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POWER GENXT

Volume 9

Published
on the day of
9th National Seminar
24th January, 2021

SOLAR ENERGY: TECHNO COMMERCIAL VIABILITY AS FUTURE GREEN ENERGY IN INDIA

NEED
National Energy Excellence Drive

Organised by:

ENGINEERS' WELFARE FORUM

THE WEST BENGAL POWER DEVELOPMENT CORPORATION LIMITED

Recognised by WBPDCL
Vide Letter No. : PDCL/CORP./HR/305/1495, Dated 3.3.2012
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CONTENTS

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THE WEST BENGAL POWER DEVELOPMENT CORPORATION LIMITED
Regn. No. : S / 1L / 74829

Bidyut Unnayan Bhaban (3rd floor) 3/C,
Block-LA, Sector-III, Bidhannagar,
Kolkata-700098,
website: www.wbpdclewf.org.in

MANOJIT KUMAR BASAK
M. Tech., Gold Medalist(CU), MIE, C. Eng.
Chief Advisor & Founder Ex. President

Residence :
5/3, Prafulla Chaki Road, Kolkata-700036
Mob: 9432987079/7980004291
e-Mail: manojit1952@gmail.com

Date: 22-01-2021

MESSAGE

I am very much glad and proud that "Engineers' Welfare Forum, WBPDCL has organized their annual program NEED - National Energy Excellence Drive, 9th National Seminar in Virtual Mode on "SOLAR ENERGY: TECHNO COMMERCIAL VIABILITY AS FUTURE GREEN ENERGY IN INDIA" on 24th January, 2021 at WBPDCL Auditorium "Bidyut Unnayan Bhaban", Salt Lake City, Kolkata-700106.

Now-a-days the proposed topic is the burning issue to the nation to enhance the electricity generation capacity by using natural source without the use of fossil fuel which is going to end from our nature. This will reduce the pollution content in our atmosphere. This seminar will help to create a platform for knowledge shearing among the well experienced engineers of different power sectors.

On the same auspicious day, Engineers' Welfare Forum, WBPDCL will publish their technical journal "POWER GENXT, Vol-IX" which will also be the knowledge shearing platform for the Engineers.

I extend my best wishes for grand success of the seminar.

(MANOJIT KUMAR BASAK)

Techno-Economic Performance Assessment of Different Types of Solar PV Systems

Dr. Prabodh Bajpai
Associate Professor,
Department of Electrical Engineering & School of Energy Science and Engineering,
I.I.T. Kharagpur-721302, West Bengal, India

Abstract:

This study presents a year-long comprehensive performance analysis of four distinct solar photovoltaic (SPV) system configurations with central inverter, micro inverter, fixed axis structure and dual axis sun tracker (DAST) structure installed at the Indian Institute of Technology Kharagpur, West Bengal, India. Technical and economic performance indices are used to analyse the impact of inverter technology and DAST structure using field data of one year. Specifically, technical parameters specified by IEC 61724 are used to compare simulated results with field data from June 2017 to May 2018. The difference between the simulated and measured values of all the configurations is mostly attributed to the variation in solar irradiance and module temperature data. Comparison of measured values through energy yield, capacity factor and performance ratio (PR) indices has confirmed the superiority of dual axis micro inverter system configuration. Additionally, the impact of seasonal variation on PR values for all four system configurations is also analysed. Economic performance for 25 years of project life using net present value and levelised cost of energy indices concludes dual axis central inverter system configuration as the most economical.

I. Introduction:

The increase in global electricity demand with need for clean and safe energy solutions has promoted renewable energy source (RES) integration in the power grid. Solar photovoltaic (SPV) system is one of the promising technology among these sources. According to the GTM Research [1], global SPV market will add over 100 GW of capacity for the first time in 2018, representing 6% annual growth. By 2050, solar power is anticipated to become the world's largest source of electricity [2]. This would require SPV capacity to grow to 4600 GW of which more than half is forecast to be deployed in China and India. Government of India (GoI) report on Energy Statistic 2017 [3] has estimated the Indian electricity consumption of 1001.191 TWh for the financial year 2015–2016. GoI is obliged to minimise the greenhouse gas emission under the United Nations 21st Conference of Parties (COP21), held in 2015 at Paris [4]. Institute of Energy Economic and Financial cabling for both FACI and DACI systems are made till the inverter through array junction box. The fixed axis micro inverter (FAMI) system, as shown in Fig. 1c, constitutes FA structure similar to FACI system with each PV module connected individually to a MI of 270 VA directly underneath the module for conversion of DC power output of PV into AC power. Fig. 1d shows a dual axis micro inverter (DAMI) system with DA automatic tracker that operates on time-based sun tracking control logic in both east-west (azimuth) and north-south (elevation) directions.

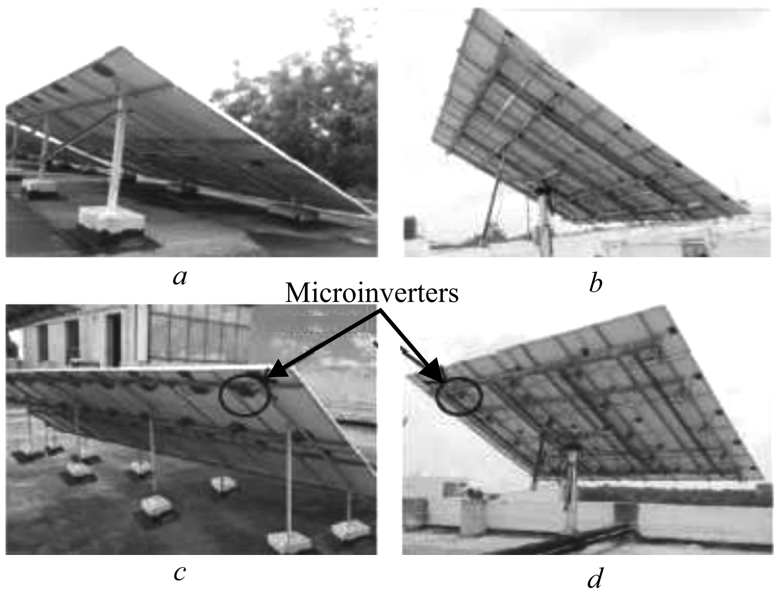

Fig. 1 Solar PV installation on
(a) FA structure connected to CI (FACI system), (b) DAST structure connected to CI (DACI system), (c) FA structure connected to MI (FAMI system), (d) DAST structure connected to MI (DAMI system)

III. Comprehensive Performance Assessment

The overall system performance for all four PV configurations is evaluated using performance indices [12] defined by IEC standard 61724 [13].

Technical performance is evaluated using annual energy yield (Eac), capacity factor (CF) and PR. The electrical energy yield from the SPV system on daily, monthly and yearly basis is an important performance index. CF is defined as the ratio of annual Eac to the maximum rated electrical energy output for a year [14]. PR is defined as ratio of the actual energy yield Eac to the calculated nominal yield. The nominal yield is calculated as the product of irradiance on panel, effective area of modules and PV module efficiency [12]. The ambient factors, SPV module dirt, mismatch loss, inverter and cable loss affect Eac and PR values significantly.

Economic performance is assessed through net present value (NPV) and LCOE. NPV [15] is a better economic index which takes into account the time value of money.

