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A Proposal on Techno-Financial Design aspects of Photovoltaic System for the Twin Districts of Rajouri and Poonch (Jammu & Kashmir)

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Abstract

In this paper, a procedural analysis involved in the optimal design of the photovoltaic system (PV) is thoroughly described. The study has been carried out by following a proposed design procedure, involving different types of photovoltaic panels and their tracking mechanisms. The proposed methodology is implemented in the twin districts of jammu & kashmir union territory (rajouri & poonch). The feasibility of the photovoltaic system has been made based on power output and the cost of generation. A detailed financial analysis is also carried out to find the levelised cost of electricity, amortisation time, and internal rate of return. This study will help the power utilities to mitigate their energy issues, by installing a photovoltaic system based on the proposed design methodology.

Keywords: cost estimation, design, photovoltaics, renewable energy, solar power

Received on 02 May 2020, accepted on 12 July 2020, published on 17 July 2020

doi: 10.4108/eai.13-7-2018.165521

1. Introduction

The global energy demand has tremendously spiked in the past, due to the increase in the human population and industrial development. This has created a large pressure on the generation entities, to increase their generation. To overcome this energy deficit, Renewable energy systems are a good option, due to the stable improvement in renewable energy technologies and green nature. There are different types of renewable energy sources (like solar, wind, etc.) which could be used as an alternative to conventional energy sytems[1-3].Some innovative sources of alternative energy generations were also found in the literature,For example in [4] a technical solution for converting the kinetic energy of press into electric power and accumulating it for further use, is proposed.In [5] a research is conducted based on the selection of the engine and windings to convert the kinetic and mechanical energy of rotation in the electric one.Also in [6] the use of microalgae to produce bio enegy is given. Microalgae are believed having high rate of photosynthetic activities producing good amount of power.Mass cultivation of microalgae can reduce the carbon dioxide emission to atmosphere and thus,reducing the impact of global warming.

Among these vatious alternative energy sources, Solar energy is the most widely used, due to its abundant availability and green nature. The use of Solar energy is advancing very rapidly throughout the whole world. During the last decade there is an abrupt increase in the use of solar energy seen. A large number of photovoltaic (PV) systems have been installed globally and the annual growth rate between 2010 and 2017 was as high as 24%[7].According to Bloomberg, the global benchmark levelized cost of electricity(LCOE) for onshore utility-scale PV systems has fallen 4% since the second half of 2019 to $50/MWh[8].
India, too, has realized its solar potential and various developments could be seen, to expand the dependence on this form of energy. The estimated solar energy incidence in the Indian mainland is approximately 5000 trillion kilowatt-hours (kWh) per year [9-10] which is higher than the possible

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energy output through all fossil reserves. The total installed capacity of solar power has reached 34 Gigawatts (GW) by Feb-2020 in India [11]. The major portion of the installed capacity is ground-mounted, comprising of mega solar power projects,which are producing power centrally and feeding to the grid. The remaining is rooftop solar, which includes residential, industrial, and commercial deployments. By July-2019, the ground-mounted and rooftop capacity has reached 27,930 Megawatts (MW) and 2,141 Megawatts (MW) respectively. India has intended a commitment, to achieve 40% of its total electricity generation,from renewable energy sources by 2030 in the Paris agreement.

In supplement to the grid-connected solar power initiatives, India is also developing off-grid solar power,through local producers [12]. Many solar products,such as solar lanterns, solar inverters, solar geysers, etc had been distributed by the government,either free or on subsidized rates to meet rural needs [13]. This is an outcome of continuous improvements in solar industries. However, despite these developments in the solar industry, there are several areas of Jammu & Kashmir Union territory(J & K UT), which are still power deficient, due to poor transmission and distribution infrastructure.These areas are also hesitant to use solar power, due to the lack of technological understanding. The capacity additions in solar power, which were made, were either of too low capacity or underutilized, resulting in too low voltages in some areas, especially in the Rajouri & Poonch district of J & K UT [14].

2. Problem Formulation

The J & K UT is most probably the only piece of land on the world map, that despite being profusely rich in many resources of self-reliance & self-satisfaction has not reaped their benefit to its full advantage. Till date, people of J & K UT, especially, twin border districts of Pir Panjal range (Rajouri & Pooch), have to face power cuts of several hours, more during the cold weathers of winter, with erratic & intermittent power supply.

It despite having a generation capacity of 20,000 Megawatts (MW), is often considered as the energy-starved regions within India [15].The main reason of this energy starvation is due to its dependence, on the hydro energy sources,which in winters fail to supply, due to the reduction in the water level in the rivers.Also an increase in energy demand is seen during winters, due to the increase in the use of heating appliances etc. Under these situations,they are meeting their energy demands throught the use of thermal generating plants, diesel generators, etc.

In addition, there are heavy transmission and distribution losses in J & K UT, due to its poor infrastructure. Due to these contions, this region has seen,power cuts of several hours and an increase in the finances. There are several areas such as (Rajouri and Poonch) which remain without power for several days and weeks.The rising energy demands in J & K UT, are creating a shortfall of more than 400 MW during winters [16].This shortfall is expected to increase,in the future, if concrete measures were not taken.

The J & K UT, however has a huge potential of renewable energy sources,especially Photovoltaics (PV). But, due to the technological & political backdrop, it has not been harnessed well and efficiently so far. To cope up with this energy starvation, there is an urgency to shift the focus, towards solar energy, as this region is quite rich in receiving good amount of solar radiations.Also, solar energy technology is currently experiencing a boost due to technological improvements and the cost of electricity generated through solar has crossed grid parity [17]. Moreover governments, are offering various incentive schemes, to achieve their renewable energy targets. Some of these are as follows:

(i) Accelerated Depreciation

By Accelerated depreciation, utilities can claim depreciation in the Ist year, by installing Photovoltaic (PV) systems. This will benefit them in tax saving, to gain some profit.

(ii) Capital Subsidies

The central government as per Ministry of New & Renewable Energy (MNRE) is offering capital subsidies of 30% on the benchmark cost for PV systems (Rooftop) in the general category states. However in certain special states like Himachal Pradesh, Sikkim, Uttarakhand, the offered subsidy is 70% on the benchmark cost [18].

