Techno-Commercial Analysis for Determining the Solar Bidding Tariff

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***Abstract*— The recent rounds of solar auctions have seen the all-time lowest solar tariffs in India. The developers are bidding aggressively to grab the market share. The EPC cost of setting up a solar plant has decreased considerably which is helping developers to sustain & defend their favorably assumed aggressive bids made in the past. The final bidding tariff is based on the cost and associated risks of several activities. This also includes selection of optimum mounting structure and DC loading. All these design parameters when seen in conjunction with the incremental cost of technology updation, land area constraint, land prices, inter-row shading impact due to squeezing of higher DC capacity in limited area, higher loading of DC capacity plays a decisive role in finalization of bidding tariff.**

The paper will present a techno-commercial analysis of calculating bidding tariff for a solar plant in India using the poly-crystalline modules and how to arrive at the correct DC AC ratio for most optimum technology combination. The Charanka Solar Park in Gujarat is a perfect example of demonstrating this calculation as the land cost in Charanka Solar Park is the highest among India's Solar Park and the limited plot area is provided to the IPP to set up plant (~4.5 acres/MWp). This puts the IPP in a situation to estimate the optimum plant generation output using different combinations to achieve the lowest possible tariff for pre-defined financial returns. The paper will throw light on techno-commercial viability of solar bids in India and how sustainable are these. (Abstract)

Keywords-component; solar tariffs in India, DC AC ratio, Techno-commercial analysis

I. SOLAR SECTOR IN INDIA

India has set an ambitious target of 20GW solar capacity addition by 2022 under the Jawaharlal Nehru National Solar Mission (NSM) which was multifold by the NDA Govt in 2014 and set to 100GW. The 60GW of this targeted solar capacity will be from the utility scale solar projects which will include majorly the projects under the Central/ State tender. Around 60% of the solar plant cost is from the solar modules. India has less than 7GW of annual installed solar modules manufacturing capacity of which around 5.2GW of capacity is under-utilization [1]. The installed capacity is lower than our annual targets. Some of the Indian make modules are categorized Tier-1, however the cost of production of Indian modules is very high due to absence of long term sustainable incentives from the Govt to this sector. As much as 90% of the Indian solar market is dominated by the Chinese solar modules. China offers the cheapest Tier-1 modules to the world and at times is accused of dumping the solar modules at unrealistic low prices, thus demolishing the local markets.

Under the NSM, the solar projects are awarded to the developer who Design, Build, Own, Operate and Finance the solar projects. The power generated from the solar project is sold to the off-taker (like NTPC, NVVN, SECI/ MPPMCL, TSSPDCL, UPCL etc.). The NTPC (erstwhile conducted by the NVVN) and SECI are conducting the bid process management at the central level and anchoring the NSM under the guidelines of MNRE. The tenders at central level are coordinated by the NTPC & SECI based on the bidding guidelines like VGF or bundling scheme. The solar tariffs in India have seen an exponential reduction from Rs. 17.91/kWh awarded in 2010 to the projects under migration scheme to Rs. 2.44/kWh discovered under the reverse auction conducted by SECI for Bhadla Solar park in 2017[3].

A. Solar Tenders in India

NTPC & SECI acts as the trader of power who signs up Power Purchase Agreement (PPAs) with the developers and further signs Power Sale Agreements (PSAs) with the state utilities. As an intermediary, the central utility of NTPC & SECI with strongest of the balance sheets and best of the credit rating gives the highest comfort to the developers in comparison to signing the agreement with debt ridden state utilities with the history of payments defaults. These central utilities have the Payment Security Mechanisms in place which ensure the timely payment to the developers even if there is some delay from the end consumer which is the state utility. The credit worthiness of the off-taker plays one of the major role in the tariff calculation of the developer, more the risk of the off-taker, more is the return expectation of the solar bidder.