Analysis [5] has estimated an increment in electricity generation by 207.01% from RESs compared to 28.9% from coal during 2017 to 2022 in India.

India, as tropical country situated between 8°4′ and 37°6′ latitudes enjoys the privilege of receiving 1600–2000 kWh/m^2 of solar insolation and witnesses 250–300 sunny days on annual basis [6]. The Ministry of New and Renewable Energy under GoI has set the world's largest renewable energy expansion program [7] with the target of integrating 175 GW of RES including a major contribution of 100 GW from SPV generation by 2022.

The major attributes in the comprehensive performance of SPV system are photovoltaic (PV) technology, inverter technology and sun tracking technology. All these are changing and improving with an impressive rate. However, monitoring and systematic analysis of SPV system performance is also an important attribute to develop good practices [8]. A comparison of the 5 kW rooftop SPV system [9] located in Morocco with the available site data from other locations reveals the significance of the systematic monitoring of PV plants to identify the potential sites for SPV generation. Hence, it is imperative to evaluate the holistic performance of SPV system for its effective development on global basis.

The International Energy Agency (IEA), under Photovoltaic Power Systems (PVPS) programme Task 2 [10] has emphasised on inadequate long-term detailed monitoring and reliability performance experience of PV systems and hence, developed an international database called PV Performance Database, containing information on technical performance, reliability and costs of PV systems. IEA PVPS Task 13 [11] focuses on compiling statistical data from different locations and compare the long-term system performance for techno-economic analysis. Moreover, performance monitoring provides the relevant information that helps in evaluating the system periodically for operation and maintenance (O&M). This has motivated the authors to evaluate the comprehensive techno-economic performance through simulation and measured values over a period of one year for four distinct rooftop mounted and grid-connected SPV system configurations installed at Indian Institute of Technology (IIT) Kharagpur, West Bengal, India. In this work, central inverter (CI) and micro inverter (MI) connected to poly-crystalline type SPV modules with fixed axis (FA) and dual axis sun tracker (DAST) systems each of 5 kWp are considered for techno-economic performance analysis.

II. Field System Description

Multiple SPV systems with polycrystalline type PV technology, different inverter technology and ST systems are installed at the rooftop of an academic building of IIT Kharagpur located at 22°18′ N and 87°18′ E in India. In this study, only polycrystalline type PV systems connected to grid through CI and MI with FA structure and DAST structure are considered. Each system is of 5 kWp capacity and SPV system with FA shown in Figs. 1a and c are connected to grid through CI and MI, respectively. Similarly, SPV system with DA structure shown in Figs. 1b and d are connected to grid through CI and MI, respectively.

Each SPV system, considered in this study, consists of 20 polycrystalline type 250 Wp modules. For fixed axis central inverter (FACI) system, all 20 modules are connected in a single string to a 5 kVA three phase CI on a fixed angle of 22° inclined and south facing FA metallic module mounting structure (MMS) as shown in Fig. 1a. Similar type of PV modules and CI are used in dual axis central inverter (DACI) system with an automatic DAST system for azimuth and elevation angle control as shown in Fig. 1b. DC

LCOE is a common index for comparing different electrical energy systems. It is defined as the NPV of all costs (initial cost, O&M cost) divided by the total electrical energy output from the system over the lifetime of the project [16].

A. *Technical Performance Evaluation:*

The technical performance of all four SPV system configurations is analysed using simulated and experimentally measured data from June-2017 to May-2018. The annual average solar insolation data measured for FA systems is 1635 kWh/m^2 with an average peak sunshine hours of 6.5 h/day. Similarly, for DAST system the data is 2011 kWh/m^2 and 8.9 h/day. These data are utilised for computing and simulating the technical performance of the system using different indices.

a. ***Annual energy yield, CF and PR***: A comparison among simulated and experimental results for a year is tabulated in Table 1 for all four SPV system configurations. DAMI system has shown the best technical performance with the highest energy yield, CF and PR values (shown in bold numerals) because it has DAST structure to capture maximum irradiance with longer peak sunshine hours and low cable losses. Simulation models have considered daily average solar insolation and monthly average ambient temperature values that leads to maximum variation of 5.1, 1.9 and 0.77% in Eac, CF and PR, respectively, compared to experimental results. Real instantaneous values from GUI are used for performance indices calculation of experimental setup.

Table 1. Experimental versus simulation results of all four system configurations for a year from June 2017 to May 2018

Performance indices	FACI system		FAMI system		DACI system		DAMI system	
	Experimental	Simulation	Experimental	Simulation	Experimental	Simulation	Experimental	Simulation
E_{ac}, kWh	6606.16	6738.28	6971.67	7111.11	9149.53	9615.65	**9318.95**	**9793.79**
CF, %	26.20	25.90	26.23	25.90	32.91	32.33	**32.94**	**32.33**
PR, %	80.01	80.63	84.43	84.97	90.07	90.41	**91.74**	**91.97**

b. ***Monthly energy yield variation***: Higher energy yields are obtained during the months of March, April and May when solar monthly irradiance is also high (around 160–180 kW/m^2 for FA system and 200–220 kW/m^2 for DAST system). Though, the mean temperature during these months in Kharagpur is also high (about 35°C), the effect of increased irradiance outcasts the loss due to internal heating of SPV modules. Solar irradiance as well as energy yield in the month of July are minimum for all configurations owing to the predominance of rainy and cloudy days. Direct conversion of DC power into AC power from each module in a DAMI system enables this system to yield 12.65–29.38% higher energy compared to other systems as shown in Fig. 2a. This is due to efficient sun tracking and minimum cable losses. Fig. 2a is showing the comparison among monthly measured energy yield from all four SPV system configurations on same bar chart along with monthly irradiance variation for both FA and DAST structures. Increase in irradiance in DAST compared to FA structure varies from 20% (minimum in July) to 26% (maximum in April) on monthly basis with an annual average of 23%.

c. ***Monthly PR variation:*** For each month, PR is computed for all four SPV system configurations using the energy yield from the system and irradiance falling on the panels considering average module efficiency of 15.37% and surface area of 32 m^2 for each 5 kW system. The values obtained for monthly PR are plotted in Fig. 2b from June-2017 to May-2018. The annual average PR is also plotted on the same figure to observe the deviation of monthly PR with respect to annual average PR. The monthly PR values for DA systems are in the range of 87–95%, however, FA system has lowest monthly PR of 77% in January 2018.