(iii) Renewable Energy Certificates

These are special certificates that can be traded for the generation of electricity from renewable energy sources. This will help the states to achieve renewable power obligations (RPO) set up by the central government.

(iv) Net Metering Incentives

By Net metering, a consumer can trade the electricity which he had generated with the local energy distributors. However this is dependent upon the incentive policy mechanism incentives offered by the state.

(v) Assured Power Purchase Agreement (PPA**)**

According to this agreement, any power producing or power utilizing company owned by central or state governments are guaranteeing the selling and buying of power for a certain period of contract. As far as distribution generation is concerned commercial PPAs are used by many schools, NGOs, etc. to purchase power other than the utilities. By this mechanism many incentives are offered to set up small distribution setups like Photovoltaics etc.

In this research work, we have given a detailed analysis, regarding the design of Photovoltaic (PV) systems with current technology breakthrough. A thorough investigation has also been carried out, for the twin districts of Rajouri & Poonch (J &K) indicating a good solar power reserve along with cost analysis.

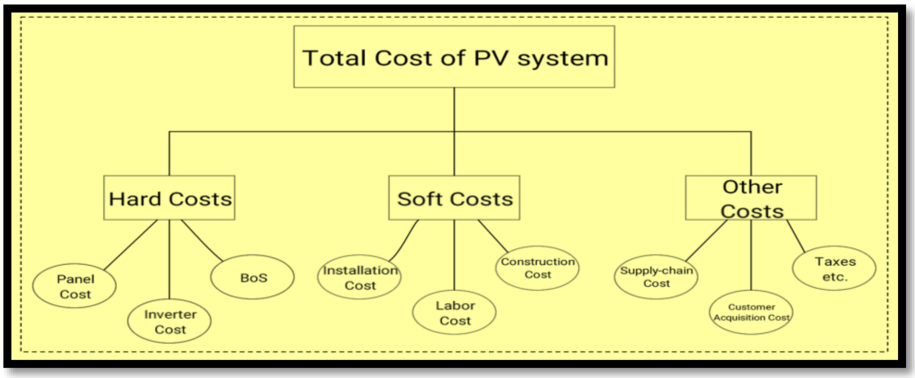

Figure.1 Composition of total cost of PV system

3. Design Method to Harness Photovoltaic Power

To set up a PV systemt, in order to harness solar energy, there are various steps involved, in the selection, design, determining specifications, etc.These steps vary, depending upon various attributes such as geographical location, solar irradiation levels, and local weather condition, etc. of the site[19]. The power output of the PV system is directly related to these attributes. Moreover this power output also depends on the type of solar module used, different types of solar radiation tracking mechanisms adopted, tilt angle of solar panels etc.

The expenditure on the installation of PV system has declined, owing to the reduction in the pricing of the various equipements involved in PV system.The reduction is by over 70% ,during the last few years.This decrease, is a result of the technological breakthrough and rising energy demand of the utilities. The overall cost of the PV system is broadly divided into hardware costs, soft costs, and other costs.Figure.1 shows the various PV cost compositions. Hardware costs comprise the costs associated with solar Modules, Inverters, charge controllers, batteries, etc. Soft costs are the costs associated with financing for installation, labour, etc. Also the other costs involve money spent on customers and taxes to be paid.

This research work aims to harness the maximum amount of solar energy in the twin district Rajouri and Poonch of Jammu and Kashmir UT. Both the regions being hilly, are posing challenges to set up new power corridors. Due to this hindrance, a large number of populations suffer from lack of electricity. By designing a PV system, the shortage of electricity will be overcome to a large extent. But to grasp maximum electricity from PV system many design factors need to be investigated for correct sizing.

The important factors which affects solar panel output is as follows:

- Type of Photovoltaic (PV) modules used
- Tilt/ Angle of Inclination
- Array tracking designs
- Systems losses
- Shading
- Temperature

3.1 Types of PV modules

Different variety of Photovoltaic (PV) modules are accessible in the market. These are broadly classified into Monocrystalline and Polycrystalline solar panels. Monocrystalline is manufactured from a single crystal and has the highest conversion efficiency of 20%. However Polycrystalline is manufactured from different crystals with a conversion efficiency of 14 %. Apart from them, there are

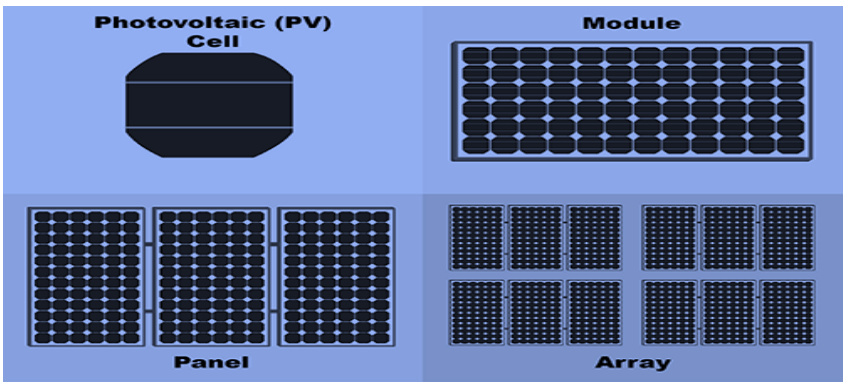

Figure.2 A journey from solar cell to solar array[27]

also amorphous solar panels available. They are least efficient but highly flexible.

These solar modules can be connected in series and parallel combinations, to get the desired current and voltage ratings as per the requirement of the load and other parameters. Solar modules connected in series result in increase in voltage, while when connected in parallel causes increase in current. These solar panels provide the rated output at standard testing conditions (STC) only.However in varied conditions of weather,there is shift in power output.Also the power output of PV panel depends upon the matrial of the PV panel as well.A research was conducted in [20],whereby the authors discussed and analysed various existing types of silicon PV panels.They illustrated the various load parameter conditions for transmitting maximum power into the load.In [21] a research was carried out to analyse the impact of radiations on the efficiencies of different types of PV Panels. A schematic diagram showing transition from solar cell to solar array is shown in Figure.2.