There are state tenders in India like the Jharkhand 1200MW solar tender which has not signed the PPA with the bidders after the opening of the financial bids. Similarly the Telangana 2000MW tender witnessed the signing of PPA at a reduced tariff then that discovered under financial bid opening. Gujarat was seen contesting for the PPA price it signed earlier in the state's FIT scheme. These were the some of the instances which also represent the black side of rapidly changing economics of the solar market. The reduced cost of the equipment particularly solar modules is allowing the tariffs to fall further, while casting the shadow on PPAs signed at the higher tariffs earlier when the equipment cost was much higher. Since the most of the agreements were signed by the State Govt., Govt. is bound to honor the agreements but sometimes at cost of delayed payments to the developers. The provisions of PSM, penalty for delayed payments are not very much enforceable atleast at this timeline of the market.

II. Conceptual Clarity

Broadly, during the technical analysis at time of bid submission, focus is to estimate the energy yield and the project cost. The energy yield depends upon the following parameters:

- Solar resource Assessment
- Module technology
- Tilt of solar array (tracker or fixed tilt)
- Plant design towards minimizing the DC & AC losses
- DC AC ratio of plant

These parameters are obvious and self-explanatory to show their significance. The calculation of the DC AC ratio requires a techno-commercial analysis and following parameters further impact this number:

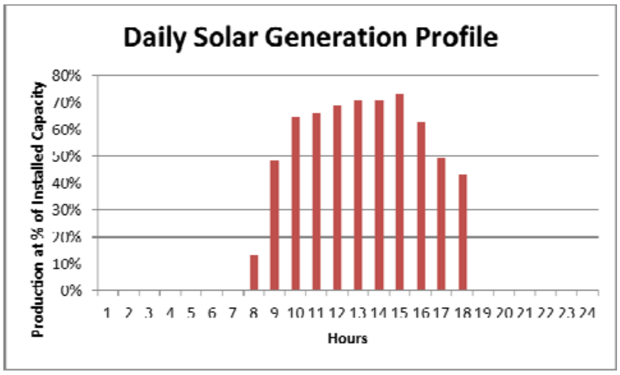
- Inter-row shading
- Cost of land
- Latitude for solar geometry
- Tender conditions etc.

A. What is DC AC ratio?

The number of solar modules that are installed in a solar plant resembles the DC capacity of solar plant, measured in kWp or MWp. This is the peak power that can be generated from the solar plant at Standard Testing Conditions with 25Deg C and 1000W/m^2 of irradiation. And the AC capacity is the inverter capacity of the plant which can be equal to the contracted capacity of the solar plant as per the tendering conditions.

The daily generation profile of a solar plant is attached in the Fig 1. Fig 1 depicts how a solar plant is always under-generating the solar power for all the hours during this particular day. As the STC conditions are lab conditions this pattern is in Fig 1 is very generic and the solar plants always under-generate during the morning and evening hours when the solar radiation is less. This gives an opportunity to install a solar project of the capacity bigger than the requirement, so that the solar plant continue to cater to its maximum contracted capacity.

For e.g, let us say that the solar energy yield at a particular location is 1700kWh/kWp/year. If for a 10MW of contracted capacity plant, we set up a solar plant of 10MWp, then that solar plant will under-generated for most times of the day. Also the inverters and transformer will remain under-loaded and so their performance efficiencies will be less. Hence it is a practice to increase the DC side of the solar plant by putting up more solar modules which will require more land area and higher engineering, procurement and construction cost.



Let us say we set up a solar capacity of 12.5MWp (which will be called DC capacity). Generally the solar inverters are capable of operating at 120% of their rated capacity. That means a 1MW inverter can also operate at 1.2MW and 10MW of inverters can operate at 12MW of capacity. This ensures that the output of the solar project will be close to the contracted capacity even for mornings and evenings. For afternoons, when the solar radiation will be at its peak, then the solar plant will generate the 12.5MW equal to its DC capacity. Now the inverters will be only capable of inverting 12MW of DC power to AC power, whereas the input is 12.5MW in our case. This additional 0.5MW power may get clipped off by the inverter.