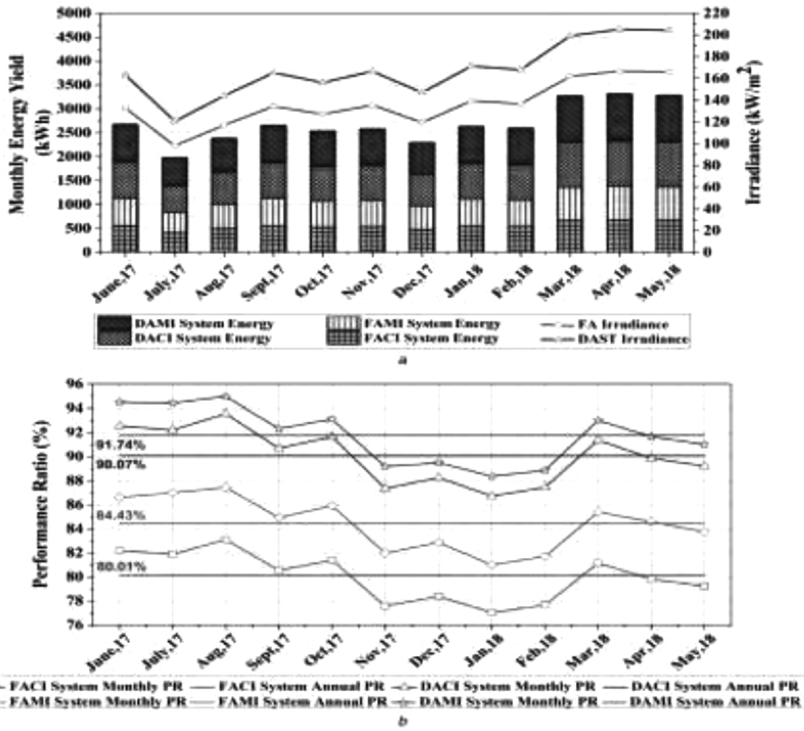

Fig. 2. Technical performance evaluation of the SPV system configurations *(a)* Measured monthly energy yield and solar irradiance from different SPV system configurations, *(b)* Measured monthly PR plot for all SPV system configurations

Kharagpur has tropical climate with average rainfall of more than 1400 mm. Monthly PR during monsoon season (June to October) is highest and winter season (November to February) has lowest PR. This is because intermittent rainfall during monsoon keeps the modules surface at low temperature and clean as well. However during winter season, high air mass and fog leads to low clearness index and therefore low PR. One of the major factors influencing the PR of any SPV system is module efficiency that depends on module temperature. After maximum rainfall in July the maximum value of PR is recorded in the month of August for all system configurations due to low module temperature and high clearness index.

B. *Economic Evaluation:*

For economic evaluation and comparison of all four SPV system configurations, the Total initial cost $C_{initial}$ of 5 kWp capacity is calculated as sum of cost of PV modules, DAST or FA structure, inverter, installation and BOS. This price is based on actual cost incurred during purchase and installation of this field system in 2016 from different local vendors in India.

Maintenance of SPV modules, DAST or FA structure and inverter insurance premium are included in annual maintenance charges (AMC). For each 5 kWp FA and DAST system, AMC of 5000 and 8000 INR/year are considered, respectively. It includes inverter replacement cost, accumulated every year in the form of fixed insurance premium of 3000 INR/year, since the life expectancy of inverters is considered as 15 years with 10% of part replacement every 10 years. Regular cleaning and periodical maintenance of the each system configuration accounts for 2000 INR/year. This leads to total 5000 INR/year AMC for FA system and DAST system. The DAST system has additional O&M cost of 3000 INR/year that includes the DAST motor AMC of 2000 INR/year and automatic DAST controller AMC of 1000 INR/year.

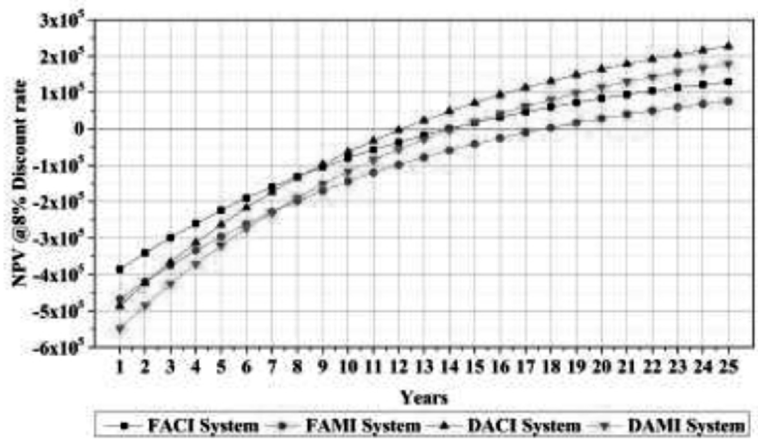

Fig. 3. NPV for different PV systems at 8% discount rate

a. ***Net present value*:** NPV values for all four SPV system configurations are calculated for a duration of 25 years at a discount rate of 8% and plotted in Fig. 3. It is observed from the plot that NPV values are negative for all SPV systems till first 12 years of installation, however, the payback period is <9 years for all the configurations. This contradiction is due to time value of money considered in the NPV calculations that reduces the profit incurred from annual savings. As observed from Fig. 3, initially the DAST system curves are at the down side, below the FA system curves due to the high initial cost, however, as the age of the project increases both the DAST system curves are rising at a faster rate than FA system curves due to higher rate of increase in energy yield and therefore higher cumulative annual savings from the DAST systems.

After 18 years of installation, NPV values are positive for all the systems, suggesting that the annual earnings generated from these systems exceeds the total system cost and hence, SPV sytems are profitable. It is also observed that NPV value is the highest for DACI system at the end of 25 years. This indicates that DACI system is economically most attractive followed by DAMI, FACI and FAMI SPV systems.

b. ***Levelised cost of energy***: To determine the unit cost of electricity from each SPV system degradation in annual energy yield, interest rate on the investment and overall life expectancy of SPV modules must be considered. LCOE is an important metric that includes all these factors to effectively estimate unit cost of energy [16]. LCOE values are computed and tabulated in Table 2 assuming project lifetime of 25 years with annual average module degradation rate of 0.8 and 1.5% and different interest rates of 8, 10 and 12%. With higher interest rate the energy cost per kWh reduces, however, with increasing module degradation rate the energy cost increases due to lower energy yields and same capital investment. Table 2 illustrates that LCOE values are minimum (9.95 INR/kWh at 0.8% energy degradation and 11.06 INR/kWh at 1.5% energy degradation – given in bold numerals) for a DACI system compared to other SPV system configurations. This economic metric reaches to same conclusion that DAST structure is more beneficial and DACI system is financially the most attractive system configuration.

Table 2, LCOE (INR/kWh) for different PV systems at different interest rates considering 0.8 and 1.5% annual energy degradation rate

Degradation rate		0.8%			1.5%	
Interest rate	8%	10%	12%	8%	10%	12%
FACI system	11.36	10.96	10.18	12.54	12.24	11.29
FAMI system	11.42	11.09	10.72	12.63	12.45	11.52
DACI system	10.90	10.36	**9.95**	11.81	11.59	**11.06**
DAMI system	11.21	10.81	10.15	12.46	12.09	11.24

IV. Conclusion

A unique comprehensive performance analysis of four different solar PV system configurations each of 5 kWp capacity installed at IIT Kharagpur, India is presented in this study. Experimental field data and estimated performance indices have shown maximum variation of about 5% compared to simulated model values due to the effect of environmental factors like intermittent ambient temperature and insolation values and clearness index.

DAMI system has shown the best performance for all technical indices with maximum increase in annual irradiance, Eac, CF and PR by about 23, 41, 25 and 14%, respectively, compared to FACI system. These benefits are attributed to DAST structure with higher irradiance and longer sunshine hours and MI system with low cable loss in direct conversion to AC power at each module level. Analysis of monthly PR variation over summer, winter and monsoon seasons inferred that monsoon season has best PR due to low module temperature and high clearness index in spite of significant rainfall in this region.