3.2 Solar Array Tracking designs

There are three types of solar array designs: fixed, single-axis tracker, and double-axis tracker. The double-axis tracker is the most efficient one, to tap a large number of solar radiations and eventually increasing the power output followed by single-axis tracking and fixed designs. The choice is dependent upon the end-user, by taking into consideration various factors like weather conditions, the terrain of the site, economy, etc. Figure.3 shows different types of tracking designs.

Based on various surveys conducted, generally the end-users prefer tracking system design rather than a fixed ground system, as a way to increase their power outputs. Investment in the automatic solar tracking system will yield a definite good return.It can contribute greatly to the welfare of humans, in reducing the greenhouse effect, while achieving continual abundant energy supplies. The yield from the solar panels increases by 30 to 50 % using a tracker instead of fixed solar panels. There is an urgent requirement of the automatic sun following trackers in the future, because of following inefficient methods of tracking given in Table. I

Table. I Comparison of different solar panels

S.No	Method	Reasons for inefficiency.
1	Fixed angle Solar Panels	It is least efficient, owing to the change in position of sun during different times of the day.
2	Manually rotated Solar Panels	A large amount of manpower is needed to shift the tilt angle of the solar panel, which is not logical.
3	Predefined rotated Solar Panels using programmed software/timers.	It becomes inefficient ,when sun gets blocked by clouds, while it still changing its position and wasting power

3.3 Tilt Angle and Azimuth

The tilt angle is the angle which solar panels make with the horizontal surface. In the case of single-axis tracking systems, it's the angle of the tracking axis with the horizontal surface. This is required to get the maximum amount of solar radiations incident on the solar panel. To optimally receive the solar radiations on the surface of the solar panel, the tilt angle is required to be changed based on seasonal variations [22]. However it's better to keep it fixed; equal to the latitude of the given location, instead of changing it every time, involving manual labour. As far as Azimuth is concerned, for south-facing solar panels, it is kept equal to 180° and for north facing solar panels its kept equal to 0^0.

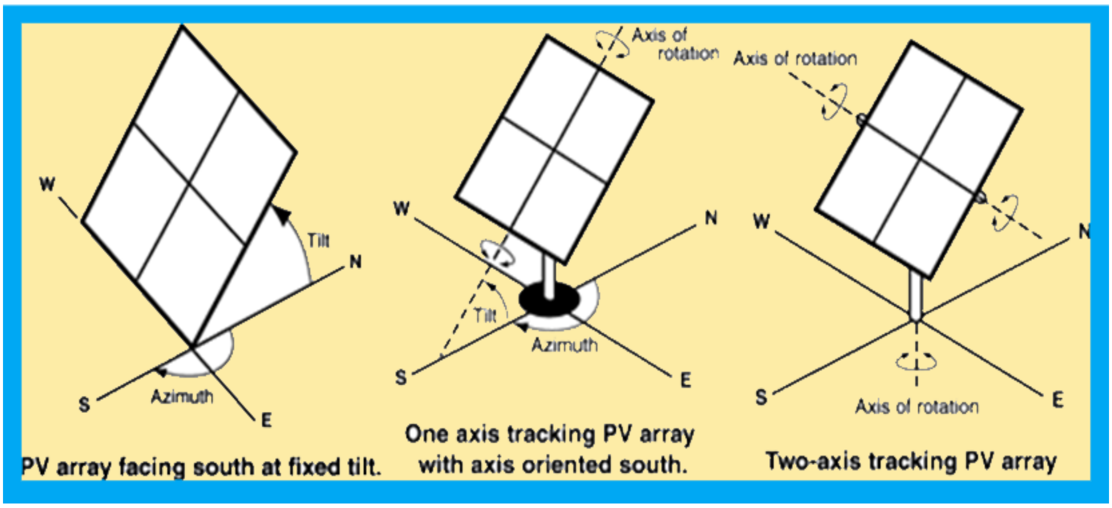

Figure.3 Different types of tracking mechanisms[26]

3.4 System Losses

A Photovoltaic system is often subjected to different types of losses. These losses results in the power supplied through PV panels different, than the power for which it was actually tested at standard testing conditions (STCs).An approximate estimation of these losses, can be very beneficial, while designing the PV setup .Following are the different types of losses which takes place in the PV system.

(i) Losses due to Reflection

The power output of PV system is differnet under outdoor conditions.This is due to the larger incidence angles of the solar radiations, resulting in higher reflection losses than under standard testing conditions.Under STCs, the incident radiations are kept perpendicular.The estimated value of reflection losses for PV panels facing equator with tilt angle equal to the latitude are about 1% yearly than at STCs.

(ii) Losses due to Soiling

These losses, are on account of acculmulated dust and foreign particles present on the surface of the PV panels.This causes decrease in the power output of PV panels,because of the decrease in solar radiations penetrating them.The soiling losses depends upon the weather and the location of the site.For example in heavy traffic places,industrial places etc the dust accumulation is very frequent.Also in certain situations like snow,the power output depends on the amount and the time for which it remains on the PV panels.Many organisations like NREL are doing research to model the impact of these losses on the power output.

(iii) Losses due to Module Mismatch

No two PV modules can be exactly same, resulting in the mismatch losses, when these are connected in series and parallel.This is due to the difference in the manufacturing methods adopted and conditions to which they are subjected. Mismatch losses can be a serious problem, while evaluating the power output of the PV array.For worst case scenario the power output of the PV array is determined by the solar module with the lowest power output. Therefore, it becomes very essential, to select the modules with less mismatch,so that the overall power output doesn’t change much.

(iv) Losses due to MPPT

There exists a single point on the PV curve of the solar module, when the power delivered is maximum.In order to continuously supply the power output at maximum,a Maximum Power Point Tracker (MPPT) is desirable.MPPT is basically a dc to dc converter which transfers the maximum power from the solar panels to the load.There are various types of MPPTs available in the market.The correct selection of these is imperative, to ensure that the power output is always maximum.The wrong rating of the MPPTs could drastically reduce the power output of the PV panels.Hence a great care should be taken while choosing the right MPPT for the PV system.

(v) Losses due to Wiring

These are Resistive losses due to the use of DC and AC wires, for connecting different PV modules,Inverters and load points.A poor wiring can cause heavy loss in power output of the PV system.

The system losses described above, if not taken into consideration, could result in the poor estimation of the power output of the PV system.This can pose a great threat to the stability electricity grid. Hence a great care has to be taken to correctly estimate them.

