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A Review on Capacity Utilization Factor and Cost Economics of Net Metering for Solar Photovoltaic Power Plants in Maharashtra and India

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***Abstract*—Conventional Energy sources cannot match the current scenario of our India because of the increment in load, so it requires an external source to fulfill this energy, hence solar energy can be an alternative non-conventional energy source. In some years the use of solar PV panels have increased steadily due to increased energy demand globally. Thus it has become very important to make the solar plant more competitive in economic terms and one way it can be done is by improving the performance of the plant. The performance output of the solar PV power plant depends mainly on performance parameters. i.e., Performance Ratio (PR), Capacity Utilization Factor (CUF). The paper overviews performance ratio, capacity utilization factor, different factors affecting CUF of solar power plant. It also analyzed the annual scenario as well as average monthly scenario of solar PV with respect to CUF in India.**

Net metering of solar PV plant is one of the new concepts used for measurement of solar energy imported and exported from the solar PV system. Net-meters are bidirectional meters which record consumer import and export energy between grid and solar plant, hence the calculation of net energy is possible by using them. This paper also reveals cost economics for installation of net metering systems in the state of Maharashtra and of solar PV power plant in India

Keywords— Performance Ratio (PR), Factors affecting Performance Ratio, Capacity Utilization Factor (CUF), Disadvantages of CUF, Net meter ,Cost Economics of Net metering

I. INTRODUCTION

India has tremendous energy needs and increasing difficulty in meeting those needs through traditional means of power generation. In 2012 world's largest blackout occurs in India stretching from New Delhi to Kolkata occurred. This blackout which was due to failure of the northern power grid, affected nearly 300 million people. The basic technology, design and engineering of PV power plants, is now well developed and proven. Countries like Germany, Spain and Italy have demonstrated the feasibility of Solar PV power generation in spite of less solar irradiation levels at most places in countries like India. [3]

In the country like India solar growth is increasing very rapidly. So it is necessary to increase the performance rate of factor. Performance factor of the solar power plant system is different for different power plants. One cannot compare one power plant CUF with the other. The CUF of the solar PV power plant mainly depends on the location and the losses in the solar plant, Hence it cannot be compare with each other. This paper gives the scenario of monthly CUF solar PV power plant for states in India. .

The success of PV power generation projects in the West has prompted investors to move rapidly towards development of similar projects in India with the support of policy framework announced by the government of India. One must not, however, lose sight of the fact that there are challenges which are to be overcome to ensure that the plant is built within the committed schedule, operates optimally and will remain feasible over its complete life period (25 years). These challenges can be classified into commercial (relating to permissions and clearances), financial (relating to equity and debt financing) and technological (related to design optimization, selection of components etc.). While the solar radiation is available in plenty amount almost all over India all throughout the year. There are certain other climatic (e.g., high temperatures), environmental (dust and grime) and infrastructural conditions (unstable grid etc.), that could make the yield of the PV plant lesser than what would be expected. It is necessary to optimize the design of solar PV power plant after due consideration of all these factors. The use of appropriate performance parameters facilitates the comparison of grid-connected photovoltaic (PV) systems that may differ with respect to design, technology, or geographic location. Performance parameters that define the overall system performance with respect to the energy production, solar resource, and overall effect of system losses are the following:

Solar PV system DC and AC side energy yield, PR, capacity utilization factor. [3]

II. Literature Review

The purpose of this literature review is to outline the performance of the plant and CUF of the solar PV system in India.

Tahira et.al. (2016) studied levelized Electricity Cost (LEC) of five Solar Photovoltaic power (SPV) plants of different capacities 1MW, 5MW, 10MW, 25MW and 151MW. The calculation has been performed from the power generated data of the year 2014. The effect of different parameters like interest rate, inflation rate, deprecation time (plant life) and cumulative utilization factor (CUF), on LEC have been analyzed. A comparative study of the plants is done by varying above parameters.[1]

M.Shravanath et.al (2016) analized 20 KWp Solar Photovoltaic (SPV) system was set up on the library roof-top in Indian Institute of Science, Bangalore, India.They worked on the evaluation of the performance of SPV systems using the popular grading systems, namely Capacity Utilization Factor (CUF) and Performance Ratio (PR).[2]