On the other side, conclusion from economic performance evaluation study through NPV and LCOE makes DACI system as the most preferred. Minimum LCOE for DACI system with 12% interest rate is around 10 and 11 INR per unit for 0.8 and 1.5% energy degradation rates, respectively, followed by DAMI systems. It is inferred from this overall study that DAST structure is definitely beneficial and DAMI system is the best overall performer in spite of little lower economic performance compared to DACI system. DAMI system has an additional advantage of better performance under partially shaded condition due to MI system that is well established in literature and practice.

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Regulatory and Economics of Solar Power Generation in India

Rajib Das

Abstract:

Around the world, majority believe global climate change is a pressing concern. Solar energy is one option for reducing future greenhouse gas emissions. India is poised to become world leader in developing Solar PV power. Acts and policies of Central and State Govts. Are working in tandem. Status of regulatory and financial aspects are discussed herein below.

Introduction:

Solar power in India is a fast-developing industry. The country's solar generation installed capacity has reached 37 GW in November 2020.

As per the Indian Electricity Act 2003,

- Generation is free from licensing.
- Captive generation is free from controls.
- Generation from Non-conventional sources have to be promoted. Minimum percentage of purchase of power from renewables have been prescribed by the Electricity Regulatory Commissions.

Technology and economics both are driving for fast development of solar industry.

All India target is to set up 100 GW by 2022, out of which 40 GW expected from Roof ToP Solar PV Sources (RTSPV).

Total capacity of ground mounted grid-scale Solar PV Sources is 33.5 GW and RTSPV capacity is only 3.5 GW. 8 States account for more than 80% of capacity installed.

STATES / Uts	Ground MountedMW	Roof Top MW	Total MW
Karnataka	7066	250	7316
Rajasthan	5002	382	5384
Tamil Nadu	3980	278	4259
Telangana	3784	149	3933
Andhra Pradesh	3650	94	3744
Gujarat	2772	866	3638

STATES / Uts	Ground MountedMW	Roof Top MW	Total MW
Madhya Pradesh	2380	58	2438
Maharashtra	1632	263	1895
Uttar Pradesh	982	235	1217
Punjab	829	119	947
Odisha	384	16	399
Uttarakhand	240	80	320
Chhatisgarh	216	24	240
Bihar	139	14	153
Haryana	131	130	261
Kerala	100	47	147
West Bengal	100	50	150

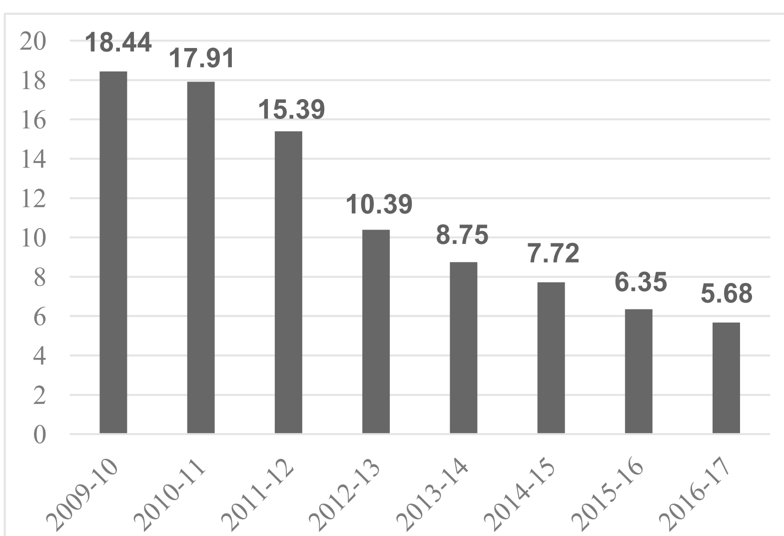
Source : MNRE

Reasons for development of higher capacity of Solar generation in few States could be higher solar insolation, availability of cheap land, government policies and regulatory environment etc.

Costs:

Prices are falling and technology is improving. Thus, both technology and economics are driving.

Central Electricity Regulatory Commission (CERC) determined generic tariff (**Rs. / kWh**) for electricity from Solar PV Projects, based on capital cost and other norms as application from 2009-10 till 2016-17.



Source: CERC Orders

Since, technology cost is coming down and market is becoming competitive, CERC stopped determining generic tariff for electricity from Solar Projects.

Next, we shall check, how market is reacting through competitive bidding: -

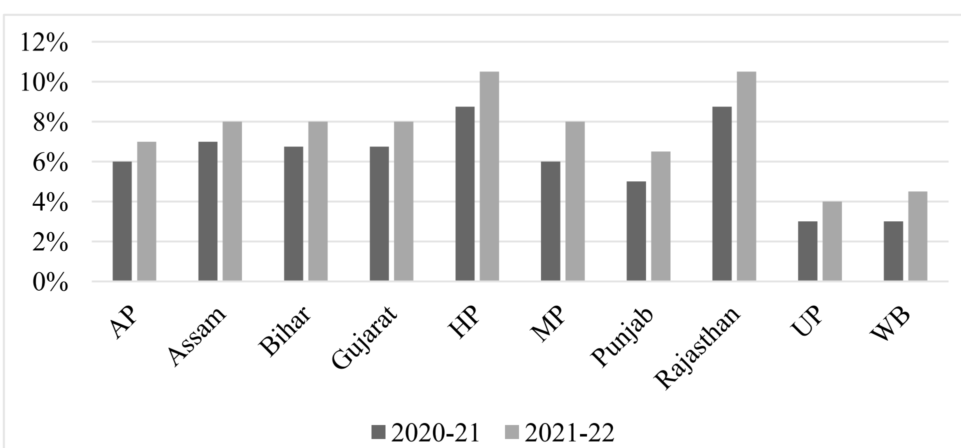
Source: MNRE

Generally, it is observed cost of PV Modules (50%); Inverter (20%); Structure (15%); Cable, JB, CB (15%) for MW Scale projects.

As per MNRE, benchmark cost of 1 kW SPV plant is 47000; 1 to 2kW Rs. 43000/kW; 2 to 3kW – Rs. 42000/kW; 3 to 10kW – Rs. 41000/kW; 10 to 100kW – Rs. 28000/kW; above 500kW – Rs. 36,000/kW.

Regulatory:

As provided in the Electricity Act and Tariff Policy and National Electricity Policy, State Electricity Regulatory Commissions specified Renewable Purchase Obligation (RPO) for the distribution companies (Discoms)