3.5 Shading

Solar radiations falling on the PV panel gets largely affected due to the shadow caused by big objects such as trees,buildings present aroung the PV arrays.Sometimes even the shadow of one PV array falls on the other PV array resulting in loss of power output.

The power output from the solar panels gets affected to a large extent even if only a part of its gets shaded. Therefore great care has to be taken to ensure no solar panel gets shaded due to other panels shadow etc. This could be done by keeping the proper spacing between the different rows of solar panels. Also, dust, etc. leads to shading, so it needs to be cleaned at regular intervals.

It could had been better to setup PV system, where there is no shade present, to minimise this loss.But this is an ideal condition and not always possible.In practical situations bypass diodes are used to minimise the power loss.These are connected between the cells in the PV module.These provide an alternate path for the currents of unshaded portion thereby restricting their flow into the shaded portion.Although, a small voltage drop occurs, but, still its not much, if no diodes are used.

3.6 Temperature

The power output mentioned on the PV panel is at standard testing condition (STCs), under which the temperature is kept around 25^{o}C.However, the temperature under outdoor conditions is variable, resulting in the variation of power output of the PV panel.Higher temperature, results in the reduction of power output.The power output not only depends upon the ambient temperature, but, also on the temperature of the cell inside the PV panel.

As the temperature of the PV panel increases, there is an exponential increase in the output current,but linear reduction of voltage.The data sheet of the PV panel, mentions the temperature coefficient percentage.It basically explains the %age change in PV panel efficiency depending upon the change in temperature.For places where frequent change in temperature takes place,a great care is to be taken to minimise the high temperature effects.This can be done by installing the PV panels in such a manner so that there is proper air flow aroud them.

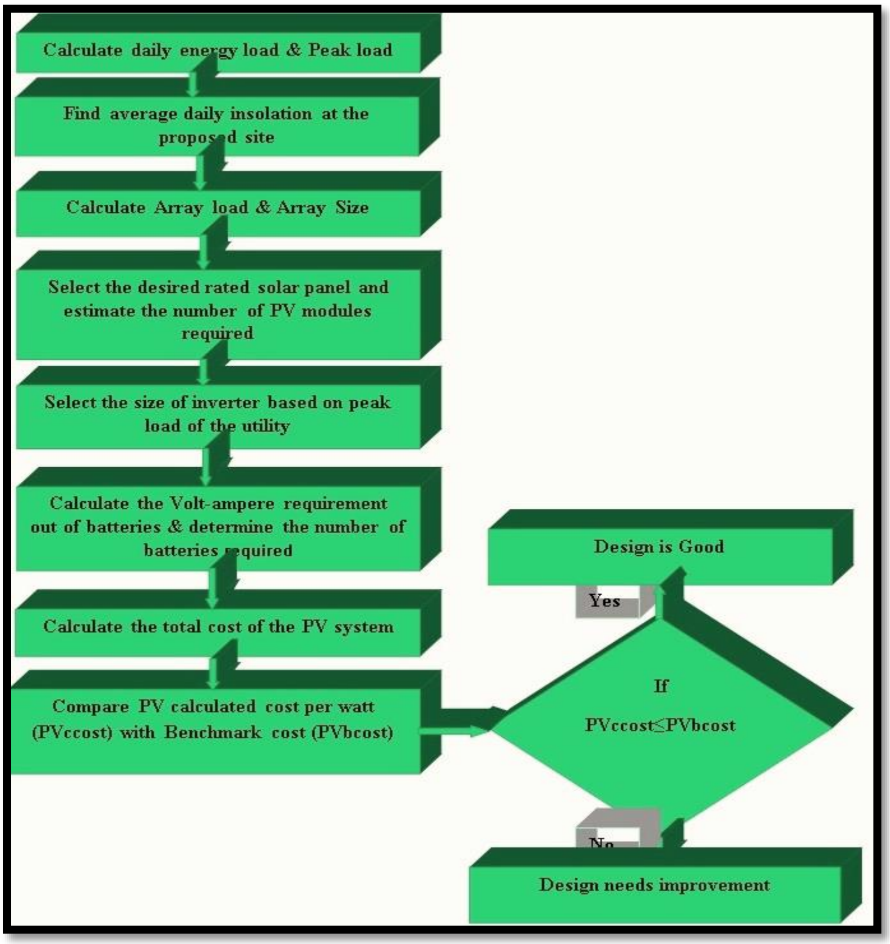

Figure.4 Proposed Flow chart for designing the PV system

3.7 Inverter Efficiency

An inverter is required to supply the AC load. The efficiency of the inverter has improved very much during the past decades. Several inverter configurations are available,touching 98% of efficiency. The size of the inverter is chosen from the solar array size and a peak load of the utility. An additional margin is also kept for future expansion. A typical value of 1.2 for DC to AC is considered reasonable.

The best/optimal selection of these components and various other factors taken together, will result in the heavy cost spend to install the PV system. There are certain procedural steps necessary to be taken, for the efficient design of the PV system. A systematic procedure is proposed as shown in the form a flow chart (Figure.4) to help the designer/utilities, etc. to correctly size the PV system, and to ascertain, whether the PV design accomplished is good/bad or needs some improvement. The decision taken, is based on the method of benchmarking, whereby the government organization such as Ministry of New & Renewable Energy (MNRE) provides the benchmark costs of the PV system per kW [23-24]. It helps the designer, to control costs and gain profits with better efficiency. It also helps in making efficient decisions like component selection, component substitution, or any other suitable alternatives.

4. Result and Discussion

4.1 Power Output and Cost of Energy

The detailed information presented in the above section is utilized, to analyse the differences in the selection of solar photovoltaic technologies, and other design procedures for getting the optimal power output. Two districts (Rajouri & Poonch) of J & K UT are considered in our research.A detailed study is carried out, regarding the choice of different PV technologies, to find the estimated power output with cost analysis. Figure.5 shows the latitude-longitude map of the regions [25]. Three types of solar modules are considered in our study.Also, these three modules are kept in fixed,single-axis tracking and double-axis tracking positions, to estimate the differneces, in the amount of solar radiations received and power outputs generated.

