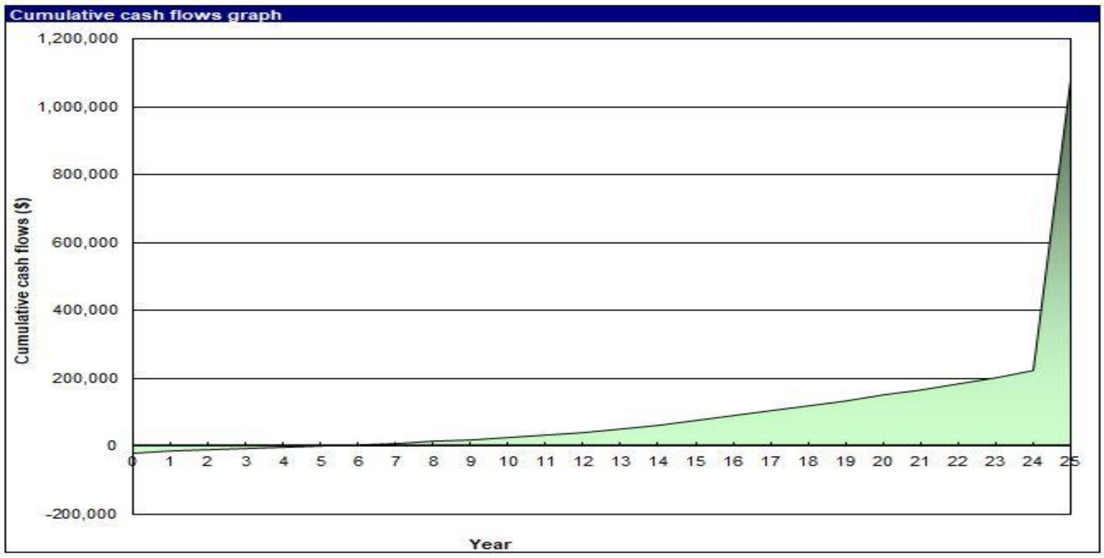

Fig 3. (c)

Fig 3. (a), (b), (c) cumulative cash flow of fixed, one axis and two axis

B. Yearly Cash Flow

The model calculates the pre-tax internal rate of return (IRR) on assets (%), which represents the true interest yield provided by the project assets over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. It is also referred to as the return on assets (ROA). Table 2. show the Yearly Cash Flow of all three-tracking system.

It is calculated by finding the discount rate that causes the net present value of the assets to be equal to zero. Hence, it is not necessary to establish the discount rate of an organisation to use this indicator. An organisation interested in a project can compare the internal rate of return to its required rate of return (often, the cost of capital). The IRR is calculated on a nominal basis, that is including inflation. Table show the camparative yearly cash flow, according to table dual axis tracker system gvies maximum 1080031$ cash flow.

Table 2: comparative yearly cash flows of all axis

Yearly Cash Flow $			
Years	Fixed Axis	One Axis	Dual Axis
0	-19,568	-19,676	-20,058
1	-18,383	-17,337	-17,387
2	-16,969	-14,710	-14,408
3	-15,317	-11,781	-11,105
4	-13,415	-8,539	-7,466
5	-11,253	-4,968	-3,473
6	-8,820	-1,053	888

7	-6,103	3,220	5,634
8	-3,089	7,868	10,783
9	233	12,908	16,354
10	3,878	18,358	22,365
11	7,859	24,237	28,836
12	12,193	30,563	35,790
13	21,278	41,766	47,741
14	30,746	53,458	60,220
15	40,616	65,662	73,249
16	50,904	78,402	86,856
17	61,629	91,702	101,065
18	72,811	105,587	115,906
19	84,471	120,085	131,407
20	96,629	135,224	147,598
21	109,309	151,032	164,513
22	122,533	167,542	182,184
23	136,326	184,785	200,646
24	150,715	202,796	219,937
25	985,125	1,045,573	1,080,031

C. Electricity Exported

The model calculates the annual electricity export income. This value is calculated by multiplying the electricity exported to grid by the electricity export rate. The annual value of the electricity export income is escalated at the electricity export escalation rate. All tracker PV system electricity export income is shown in table 3.

D. Total annual savings and income

Total annual savings and income is combination of Electricity export income and Fuel cost - base case. Both are define as:

- Electricity export income: The model calculates the electricity export income. This value is calculated by multiplying the electricity exported to grid by the electricity export rate. The annual value of the electricity export income is escalated at the electricity export escalation rate.
- Fuel cost - base case: The model calculates the total fuel cost for the base case. The annual value of fuel cost for the base case is escalated at the fuel cost escalation rate. Table 3 shows the comparative analysis of all tracker modes.

E. GHG reduction credit duration

The user enters the GHG reduction credit duration (year). This value typically represents the number of years for which the project receives GHG reduction credits. It is used to determine the GHG reduction income over the project life. For Clean Development Mechanism (CDM) projects, two options are currently available for the length of the crediting period (i) a fixed crediting period of 10 years or (ii) a renewable crediting period of 7 years that can be renewed twice (for a maximum credit duration of 21 years). If a crediting period of 10 years is selected, once the project has been validated and registered, Certified Emission Reductions (CERs) can be certified and issued for the 10 years of the project without revisiting the baseline. However, in the case of a renewable 7-year crediting period, the project will have to be validated after each 7-year period in order to receive CERs for the subsequent 7 years.