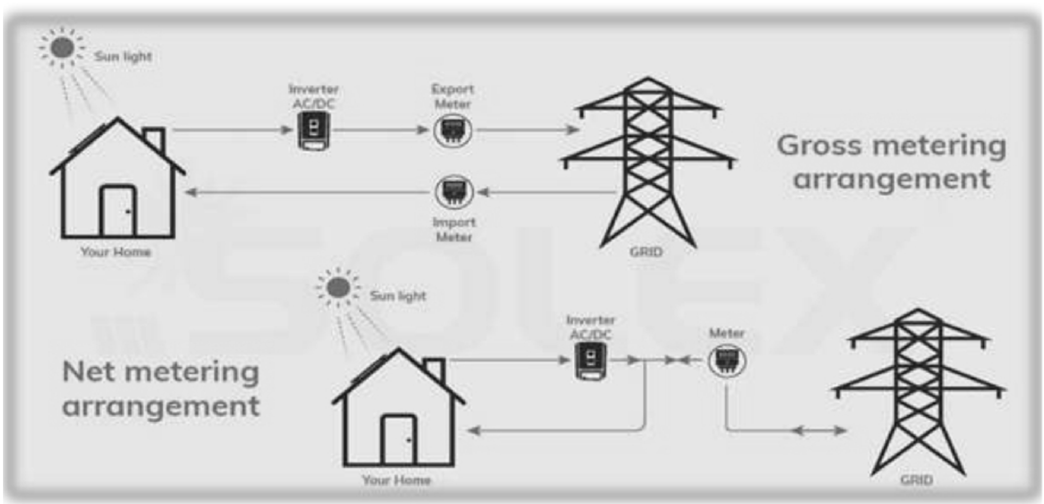
Source: National Portal for RPO

RPO is the single most important policy driving renewable energy installations in India towards achieving its aggressive goal of installing 175 GW by 2022. Majority of the States (Discoms) are not fully complying with their RPO targets, mainly due to non-availability of sources locally. Regulatory Commissions in few cases, in Suo-moto proceedings, asking distribution companies to meet RPO, as per the target. Directions are there to create RPO Regulatory fund to meet RPO obligations. AP, Karnataka, Tamil Nadu, Gujarat, Rajasthan, MP, Telangana etc. are the States who have achieved more than 60% of RPO compliance.

Discoms are willing to procure energy from SPV sources based on competitive bidding where prices discovered are low comparing with any other sources. These are generally ground mounted and MW-Scale and EHV grid connected sources.

RoofTop SPV Sources are generally connected with HV / LV distribution system. Provisions for grid connectivity is there under net metering or gross metering.

Under net metering, energy import by a consumer having RTSPV and energy export to the grid is measured and billing is done by the Discom on the basis of net energy drawal. Under gross metering generation of electricity from the source is measured and amount for the generation is credited into the consumer bill.



Gross metering - Injection to the Distribution System, PPA, Cost of Generation from Other Sources vis-à-vis Cost of Power from PV Sources
Net metering - Self-consumption, Comparison with Utility Tariff, Energy efficiency

Under net metering, Discoms have a fear that if rooftop solar can grow without restrictions, they will lose some of their largest and best-paying Customers. Cross-subsidy is highly prevailing at retail tariff. Some consumers are paying at much higher rate than average cost of supply and they are willing to move away. There is issue in tariff design - Cost a licensee incurs fixed and variable; tariff has also two components fixed and energy charge. Fixed charge that is recovered from consumers is only a percentage (10% to 20%) of fixed cost that we incur. Balance cost is recovered through energy charge. Thus, for reduction of energy drawal by consumer, there will be under recovery of fixed cost.

Gross Metering policy can help resolve this issue. Under Gross metering, Discom purchases the entire energy generated by rooftop plants. The entire electricity produced should be metered and exported to the grid.

Discom will buy at a rate determined by the State Commission. There has to be equitable distribution of revenue between Discom and rooftop owner.

Electricity Regulatory Commissions has provided for grid connectivity of SPV sources under net metering / gross metering. Commissions have specified provisions of minimum and maximum capacity for net metering, supply voltage, capacity w.r.t. sanctioned load, total capacity w.r.t. distribution transformer capacity, ownership – which are listed below for some State Commissions.

	Rajasthan	Gujarat	Maha	UP for Dom	Telengana	TN	Delhi
Capacity							
Min	1kWp	1kWp		1kWp		1kWp	1kWp; 5kWp for Group/Virtual Net Metering
Max	1MWp	1MWp	1MWp	2MWp	1 MWp	Linked with shadow fre area	1MWp; MkWp fo Group/Virtual Ne Metering
Voltage							
1 Ph	Upto 5kWp	Upto 6kW	Upto 8kW	Upto 5kWp	Upto 5kWp	10kWp	10kWp
3 Ph	5~50kWp	6~100kWp	8~80/150kW	5~50kWp	5~75kWp	10 ~100kW	10~100kWp
HT/EHT	11kV > 50kW	11kV > 100kW	11kV - > 80/150kW	11kV - 2 MW; 33/66kV - 5 MW	>75kW	>100kW	>100kW
Conditions							
Sanctioned load	80%	Residential 100%; Others 50%	< 100%	< 100%	Residential 100%; Others 80%	<100%	Consumer may enhance line capacity > sanctioned load; F.C. not to be levied beyond SL
DTR Capacity limit	< 30%	< 30%	< 70%	< 75%	< 50%	< 30%	< 20%
Ownership	Self (Capex)	Self (Capex)	Self	Self	Self	Self	Self
	Third Party		Third Party	Third Party	Third Party	Third Party	Third Party

Source: SERC Regulations

Billing for net metering is generally done on net energy drawal by a consumer, excess generation is credited for next bill. At financial year end, unadjusted units are settled at a rate by State Electricity Regulatory Commission.

Rules by MoP, GoI:

Recently finalised Rights of Consumers Rules 2020 by MoP, GoI dealt issues relating to Standards of Performances of distribution companies, prosumers (who consumes electricity from the grid and can also inject electricity into the grid using same point of supply), net metering and gross metering: -

- Prosumers will maintain consumer status and have the same rights as the general consumer, they will also have right to set up Renewable Energy (RE) generation unit including roof top solar photovoltaic (PV) systems – either by himself or through a service provider.
- Net metering will be available for loads up to ten kW and for gross metering for loads above ten kW.
- Distribution company will create online portal for receiving applications from prosumers. The portal will display detailed procedure for installation and commissioning of SPV system, applicable charges, empanelled list of service providers, format of connection agreement, financial incentives from Govt. schemes etc.
- There will be time lines for technical feasibility study, signing of connection agreement

WBERC Regulations:

West Bengal Electricity Regulatory Commission, has recently amended Regulations and the provisions are hereunder: -

- Minimum Solar PV capacity of a consumer is 1 kWp
- Maximum Solar capacity for net metering arrangement is 5 kWp
- Above 5 kWp Solar capacity arrangement will be net billing, effectively gross metering – energy generated from Solar is purchased by the Discom and the Discom raises the bills on the consumers for his consumption at the approved tariff and credit is given for the total electricity sold out to Discom at a pre-determined tariff set by the Commission.
- Under net metering, any excess energy injected more than 90% of consumption by the consumer from Discom in each billing period shall be carried over to next billing period. At the end of financial year, if energy injected is more than 90% of energy consumption for the year, the Discom shall not pay any charge to the consumer.

Incentives:

Various incentives offered in different States for promotion of Solar PV Sources – e.g.

- According to CERC Regulations, no transmission charges and losses for the use of Inter State Transmission system (ISTS) will be payable for solar projects
- Exemption / reduction from wheeling & cross subsidy surcharge if applicable
- Exemption of electricity duty
- Banking of energy; exemption from banking charges
- No distribution losses and charges
- Subsidy is applicable as per SECI guidelines
- Accelerated depreciation
- Tax holiday

Conclusion:

India has targeted 100 GW Solar PV by the year 2022. Focus is on large size SPV plants as well as on small-size projects. Now, India has embarked on an ambitious target of having 450 GW of renewable energy by 2030. This is required to meet climate commitments as well as to achieve energy security of the country. Various study shows, potentials are there. Economics for all stake holders (developers, distribution companies, generating companies, consumers), technical acceptability to grid operation and and regulatory provisions will address the concerns and show path forward to achieve the target.