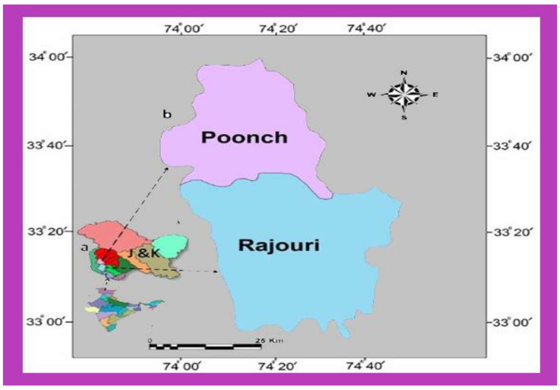

Figure.5 Latitude & Longitude diagram of Rajouri and Poonch

Table.II Rating of chosen parameters kept

S.No	Particular	Remarks
1.	Solar radiation source	NREL(TMY)
2.	System Losses	14%
3.	Efficiency of Inverter	96%
4.	Annual degradation factor	0.5%
5.	Life of the plant	25 years
6.	Tracking mechanisms	All
7.	Average Cost of per unit of electricity	Rs. 5/kWh

The detailed analysis is carried out using the above design procedures with the aid of various software such as PV watts calculator, System Advisor Model (SAM) of National renewable energy laboratory (NREL) [26]. The values of various input parameters which have been kept in the design procedure are shown in Table. II.

Five output parameters have been evaluated, using different types of solar photovoltaic technologies both for Rajouri and Poonch. For Rajouri (latitude: 33.5 & longitude:74.35), the size of the Photovoltaic system of 1 Megawatt (MW) was considered. The power output and cost of energy were evaluated, using different design procedures as shown in Table.III. Two graphs are also plotted, to find out the highest power output and the cost of energy involved.The highest power output and highest cost of energy is supplied, using monocrystalline solar panels with a double-axis tracker as shown in Figure.6 & Figure.7.simultaneously. The same analogy has been kept, for the Poonch district (latitude: 33.75 and longitude: 74.05) of J & K UT. The results obtained, are depicted in Table.III, Figure. 8 & Figure.9 accordingly.

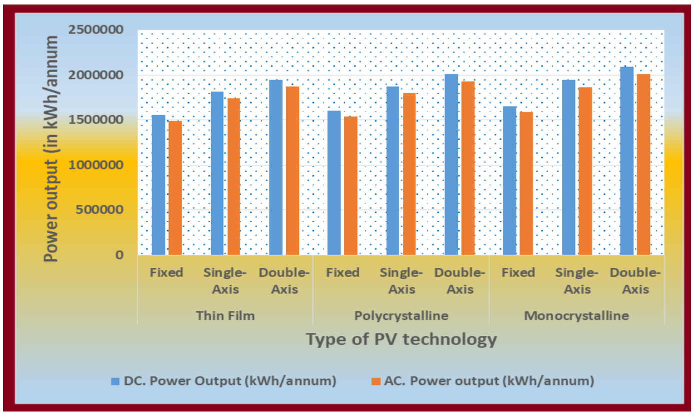

Figure.6 Power output vs. Type of photovoltaic technology for district Rajouri

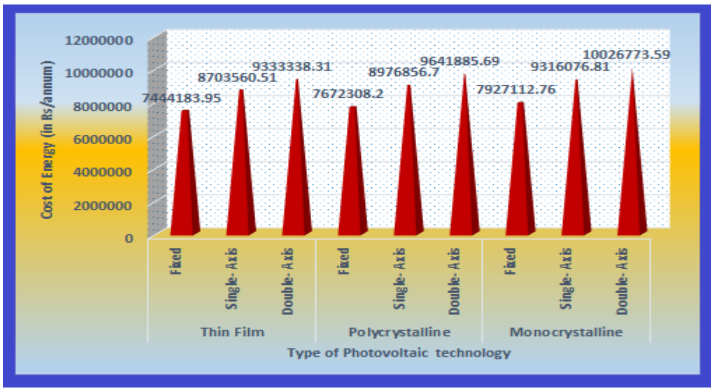

Figure.7 Cost of Energy vs. Type of Photovoltaic technology for district Rajouri

Table.III Analysis for district Rajouri (J&K)

Case I: Rajouri			***Latitude: 33.35***		***Longitude:74.35***	
Type of Panel	**Type of Tracking**	**Solar radiations ($kW/m^2/day$)**	**DC. Power Output (kWh/annum)**	**AC. Power output (kWh/annum)**	**Cost of Energy (Rs/annum)**	**Capacity Factor**
Thin Film	Fixed	5.55	1553391.172	1488836.789	7444183.95	17
	Single- Axis	6.45	1814010.453	1740712.102	8703560.51	19.9
	Double- Axis	6.99	1944632.477	1866667.664	9333338.31	21.3
Polycrystalline	Fixed	5.55	1600935.242	1534461.641	7672308.2	17.5
	Single- Axis	6.45	1871068.273	1795371.336	8976856.7	20.5
	Double- Axis	6.99	2009111.313	1928377.133	9641885.69	22.0
Monocrystalline	Fixed	5.55	1654169.961	1585422.555	7927112.76	18.1
	Single- Axis	6.45	1941980.672	1863215.359	9316076.81	21.3
	Double- Axis	6.99	2089709.828	2005354.719	10026773.59	22.9

Table.IV Analysis for district Poonch

Case II: Poonch		*Latitude: 33.75*			*Longitude:74.05*	
Type of Panel	**Type of Tracking**	**Solar radiations ($kW/m^2/day$)**	**DC. Power Output (kWh/annum)**	**AC.Power output (kWh/annum)**	**Cost of Energy (Rs/annum)**	**Capacity Factor**
Thin Film	Fixed	5.56	1576713.461	1511371.906	7556859.52	17.3
	Single- Axis	6.49	1839831.5	1765630.664	8828153.31	20.2
	Double- Axis	7.00	1972460.219	1893489.945	9467449.72	21.6
Polycrystalline	Fixed	5.56	1618956.383	1551891.461	7759457.32	17.7
	Single- Axis	6.49	1890182.195	1813845.406	9069227.03	20.7
	Double- Axis	7.00	2029757.102	1948303.688	9741518.45	22.2
Monocrystalline	Fixed	5.56	1665588.039	1596513.281	7982566.41	18.2
	Single- Axis	6.49	1952707.984	1873651.344	9368256.72	21.4
	Double- Axis	7.00	2101377.867	2016743.43	10083717.18	23