Ashish et.al (2015) studied various performance parameters. i.e., Performance Ratio (PR), Cumulative Utilization Factor (CUF), factors contributing to the performance of solar power plants. i.e., radiation, temperature, and other climate conditions, design parameters, PR which should be taken care during initial state at the time of engineering of plant to get better performance and generation results of solar power plant in 25 years of time span.[3]

B. Shiva Kumar et.al (2015) studied the solar PV plant design and its annual performance. The various types of power losses (temperature, internal network, power electronics, grid connected etc.) and performance ratio are also calculated. The performance results of the plant are also compared with the simulation values obtained from PV syst and PV-GIS software.[4]

Mevin et.al (2014) studied the potential and the cost-effectiveness of a solar photovoltaic power plant for meeting the energy demand of garment zone at Jaipur (India) is analyzed. Also, the energy demand of garment zone for year 2011has been estimated (2.21 MW) and the design of the solar PV power plant of 2.5MW capacity has been explained.[5]

M. Hosenuzzamana, et.al analyzed the impact of different factors that influence on PV power generation and added the suggestions for the system so that maximum performance and efficiency can be achieved by the solar photovoltaic system.[6]

Report of Government of India, Ministry of New and Renewable Energy 2015, calculated the scenario of the solar PV Ground mounted system with the thin and crystalline technology. The average CUF of States and months in the year 2014.[7]

Draft MERC (Net Metering for Rooftop Solar Systems) Regulations, 2015 gives the detailed idea about the measuring parameter of net-metering. It also gives the Rules and regulation for consumers for net metering of solar rooftop photovoltaic system.[8]

III. Performance Parameter

A. *Performance Ratio*

The plant performance ratio is one of the mostly used performance indicator and commonly known as plant quality factor which can be effectively used to compare plants installed at different locations. The PR is defined as the ratio of actual and theoretical or plant output.

Performance ratio is defined as the quality factor which is independent of the location. It is given by the formula:

$$PR\ (\%) = \frac{\text{Actual Plant Output (kwh)}}{\text{Calculated plant output (kwh)}} * 100$$

Where,
Calculated Plant output = GHI in (kWh/m^2)* Rated module efficiency*Total PV area (in m^2)[2]

B. *Factor Affecting the Performance Ratio*

The following factors can have influence to the PR value:

a) Environmental factors

- Temperature of the PV module;
- Solar irradiation and power dissipation;
- The measuring gage is in the shade or soiled;
- PV module in the shade or soiled.

b) Technical factors

- Recording period;
- Conduction losses;
- Efficiency factor of the PV modules;
- Efficiency factor of the inverter;
- Differences in solar cell technologies of the measuring gage and of the PV modules.

The performance of solar power plants is best defined by the CUF, which is the ratio of the actual electricity output from the plant, to the maximum possible output during the year. The estimated output from the solar power plant depends on the design parameters and can be calculated, using standard software. But since there are several variables

which contribute to the final output from a plant, the CUF varies over a wide range. [4]

IV. Capacitor Utilization Factor

Capacity Utilization Factor (CUF) term use in India for the performance of the any power plant. CUF can be calculated by

$$CUF(\%) = \frac{\text{Annual Energy Generated}}{\text{Plant Capacity} * 24 * 365} * 100$$

For Example:
Annual Generated Energy= 8000000Kwh
Plant Capacity = 3.5MW
Operating Days = 300 days
Actual operating hours = 300*24 =7200hrs
CUF (%) = (80000000)*100/(3.5*1000*7200)
= 31.27 %

The capacity factor of a fixed tilt PV plant in India is typically in the region of 18%-19%. This means that a 1 MW plant will generate an equivalent energy of a continuously operating 0.19 MW plant. Plants in India operating within a reliable grid network are expected to have a similar capacity factor. The CUF does not take into account any environmental factor like variation on irradiance from one year to another nor does it take into account the de-rating or degradation of the panels These could be on account of poor selection/quality of panels, derating of modules at higher temperatures, other design parameters like ohmic loss, atmospheric factors such as prolonged cloud cover and mist. Generally most widely used type of solar are solar roof top system and Ground mounted solar system. [14]

A. CUF of Solar Rooftop PV System

As from the reference of the solar rooftop system connected on the roof of the IISC Bangalore. The CUF of the system is equal to 16.5%. CUF of the SPV system is 16.5% and is well within the range of average CUF of all the roof top SPV systems in India, which is 16–17%.[17] CUF is dependent on the location. For example, the average CUF of SPV system located in Arizona, USA is 20%, where as in Massachusetts, USA, it is up to 15%. The CUF of the system is mainly dependent on the GHI at the location of the SPV system and the cell efficiency of the SPV modules. [15]