Rooftop PV in West Bengal under the new regulation regime

Er. Shreya Karmakar
Renewable Energy Professional, also studying Power Systems in IIT, Dhanbad. Opinion in this article is personal.

Er. Joy Chakraborty
Renewable Energy professional. Opinions in this article are personal.

Introduction:

Since the Rio De Janeiro Earth Summit in 1992, the Climate Change has surfaced as the worst threat against the very existence of human civilisation in this planet earth. The Indian Meteorology Department in its Climate of India during 2020 report, as released on 04.01.2021 says that the year 2020 is the 8th warmest year in India since 1901. Extreme weather has killed some 1400 people in India in 2020.The Ministry of Health & Family Welfare, Govt. of India in its report in December, 2020 has shown that some 15 lacs of people have died in 2020 in India from Air Pollution. In this background, the country has adopted strategies to reduce its Green House Gas (GHG) emissions. These are through capacity addition from Renewable Energy and phase-wise replacing the fossil fuel driven transport system by electric vehicles.

In 2008, the Govt.of India, had introduced Prime Minister's National Action Plan on Climate Change [NAPCC].This includes 8 National Missions including Jawaharlal Nehru National Solar Mission (JNNSM) and Enhanced Energy Efficiency Mission. In 2011, the National Hybrid Mobility (Electric Vehicle) Mission was introduced.

After the tenure of the Kyoto regime [2007-2012], the Paris Climate Accord was signed in 2015.The Paris Climate Accord targets: 'reducing the GHG emissions at 33 to 35 % below of 2005 emission intensity level of GDP [unconditional] and 'non-fossil fuel share of cumulative power generation capacity of 40% by 2030 [conditional] .' These exercises are aimed to limit the global temperature rise within 1.5 degree Celsius by 2100.

To meet the commitment in accordance to the Paris Accord, the Indian Government has introduced target based capacity addition from RE sources, energy efficiency measures etc. In 2015, India had fixed up the target to add 175 GW of Renewable Energy [RE] in its grid [it includes 100 GW of Solar and it covers 40 GW of Rooftop Solar] by 2022. By October, 2020, India has already achieved 89.63 GW from Renewable. [Source: RE Invest: Govt. Of India: November 26-28, 2020] So, India has to achieve 85 GW further of Renewable Energy to reach at its 'intended nationally determined RE contribution goal' of

175 GW by 2022. Observing enthusiastic achievements, the Govt. of India has upgraded its RE target from 175 GW to 220 GW by 2022. [Convocation: Pandit Deendayal Upadhyaya Petroleum University: Speech of the Hon'ble Prime Minister of India : November,2020] The further target is 450 GW of RE by 2030 which is to accomplish India's goal to enhance its RE penetration to its grid energy mix to 40% by 2030.

In recent past, India has witnessed steady growth in Solar and Wind Energy sectors. In recent biddings, Solar PV has become the cheapest source of electricity in India. The latest available tariff is Rs.1.99(in the NTPC bidding on 19.12.2020) for each (kwh) unit for Solar PV. The International Energy Agency on 30.04.2020 has said that Renewable Energy will be the only energy source that will be resilient to the coronavirus pandemic.

The transition at a glance:

In June , 2020, the Central Electricity Authority [CEA] ,Govt. of India has released data, which shows India's overall installed power generation capacity has reached from 357 GW to 371 GW.Out of this total 14 GW of capacity addition , conventional sectors have contributed[from 278 to 283 GW] 5 GW and the Renewable have contributed[from 78 to 87 GW] 9 GW . The annual electricity generation from conventional sources [April, 2019 to May, 2020] has decreased from 226 BU to 177 BU , whereas for Renewable, annual electricity generation has increased from 22BU to 23 BU. For the percentage contribution to grid, presently RE stands for 10 % +. In recent days, Solar PV has emerged as the cheapest source of electricity in India.

In the Economic Times webinar on 20th November, 2020 , the Niti Ayog has uttered that Indian Power Sector infrastructure , at present is enough to accommodate upto 17 % grid penetration from RE. Though experts say that, presently India is managing the grid for accommodating the entry of newly installed fast growing Renewable by reducing generation from coal based plants which is an extremely inefficient way and it adds operational cost. On the other hand, the rapid growth in capacity addition from RE sources indicate that the said 17 % limit is not enough because near 20 % grid penetration from RE is a matter of some months ahead. In such a position, reducing the peak demand through Energy Efficiency measures and propagation of large scale advanced and efficient storage has become inevitable.

During the recent lockdown, Adani Greens have bagged a 45,000 crores order from the Maharashtra Government for 8GW Solar Power. With 15 GW of present Renewable Portfolio Assets, Adani Green is inching closer of becoming the world's largest Renewable Energy company (as well as a Net Zero energy company) by 2025.They have Solar Module manufacturing facility, EPC business, Solar Generation in Solar Parks etc.

In the said background, in recent past, the Govt. of India has introduced a New Model Rooftop Metering Regulation. In West Bengal, the West Bengal (State) Electricity Regulatory Commission has issued the New Regulation on 24.12.2020. The said regulations create many confusions and debaters in respect of promoting the Rooftop Solar power in India and as well as in West Bengal in coming days. An attempt is made in following paragraphs to have an overview of current confusions and debates.

Rooftop Solar: Phase wise development in global scenario

According to policy analysts and experts; the growth of Rooftop Solar in a country, generally, takes place in three phases. It starts with the concept phase which involves demonstrating the success of the technology. Then comes the market transformation phase, where regular updates, informed decisions on parts of prosumers, capacity building of entrepreneurs, developers become the focus of activities. The most important role in this phase lies with the market facilitators that are Regulator and the Government. India is now passing through this phase. The final phase is the self-replication phase; where the market forces with optimized technologies itself lead to an increasing number of installations. This is the phase that countries like the Japan and Germany are currently in.

General Advantages of Rooftop Solar:

For a developer, it includes reduced land and interconnection costs, higher tariffs due to increasing commercial and industrial tariffs, and increased profitability. Rooftop Solar PV assists Distribution Companies (DISCOMs) by reducing the peak demand during daytime and decreases Transmission and Distribution (T&D) losses as the power is consumed at the point of generation. According to PwC analysis, more than 10,000 MU of electricity will be saved as avoidance of T&D losses alone in year 2022 alone if 40 GW Rooftop PV is achieved by 2022. Further, commercial benefits in avoiding investments in transmission system are huge. Finally and most importantly, it reduces the dependence on grid power, diesel generators. It is a long-term reliable and cheapest power source for consumers.

Rooftop Solar in India:

According to the Bridge to India Report of June, 2020, the cumulative Rooftop Solar installation stands for 5953 MW in India (In West Bengal , it was 143 MW, then) .According to the Ministry of New and Renewable Energy (MNRE) about 2320MW of solar capacity was added between January and September,2020 with around 1,437MW of that being ground-mounted and 883MW of Rooftop Solar .The states of Rajasthan (360MW), Tamil Nadu (341MW) and Maharashtra (165MW) led in terms of large-scale installations in Ground Mounted Solar projects . With 380MW of capacity additions in Rooftop in the first nine months of 2020, or 43% of total installations Gujarat stood first in Rooftop PV.This was followed by Rajasthan (150 MW) and Tamil Nadu (92 MW).