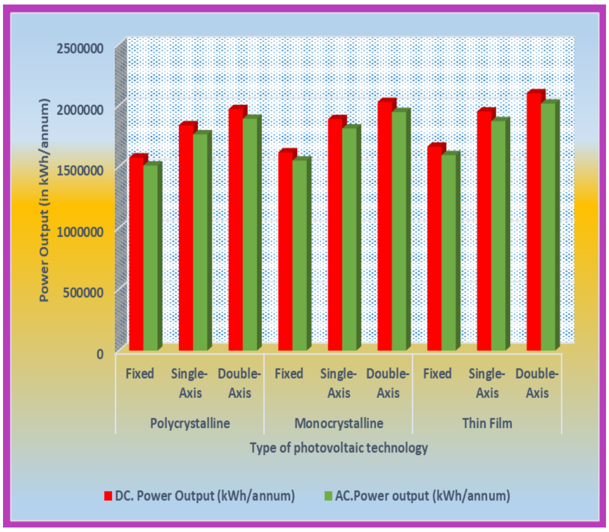

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Figure.8 Power output vs. Type of photovoltaic technology

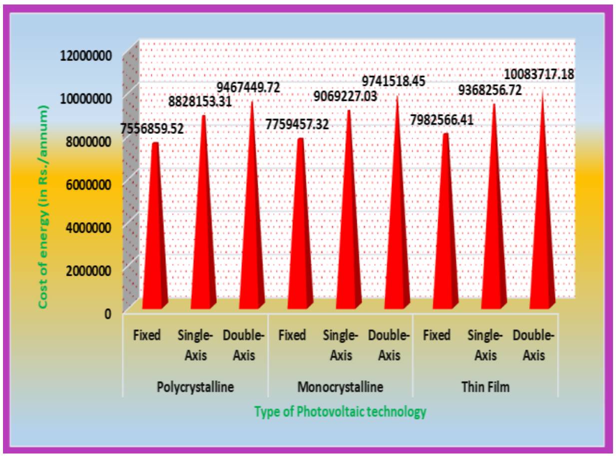

Figure.9 Cost of Energy vs. Type of Photovoltaic technology

4.2. Financial Analysis and outcome

The J&K UT can install the PV systems by their expenditure or offer the enterprises to follow the Build Own Operate (Transfer) BOO(T) Model to install the PV system,if they are hesitant, owing to the initial investment required in building the PV system. This model allows the utilities to consume the electricity generated through PV plants and an option of transfer in the future as well to the utilities after a certain gap of agreement.

To help the utilities in taking a decision, a return on investment is also carried out to find out the levelised cost of electricity (LCOE) for Rajouri & Poonch based on the results that we have obtained in the above discussion. The annual yield for both locations is found using the annual power output and size of the solar plant for different PV technologies. Using it and by selecting several other parameters (Table.V.) different return on investment parameters are computed for both the locations as shown in Table.VI.

Table.V Parameters chosen for return on investment

S.No	Parameter	Value
1	Life of Plant	25 years
2	Nominal Power	1000kWp
3	Degradation factor	0.5%/year
4	Feed in tariff	Rs. 5/kWh for 20 years
5	Current Price of Electricity & its inflation	Rs.5/kWh with inflation of 2 % /year
6	Maintenance cost	0.5%/year
7	Inflation rate	2%

For both districts, a total of nine cases are considered which are evaluated for three parameters: Amortisation time, Levelised cost of electricity, and internal rate of return. It was revealed that the levelised cost of electricity was found to vary between Rs.1.811 to Rs. 2.454 per kilowatt-hour (kWh) indicating, that it's a very good investment. The graphical representation for both locations is shown in Figure.10 and Figure.11.

Table.VI. Obtained values of various financial indices for different types of PV technologies.

Case I: Rajouri			***Latitude: 33.35***		***Longitude:74.35***		
Type of Panel	**Type of Tracking**	**Benchmark Cost**	**Annual Yield**	**Present value of net income (in Rs.)**	**Levelised cost of energy (in Rs./kWh)**	**Amortisation time (in yrs)**	**IRR (in %)**
Thin Film	Fixed	Rs.50/kWp	1488.837	119501152	2.454	6.6	13.5
	Single- Axis		1740.712	140580051	2.099	5.9	16.2
	Double- Axis		1866.668	151120999	1.957	5.5	17.5
Polycrystalline	Fixed		1534.462	123319397	2.381	6.8	14
	Single- Axis		1795.371	145154364	2.035	6.1	16.8
	Double- Axis		1928.377	156285331	1.894	5.6	18.1
Monocrystalline	Fixed		1585.423	127584205	2.304	7	14.6
	Single- Axis		1863.215	150832083	1.961	5.9	17.5
	Double- Axis		2005.355	162727419	1.822	4.1	18.9
Case II: Poonch			***Latitude: 33.75***		***Longitude:74.05***		
Type of Panel	**Type of Tracking**	**Benchmark Cost**	**Annual Yield**	**Present value of net income (in Rs.)**	**Levelised cost of energy (in Rs./kWh)**	**Amortisation time (in yrs)**	**IRR (in %)**
Thin Film	Fixed	Rs.50/kWp	1511.372	121387067	2.417	6.7	13.8
	Single- Axis		1765.631	142665432	2.069	6	16.5
	Double- Axis		1893.49	153365698	1.929	5.5	17.8
Polycrystalline	Fixed		1551.891	124778061	2.354	6.9	14.2
	Single- Axis		1813.845	146700419	2.014	5.9	17
	Double- Axis		1948.304	157952941	1.875	4.2	18.3
Monocrystalline	Fixed		1596.513	128512364	2.288	7.1	14.7
	Single- Axis		1873.651	151705448	1.950	5.7	17.6
	Double- Axis		2016.743	163680515	1.811	4	19