Thus in selecting a crediting period, the benefits of the potentially longer crediting period of the renewable crediting period (e.g. up to 21 years) must be weighed against the additional transaction costs of re-validating the project after each 7-year period, and the risk of the project potentially not meeting validation requirements at that time. As shown in table 3.

F. Total annual costs

The total annual costs are calculated by the model and represent the yearly costs incurred to operate, maintain and finance the project. It is the sum of the O&M, fuel cost for the proposed case system and debt payments. Note that the total annual costs include the reimbursement of the "principal" portion of the debt which is not, strictly speaking, a cost but rather an outflow of cash. These costs are described briefly below. Table 3 show that total annual cost is highest is case of dual axis tracker mode.

Table 3: Project costs and savings/income summary & financial viability

Project costs and savings/income summary		**Unit cost**	**Fixed axis**	**Single axis**	**Dual axis**
Initial costs					
Feasibility study	0.0%	$	0	0	0
Development	1.2%	$	800	800	800
Engineering	3.1%	$	2,000	2,000	2,000
Power system	76.7%	$	50,047	50,383	51,559
Heating system	0.0%	$	0	0	0
Cooling system	0.0%	$	0	0	0
User-defined	0.0%	$	0	0	0
Energy efficiency measures	0.0%	$	0	0	0
Balance of system & misc.	19.0%	$	12,378	12,405	12,500
Total initial costs	**100.0%**	**$**	**65,225**	**65,588**	**66,860**
Incentives and grants		$	0	0	0
Annual costs and debt payments					
O&M		$	106	106	106
Fuel cost - proposed case		$	0	0	0
Debt payments - 12 yrs		$	4,384	4,408	4,494
Total annual costs		**$**	**4,490**	**4,514**	**4,599**
Periodic costs (credits)					
		$	0	0	0
		$	0	0	0
End of project life - credit		$	-391,350	-393,530	-401,158
Annual savings and income					
Fuel cost - base case		$	2,507	2,507	2,507
Electricity export income		$	2,948	4,071	4,468
GHG reduction income - 0 yrs		$	0	0	0
Customer premium income (rebate)		$	0	0	0
Other income (cost) - yrs		$	0	0	0
CE production income - yrs		$	0	0	0
Total annual savings and income		**$**	**5,455**	**6,578**	**6,975**
Financial viability					
Pre-tax IRR - equity		%	21.4%	24.5%	25.4%
Pre-tax IRR - assets		%	13.2%	14.3%	14.5%
After-tax IRR - equity		%	21.4%	24.5%	25.4%
After-tax IRR - assets		%	13.2%	14.3%	14.5%
Simple payback		yr	12.2	10.1	9.7
Equity payback		yr	8.9	6.2	5.8
Net Present Value (NPV)		$	304,446	333,548	347,049
Annual life cycle savings		$/yr	21,601	23,666	24,624
Benefit-Cost (B-C) ratio			16.56	17.95	18.30
Debt service coverage			1.27	1.53	1.59
Energy production cost		$/MWh			
GHG reduction cost		$/tCO$_2$	(680)	(618)	(606)

IV. CONCLUSION

The study show that variable axis tracking PV module power plant gererated the elelctricity and analyzed standalone PV model. The RETScreen financial analysis accounts for all the design factors affecting the financial viability of a project, including initial costs, energy savings, operation and maintenance (O&M), fuel charged, taxation, greenhouse vapour (GHG) and renewable energy (RE) work belief. It automatically calculates important indicators of financial viability, permitting users to evaluate scheme supported on their own criteria. Then RETScreen can research the sensitivity of the key financial indicators to changes in the inputs. During this analysis, the author should keep in belief that indicators that observe profitability over the energy of the scheme, such as the IRR and the NPV, are preferable to the simple payback. In this proposed work evaluate prefeasibility analysis of grid connected PV system at various mode of solar tracker system and found that dual axis tracker mode represent more feasible output results as compare to fixes and one axis tracker mode. Dual axis tracker system extract 35% more power from the solar irradiation as compare to fixed axis system. The net present value, benefit to cost ratio and IIR etc are also higher during project life of system.

Indian government and involving authorities should not encourage private investments and apply adder supports to 16 MW PV projects as it is not economic viable and will become just a wasteful financial burden to all parties. This does not mean that any adjustment in policies would not help the small PV projects at all, but it means that those adjustments have to be radical and it is not likely that such changes could create more benefits than costs. 16 MW PV projects are the most promising scale comparing to the other two as the projects result in positive NPVs in all scenarios. Without adder, the projects would yield negative NPV in all locations, but the projects become highly profitable with the adder supports. Investment in this scale is still recommended if there is power purchase agreement to guarantee the adder supports. However, supporting this large scale PV technology may pose the financial burden to electricity consumers. To support this scale of PV project, Indian government would have to subsidize. The adder supports are funded by the fuel adjustment cost (Ft) in electricity price. In other words, the more adder supports are granted, the more expensive the electricity price will become in long run.

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