Despite the challenges of COVID-19, Gujarat was able to add significant capacity in Rooftop Solar because of the Surya Urja Rooftop Yojana – Gujarat, a major government incentive program in the region that targets solar rooftops for eight lakh or 0.8 million residential consumers by March 2022. The scheme allows consumers to claim state subsidy of 40% for solar installations up to 3kW, and 20% for 3kW-10kW capacity range. Additionally, a Micro, Small and Medium Enterprises (MSME) policy brought in September 2019 by the Gujarat state government. It allows the installation of solar projects with more than 100% of their sanctioned load or contract demand for MSMEs.This drive has helped rooftop solar additions, as the popular policy allows MSMEs to sell excess solar to the State government for Rs.1.75/kWh, and buy solar power from third parties.

Solar Energy Scenario in West Bengal:

One of the major achievements in respect of Solar Photovoltaic activities in West Bengal is providing rooftop grid connected Solar Photo Voltaic [PV] systems .The grid connected Solar PV systems are set up on the roofs of such building and the solar electricity as produced from sun light supplements electricity as supplied by the CESC, WBSEDCL etc through net-metering arrangement .

Through such exercises, West Bengal [according to the Bridge to India Report, June, 2020] has installed 143 MW Solar Power Plants at Rooftop. Most of such installations have taken place under private initiatives and at private buildings. Unlike other parts of this country, as on date in West Bengal penetration of Rooftop Solar is equal with Ground Mounted Solar power Projects. This is because of land availability issues in this state.

Type of Solar Power Plant	Ground Mounted Solar Power	Rooftop Solar Power
INDIA	42 GW	6GW
WEST BENGAL	118 MW	143 MW

The New Regulation Regime:

The regulation says:

Net Metering allows a set off the number of units produced from the total consumption and the consumer pays electricity charges only what he has derived from the grid of the DISCOM. In April, 2019, the CERC has released a '**Draft Model Regulation for Grid Interactive Distributed Renewable Energy Sources'**. The stake holders, especially the Solar Energy Federation of India has then fought for abolishing any upper cap for Net Metering in respect of Rooftop Solar PV. In recent days, the Ministry of Power [MoP], Govt. of India has introduced the draft **Electricity Rights of Consumers Rules, 2020** which was floated for stakeholders' consultation, the Net Metering was proposed to be upto 5 KW. Based on the comments from the consumers, industry and DISCOMS, it was taken to increase it to 10 Kw.

The Ministry of Power [MoP] says:

The MoP has said that: 'Discoms financial health is very important for the sustainability of the entire value chain of power sector. However, some representations have been received on this issue, which are being examined and based on this; a call will be taken for balancing the interest of all stakeholders.'

National Solar Energy Federation [NSEF] of India says:

- MSMEs in Rooftop Solar business will be adversely affected. Roof Top Solar business may shrink by 50 %.
- New rules have created regulatory uncertainty concerning the applicability of Net Meter regulations for existing and on-going projects.
- Roof Top Solar business will collapse as Commercial & Industrial consumers will be discouraged for opting to Rooftop Solar. The payback period for 150 – 300 KW range of Solar installation will be high. Commercial & Industrial consumers will not be interested to install Rooftop Solar.
- Heavy industries like the Iron & Steel, Paper Factory can only install Rooftop Solar under gross metering mode, because they may afford the higher payback period.
- The Govt. is trying to edge out small players from the market leaving it open for big players who can handle higher costs.
- Commercial benefit to the consumer is far less in case of gross metering, compared

to net metering thus making adoption less commercially attractive. Balancing interest of stake holders [DISCOMs, Solar Developers, High Load Consumers] is needed.

- NSEF now feels betrayed with centre bringing out rules contrary to their own targets [40 GW Rooftop Solar target by the Government of India] as announced by them.
- There should not be any upper cap for Solar Rooftop Net Metering projects. Then only India's ambitious target of 40 GW can be meet up.
- Discoms financial health is important for sustainability of the entire value chain of the power sector, but nowhere it is established so far that the DISCOMs are losing their business for Rooftop Net Metering. Rather, PwC analysis, more than 10,000 MU of electricity will be saved as avoidance of T&D losses alone in year 2022 alone, if 40 GW Rooftop PV is achieved by 2022.Win win situation for DISCOMs , Solar Developers , High Load Consumers is needed to meet the Government's 40 GW Rooftop Solar target by 2022.
- For no case, the environmental concerns can be compromised, because, according to the United Nation's Framework Convention on Climate Change, one Million Unit of Solar Power generation corresponds to avoidance of 700 tons of CO2 emission to the atmosphere.
- Different states including West Bengal has not yet published the Solar Rooftop policy, which are to be cleared on an early date. The distributed generation could be an appropriate solution to meet the Solar Rooftop target, if the government is refrained from unnecessary restrictions.
- As per the MERCOM Q2 report, 96 % of distributed solar as installed so far in India is in Industry & Commerce sector , as it is the cheapest power source to them.

Environmental Impact of Solar Power

Every 10MW Solar Power Plant Installation means the following environmental impact.

Reducing Carbon Dioxide Emission in its lifeti	30 Crore Kgs
Has the same effect as planting	6 Lacs Mature Trees
Has the same effect as saving	500 Lacs Litresof Water
Has the same effect as saving	21 Lacs Kgs of Sulphur Dioxide
Has the same effect as saving	13 Lacs Kgs of Nitrous Oxides

Legal aspects:

- As per the Electricity Act, 2013, the business of generating electricity is de-regulated which means no permission is required to set up a power plant. The regulation only plays a role in the sale of electricity to DISCOMs who buy it to consumers.
- The Solar Industry can challenge the regulations in the State High Court under the Article 19 (freedom to practice any profession) and Article 14 (Right to Equality). There should not be any interference or prohibition when it comes to the discretion to choose gross or net meters.

- MSMEs' right to generate electricity is being restricted while giving leeway to big players who can afford to generate electricity through their captive solar projects.
- If DISCOMs are losing their business, can small Roof Top Solar players be sacrificed? How Solar RT , EPC , environment etc become secondary to the need of DISCOM?
- Considering the sharp rise of Renewable Energy capacity addition and increase in complexities of such issues, it is imperative to build internal capacity in Electricity Regulatory Commissions with Renewable Energy expertise. The Ministry of Power / Forum of Regulators may consider recommending that each State ERC have more technical manpower for RE specific skills.

The roll out: Maharashtra Story:

The Maharashtra Electricity Regulatory Commission [MERC] has issued draft regulation in 2019. It had faced protest and finally it is changed from the proposed draft. Now, the MERC regulation says:

- It is non- discriminatory to ' first come , first serve' basis to eligible consumers who have already installed or are likely to install a Renewable Energy Generating System [REGS] , as connected to the network of the DISCOM.
- The cumulative capacity of all such RE systems should not exceed 70 % the rated capacity of the Distribution Transformer [DTR]. The Lower Cap [minimum capacity] is 1 Kw . The upper cap is decided to the tune of the cumulative capacity of the DTR.
- The, REGS which is to be connected to the DISCOM grid , should not exceed the sanctioned load ((KW) or approved contract demand of the consumer (KVA).
- HT Consumers can connect RE System at its LT side bus bar. Net Meter will be on HT side.