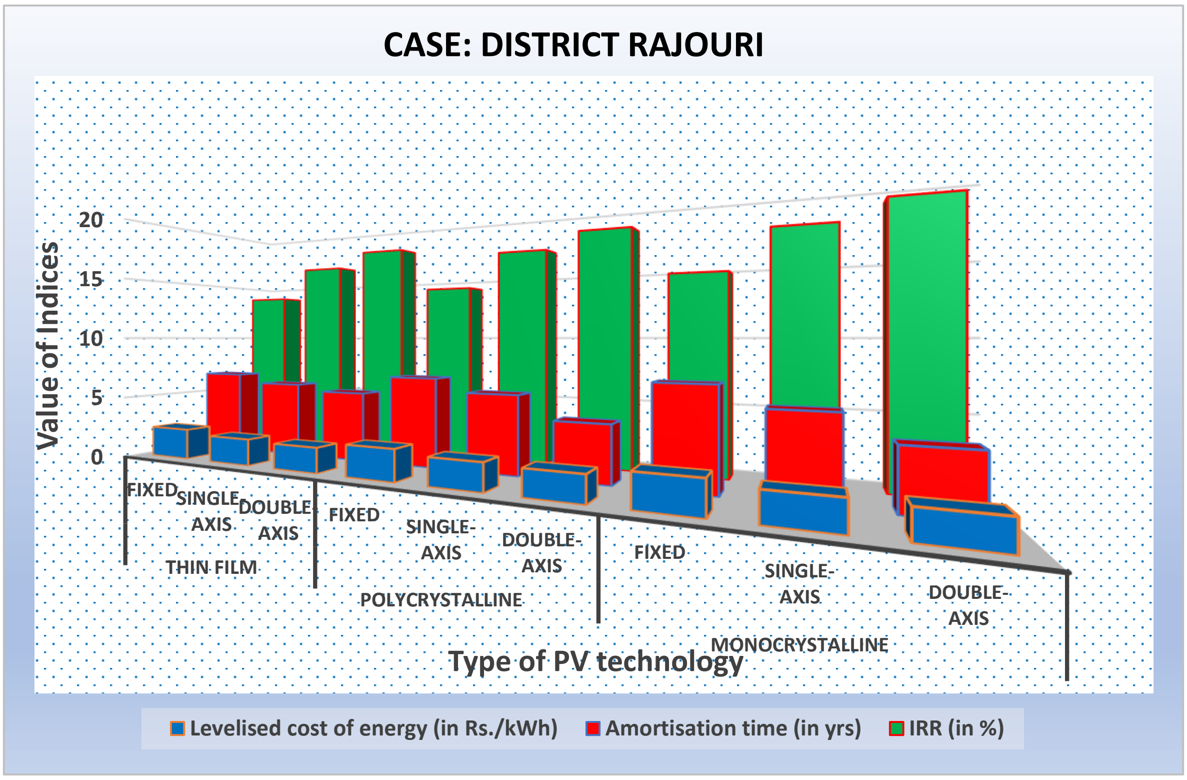

Figure.10 Graphical representation of various financial indices against different PV technologies

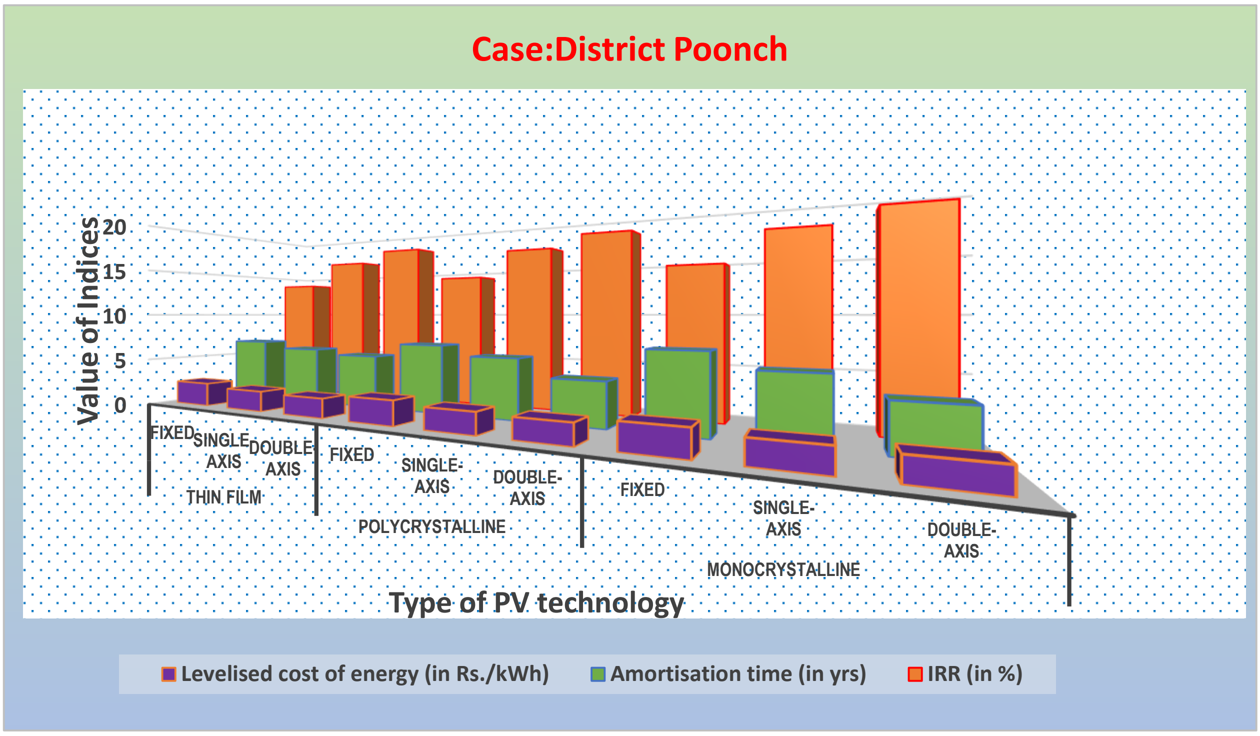

Figure.11 Graphical representation of various financial indices against different PV technologies

5. Conclusion

In this paper, different types of PV technologies were analysed for power output and the cost of energy. It was revealed that the efficiency of the PV system increases, using a tracking mechanism instead of fixed panels. Also, it was found that the power output of Monocrystalline is highest among all other types of solar panels. However solar panels with a tracking mechanism and monocrystalline are found very costly.