B. CUF of Solar Ground Mounted System:

Solar Ground mounted system is the system having capacity more than 10KW. Solar Ground Mounted System CUF depends on the location and the irradiation. As the horizontal irradiation is more CUF becomes more.

a) State-wise Scenario of CUF of Different Solar PV Technologies

According to Ministry of Renewable Energy India the recent survey of CUF of different states with respect to type of technology is calculated which is shown below:

Table .I. State Wise Description of Overall CUF [4]

Sr. No	State	Average CUF (%) (period Jan 2014- Dec 2014)	
		Crystalline Technology	*Thin Film Technology*
1	Andhra Pradesh	17.81	19.78
2	C.G.	18.99	--
3	Haryana	13.99	14.63
4	Jharkhand	15.22	15.64
5	Karnataka	17.59	--
6	M.P.	18.36	15.67
7	Maharashtra	17.73	--
8	Odisha	13.77	17.94
9	Punjab	16.67	16.01
10	Rajasthan	20.85	17.78
11	Tamilnadu	16.87	17.01
12	U.P.	17.49	12.27
13	Uttarakhand	15.67	15.61
	Average	17.00	16.23

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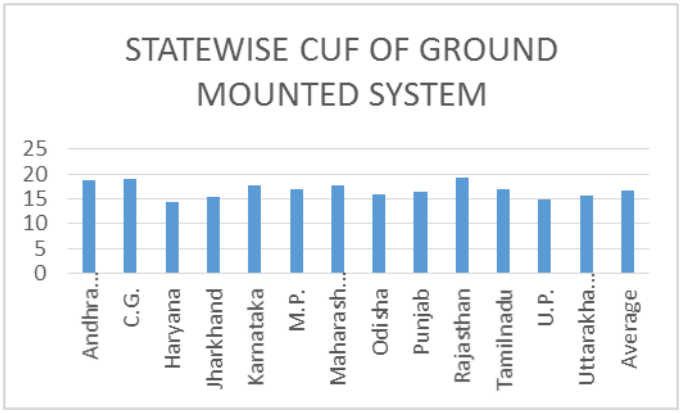

Figure .1 Graphical Representation of the State wise solar ground mounted PV system

In the above table two types of solar cells were used i.e crystalline and\Thin film technology .In Madhya Pradesh, Rajasthan and Uttar Pradesh, CUF of Crystalline Technology is more than thin film but in Andhra Pradesh, Odisha CUF of thin film is more than Crystalline Technology. Overall CUF of Crystalline Technology is more than thin film technology. [7]

b) Monthly average of different states of Solar PV Ground mounted PV systems

According to Ministry of Renewable Energy India the recent survey of Month-wise average of different states has been calculated and shown in the form of table and Graph below

Table 2 Monthly Description of CUF [4]

Sr.no	Month (Jan 2014- Dec2014)	CUF (%)
1	January	17.95
2	February	20.67
3	March	22.54
4	April	23.67
5	May	22.63
6	June	22.68
7	July	19.90
8	August	20.48
9	September	21.50
10	October	20.71
11	November	19.90
12	December	18.49
	Average	20.92

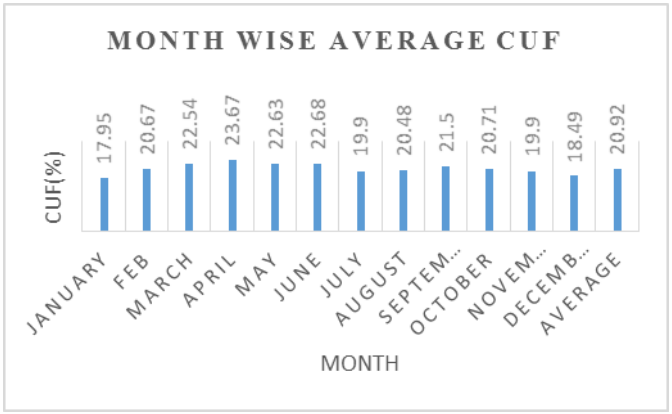

Figure2: Monthly Average CUF of Solar Ground mounted PV System

c) Disadvantages of CUF in Solar PV Power Plant

The following are the disadvantages of CUF:

- The CUF measure does not take into the account the details of the particular location – for instance, the irradiation for the location.
- It doesn't also consider degradation of the panels and grid availability.
- CUF does not truly represent the potential of the solar-PV technology itself because it does not factor in the following:
- Solar PV systems do not work at night because there is no sunshine
- Solar irradiation changes during the seasons.
- Plant output depends on temperature of the location too

Considering the above, CUF technically doesn't paint a highly accurate picture of the plant's performance and it cannot be used as a measure of control especially for intermittent sources of energy like solar/wind [11]

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C. Discussion

From overall Indian scenario it is observed Rajasthan have more CUF compared to other states is 19.37. The Lower CUF state is Haryana equals to 14.31.The reason for larger CUF in the state of Rajasthan because of more daily solar radiations and cooling days required. As cooling days more means radiation level is more and hence solar energy generation is more. Haryana having less number of cooling days and daily solar radiations hence its CUF is lesser compared to other states.

It does not mean that the overall CUF of all the region in the particular state having same scenario. For example the daily solar radiations of Kolhapur and Mumbai are different and hence the CUF is also different for these cities. Hence it can be concluded from this scenario it is proved that the CUF is totally depend on the particular location. CUF of the system can be improved by increasing solar radiation and sun hours operation in the solar PV system. It can be done by solar tracking or by using concentrated solar PV system

V. Net Metering Of Solar PV System

Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid. For example, if a residential customer has a PV system on the home's rooftop, it may generate more electricity than the home uses during daylight hours. If the home is net metered, the electricity meter will run backwards to provide a credit against what electricity is consumed at night or other periods where the home's electricity use exceeds the system's output. Customers are only billed for their "net" energy use. On average, only 20-40% of a solar energy system's output ever goes into the grid. Exported solar electricity serves nearby customers loads. [12]

A. Cost Economics of Net Metering in Solar PV System in Maharashtra

According to the MERC (Maharashtra Electricity Regulation Commission) the following are the regulations are given for placement of the net meter. The accounting of electricity exported and imported by the Eligible Consumer shall become effective from the date of connectivity of Rooftop Solar System with the distribution network under these Regulations.

For each billing period, the Distribution Licensee shall show separately;

a) The quantum of units of electricity exported by Eligible Consumer

b) The quantum of units of electricity imported by Eligible Consumer

c) The Net units of electricity billed for payment to the Eligible Consumer and

d) The Net units of electricity carried over to the next billing period.

Provided that in the event, the units of the electricity exported exceeds the units of electricity imported during the billing period, such excess units of electricity exported shall be carried forward to the next billing period as credited units of electricity. Provided that in the event, the units of electricity imported by the Eligible Consumer during any billing period exceeds the units of electricity exported by the Eligible Consumer's Rooftop Solar system, the Distribution Licensee shall raise invoice for the Net electricity consumption after taking into account credited units of electricity. [8]

Provided that at the end of each financial year, unadjusted net credited units of electricity limited to 10% of total units generated during the year by the Eligible Consumer, shall be purchased by the Distribution Licensee at the Commission's approved Average cost of Power Purchase of the Distribution Licensee for respective year. Provided that any unadjusted net credited units of electricity above 10% of total units generated during the year by the Eligible Consumer shall be treated as unwanted /inadvertent injunction and no payment for the same shall be made by the Distribution Licensee. Provided that at the beginning of each settlement period, cumulative carried over injected electricity will be reset to zero. [8]

B. Cost of Net Meter of Solar PV Systems in Maharashtra:-

Table3. Cost of Net Meter of Solar PV Systems In Maharashtra [20]

Sr No	Class of Accuracy	Cost (Rs)
1.	CLASS 0.5	5000/-
2.	CLASS 0.2	1,75,000/-
3.	CLASS 0.02	1 Crore/-

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C. Discussion:-

Net meter is a bidirectional device which can store the net energy between Grid and solar PV system. From above it was understood that if more number of units are generated by consumer then it can be stored, at the end of month, similarly at the end of the year annually saved units 10% can be credited to the consumer.

CONCLUSION

The results shows that CUF of the solar system is not comparable. The CUF only depends on the location and the solar radiations. The CUF cannot be relate with the other plant CUF because every plant having its different parameters. It can be depend on parameters of plant only. CUF and PR are two different metric factors. It cannot be compared. Rajasthan having higher CUF than the other states and also in the month of April average CUF is high.

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