Current Position of West Bengal in Rooftop Solar adoption

		Distributed Capacity (MW)			
Rank	**States**	**Total (MW)**	**Commercial**	**Industrial**	**Public Sector**
1	Maharashtra	851	170	614	67
2	Rajasthan	526	79	402	45
3	Tamil Nadu	481	94	353	34
4	Karnataka	402	117	232	53
5	Gujarat	383	53	269	61
6	Uttar Pradesh	334	128	136	70
7	Madhya Pradesh	313	40	241	32
8	Haryana	275	74	172	29

Source – Bridge to India report of June 2020

9	Andhra Pradesh	238	86	120	32
10	Delhi	178	61	27	90
11	Telangana	174	55	91	28
12	Punjab	169	88	66	15
13	West Bengal	143	38	64	41

Economic Impact of New Regulation in West Bengal

1. There are around 250 Solar Companies in West Bengal which provide direct employment to around 6000 peoples and indirect employment to around 10,000 peoples which includes electrical job, masonry job, civil job, mechanical job. As a result of fallout of the policy there would be unemployment among the above mentioned number of people
2. Large Industries/MSME/SME industries would find it difficult to compete with cost of production of their material. Other states have comparatively cheaper tariffs also they have conducive solar policy from which they are able to draw cheaper tariff in the range of Rs 3 to 4/kWh as a result of that Industries/Commercial from WB would lose the competitive edge, as West Bengal is among top 3 states (after Maharashtra and Madhya Pradesh) which has one of the highest power tariff.
3. The global Coronavirus pandemic has made commercial and industrial customers realize that going solar is one of the best ways to cut down operational costs. Energy cost account for around 30-40% of operational expenses for Commercial and Industries. With solar power prices dropping drastically over the years, it makes sense for business to adopt solar to save cost. These projects could have helped businesses save enough money to stay afloat and help generate income. With the new policy MSME/SME would find it difficult to survive.
4. As per Mercom report (Q2, 2020 India Solar Market Update), about 96% of the distributed solar installations has come from Industrial and Commercial consumers. Rooftop Solar is the cheapest form of energy available for Industries and Commercial consumers.

For comprehensive development of Solar Energy Scenario in West Bengal , what to do :

- **There should not be any upper cap for Solar Rooftop Net Metering projects. Then only India's ambitious target of 40 GW can be meet up.**
- Discoms financial health is important for sustainability of the entire value chain of the power sector, but nowhere it is established so far that the DISCOMs are losing their business for Rooftop Net Metering. Rather, PwC analysis, more than 10,000 MU of electricity will be saved as avoidance of T&D losses alone in year 2022 alone, if 40 GW Rooftop PV is achieved by 2022.Win win situation for DISCOMs , Solar Developers , High Load Consumers is needed to meet the Government's 40 GW Rooftop Solar target by 2022. **So, Discom is losing business for Solar Net Metering: this proposition is tro be verified by an expert committee.**

- For no case, the environmental concerns can be compromised, because, according to the United Nation's Framework Convention on Climate Change, one Million Unit of Solar Power generation corresponds to avoidance of 700 tons of CO2 emission to the atmosphere.
- Different states including West Bengal has **not yet published the Solar Rooftop policy**, which are to be cleared on an early date. The distributed generation could be an appropriate solution to meet the Solar Rooftop target, if the government is refrained from unnecessary restrictions.
- Considering the sharp rise of Renewable Energy capacity addition and increase in complexities of such issues, it is imperative **to build internal capacity in Electricity Regulatory Commissions with Renewable Energy expertise**. The Ministry of Power / Forum of Regulators may consider recommending that each State ERC have more technical manpower for RE specific skills.

Conclusions:

The RE push in Indian Power Sector creates a scope of greener environment. An integrated and alternative approach through elevating indigenous RE manufacturing capacity and extending Net Metering exercises can ensure propagation of RE Sector in West Bengal in more sustainable and inclusive. Other than organised sector employment, an eco-system for ancillary, maintenance services is also to be developed like what has happened for India's top car maker Maruti. This will reduce the GHG emissions, enhance RE penetration and will provide new scope of employment to the youth, jobless and other marginalized population in West Bengal. Otherwise, only giant companies will have all the benefits of this RE transition in India, as well as in West Bengal.

A dedicated PV module waste management and recycle policy is essential today : a brief write up.

Gautam Kr Das

Deputy General Manager, Development Consultants Pvt Ltd

The Government of India is insisting for increasing the share of renewables in the total electricity mix. The cumulative solar capacity is aimed to reach 100 GW by 2022. Energy storage is also gathering much attention with the growing share of renewable energy in the grid to overcome generation intermittency. Large-scale battery and cell manufacturing is now profitable business in India. Lead-Acid Battery, which have been in use for energy storage and uninterrupted power supply solutions for many decades are now moving towards alternative battery chemistries for new ventures of manufacturing efficient batteries with increased life. Although the augmentation of solar and storage capacity ensures access to sustainable energy for all, it carries an impending issue of disposal and management at the end of their useful life. The expected useful working life of solar photovoltaic (PV) modules is between 25 and 30 years, after which they have to be discarded.

According to the declared analysis, the current 31 GW solar capacity alone may produce in the scale of 100,000 tons of waste by 2022. Interestingly, none of this waste would come from the expected end-of-life of the running solar modules.

About 20% would result from damages during transportation and installation process. The remaining, about 80% would result from early failures during the plant operation phase. This waste amount will grow continuously as more solar capacity is deployed in future.

Similarly, for batteries, the expected life varies from 3 to 10 years depending on the battery chemistry. Further, there are other many factors such as overheating, deep discharging, and low or high surrounding temperature, can result in an early life failure of batteries. With the continuous up gradation of technologies, waste shall be increased. In the absence of a regulatory framework, this entire waste would end up in landfills, thus adversely impacting the environment. Both PV modules and batteries contain metals as an active component. In case of PV modules, two different technologies are prevalent:

crystalline silicon and thin-film. The major components of a crystalline silicon module are silicon, aluminium, copper, silver etc. Thin-film modules contain compounds of tin, cadmium, and lead besides aluminium, copper, and silver. Besides, the battery technology is dominated by different chemistries of the lithium-ion, the main metallic components of which are lithium, manganese, nickel, iron, and cobalt. While aluminium and silicon are relatively less toxic, the heavy ones such as cadmium, tin, and lead are hazardous. The broken glass modules are also threats to the environment. Various researches have been conducted by the Council on Energy, Environment and Water (CEEW) in this context.

Most of the PV modules are made of aluminium frames, glass and metallic components. The recycling of PV modules involves dismantling, combustion, etching, removal of metal frames, removal of the organic components etc. The process should ensure recovery of glass and solar cells without breakage. Etching involves treating the residual mixture of glass and metals with acid or alkali for the separation of these two components. After recovering glass, the composition of acid or alkali solution is changed to recover the different metals.

There are varieties of steps, some old methods are energy intensive and less efficient and now the focus of the recycling processes to recover and reuse materials should be simple and less energy intensive. Regulatory guidelines from CEA/MoEFCC/BIS shall also to be established or else a separate statutory body shall be formed to have a dedicated PV waste management and recycling policy since as of now, solar module and battery waste is treated as general electronic waste.

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Some other ways to save power

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- Check BEE Label and number of stars on electric appliances while purchasing
- Set AC temperature at 24 degrees to save up to 35% energy
- Switch off lights, fans and other electric gadgets after use