This study will help the power analysts/utilities in deciding to choose, which type of PV technology would be beneficial from them, depending upon the load requirement and various costs involved. It was also found, that using PV system in two places (Rajouri & Poonch) will be very beneficial, since both of these places are receiving good amount of solar radiations,due to their geographical location. This will solve the long pending demand of the people of these places, to receive better power, which is pollution-free thereby saving the environment too.The estimated levelised cost of electricity for both regions is found to vary between Rs.1.811 and Rs. 2.454 per kilowatt-hour (kWh).This indicates it's a very good investment.This much cost, is highly competitive as compared to what we are paying currently.

References

[1]. Makbul. A.M Ramli, Ayong hiendro, Khalid Sedraoui, Ssennoga Twaha.(2015) "Optimal sizing of grid-connected photovoltaic energy system in Saudi Arabia." Renewable Energy,Volume75,March,2015,pp.489-495 https://doi.org/10.1016/j.renene.2014.10.028

[2]. Mekhilef S., Saidur R,Safari A. (2011) "A review on solar energy use in industries." Renewable Sustainable Energy Reviews. 2011; 15:1777–90.

[3]. Cheng J., Choobineh FF. (2017) "A comparative study of the storage assisted wind power conversion systems." In: 2017 6th International Conference on Clean Electrical Power (ICCEP). IEEE, pp 608–613.

[4]. Arhun S., Hnatov A., Dziubenko O., Ponikarovska S. (2019) "A Device for Converting Kinetic Energy of Press Into Electric Power as a Means of Energy Saving." Journal of the Korean Society for Precision Engineering 36:105–110 . https://doi.org/10.7736/KSPE.2019.36.1.105

[5]. Hnatov A., Arhun S., Dziubenko O., Ponikarovska S. (2018) "Choice of Electric Engines Connection Circuits in Electric Machine Unit of Electric Power Generation Device." Majlesi Journal of Electrical Engineering 12:87–95

[6]. Milano J., Ong HC., Masjuki HH., Chong WT., Lam MK., Loh PK., Vellayan V. (2016) "Microalgae biofuels as an alternative to fossil fuel for power generation." Renewable and Sustainable Energy Reviews 58:180–197

[7]. Marta Victoria., Gorm B. Andresen.(2019) "Using validated reanalysis data to investigate the impact of the PV system configurations at high penetration levels in European countries." Progress in Photovoltaics: Research and Applications; DOI: 10.1002/pip.3126

[8]. https://www.renewableenergyworld.com/2020/04/28/bnef-says-solar-and-wind-are-now-cheapest-sources-of-new-energy-generation-for-majority-of-planet/#gref
[9]. Muneer T., Asif M., Munawwar S. (2005). "Sustainable production of solar electricity with particular reference to the Indian economy". Renewable and Sustainable Energy Reviews. 9 (5): 444. doi:10.1016/j.rser.2004.03.004.
[10]. "Solar". Ministry of New and Renewable Energy, Govt. of India. Archived from the original on 25 February 2014. Retrieved 21 February 2014.
[11]. "Physical Progress (Achievements)". Ministry of New & Renewable Energy.
[12]. "Annual Report 2015-2016". Ministry of New & Renewable Energy.
[13]. "Solar water pumps can help India surpass 100 GW target: Report". Retrieved 2 August 2017.
[14]. https://www.greaterkashmir.com/news/more/news/rajouri-poonch-plunge-into-darkness/?amp
[15]. Mughal S.N. (2015) "J and K- A Power Potential Source or Power Deficit State" International Journal of Research and Scientific Information, Vol.II, Issue VII July 2015,pp.14-17(ISSN:2321-2705)
[16]. https://energy.economictimes.indiatimes.com/news/power/j-k-faces-power-shortage-of-408-mw/72368887
[17]. Mughal S.N., Sood Y.R., Jarial R.K. (2018) "A review on Solar Photovoltaic technology and future trends", International Journal of Scientific Research in Computer Science Engineering and Information technology(IJSRCSEIT-2018), Vol 4, Issue1, ISSN: 2456-3307
[18]. Ministry of New & Renewable Energy, Memorandum "Operational guidelines for implementation of Phase-II of Grid connected Rooftop solar programme for achieving cumulative capacity of 40,000 MW from Rooftop Solar(RTS) Projects by the year 2022.dated-20,Aug,2019.
[19]. Mughal S.N., Sood Y.R., Jarial R.K. (2019) Design and Techno-Financial Analysis of Solar Photovoltaic Plant for School of Engineering and Technology at BGSB University, Rajouri (J&K).Applications of Computing, Automation, and Wireless Systems in Electrical Engineering. Lecture Notes in Electrical Engineering, Vol 553. Springer, Singapore. pp. 231-243
[20]. Patļins A., Arhun S., Hnatov A., Dziubenko O., Ponikarovska S. (2018) "Determination of the Best Load Parameters for Productive Operation of PV Panels of Series FS-100M and FS-110P for Sustainable Energy Efficient Road Pavement." In: 2018 IEEE 59th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON 2018): Conference Proceedings. Riga, Latvia, pp 1–6
[21]. Jiang F., Wong A. (2005) "Study on the performance of different types of PV modules in Singapore." In: 2005 International Power Engineering Conference. IEEE, pp 1–109
[22]. Hasan N. Muslim. (2018) "Solar Tilt Angle Optimization of PV Systems for Different Case Studies" EAI Endorsed Transactions on Energy Web. Volume 6 , Issue 23 , e7, doi: 10.4108/eai.13-7-2018.157038
[23]. RICS Practice Standards, UK (2011). "Cost analysis and benchmarking" (PDF). RICS QS & Construction Standards. 1.
[24]. "Benchmark costs for Grid Connected Rooftop Solar Power Plants for the Year 2019-20."Ministry of New & Renewable Energy. https://mnre.gov.in/solar/standard-specs-cost
[25]. Dar Gh. Hassan.,Malik Akhtar H.,Khuroo Anzar A.(2014) "A Contribution to the Flora of Rajouri and Poonch Districts in the Pir Panjal Himalaya (Jammu & Kashmir), India" Check List 10(2): 317–328, 2014, Journal of species lists and distribution.
[26]. https://pvwatts.nrel.gov/
[27]. https://el-engineering.com