The plant load factor (PLF) will be calculated on the DC side in the following manner:

PLF_{DC} = 12.5MW*1700)/ (12.5MW*365*24)

$$PLF_{DC} = 19.4\%$$

The PLF for the contractual purposes will be calculated on the contracted capacity in the following manner:

$$PLF_{AC} = (12.5MW*1700)/(10MW*365*24)$$

$$PLF_{AC} = 24.2\%$$

In this arrangement, the DC AC ratio is 1.25 and has the following implications:

- Higher EPC cost
- More land area requirement
- Better loading of inverters during morning/evening times, thus better efficiencies
- Slightly reduced PLF_{DC} because of clipping of solar power during afternoon time by inverters
- Better PLF for the contracted capacity.

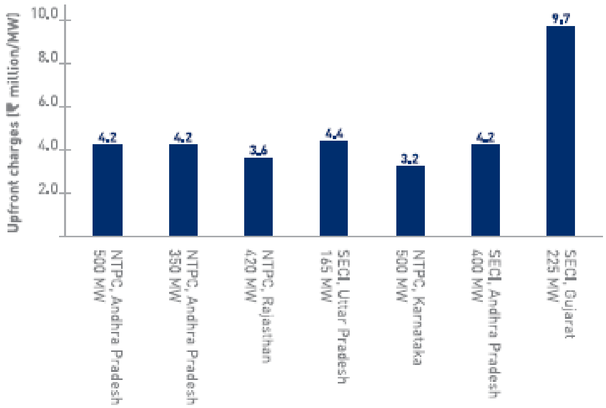
The paper will demonstrated the selection of the right DC AC ratio in further details. It is also to be noted that there has been tenders in India where the injected power capacity at the interconnection point of the grid was constrained to be equal to the contracted capacity. In such case the DC AC ratio has to be kept equal to 1.

Also in this case, we have demonstrated the numbers assuming the availability of infinite piece of land and so there was no impact of inter-row shading in the solar plant. In practical cases the land acquisitions is the biggest challenge. The first solar park of India at Charanka Gujarat is land constrained and the every developer gets at ~4.5 acres/MW of land[4]. So if a developer installs more MWp than the contracted MW, then there is bound to be losses during the inter-row shading as the developer will be compelled to squeeze the more MWp of solar modules in the same area. Also, developer has to take an extremely optimum calculation to estimate the right mounting structure. As a general experience of the solar park, we can say that it is not feasible to set up single axis solar tracker and the developer shall go for seasonal tilt system. But we will infer the same by our calculations by demonstrating in coming sections.

III. Calculation of DC AC Ratio

The Charanka solar park in Gujarat is India's first solar park where developers can come and set up the solar plant. The solar park offers land, evacuation infrastructure, common security, water supply etc. The concept of solar parks has reduced the project development risk as now the land and evacuation are pre-arranged by the solar park development authority. But these facilities come at a cost and relatively the solar park charges in Gujarat are amongst the highest in the solar parks of India[3].

Figure 7: Solar park charges (excluding service tax)



We will infer at the best possible combination of technology by representing the results in Table 1. The representation of the information in matrix will help in determining the right technology combination and the optimum DC AC ratio to estimate the bidding tariff for financial returns at 12%.

A. *Key Assumptions*

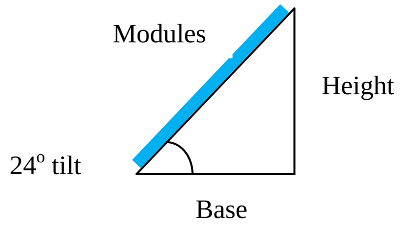
1. The tilt is taken as 24degrees.
2. The shadow affect is taken as 1.5 times the height of the table.
3. The poly-crystalline module technology is used as the same has been almost exclusively used for all the solar projects in India.
4. The ongoing rate of EPC cost is 3.2 Crores/MWp with poly-crystalline modules[3]. However, the developers have been making the aggressive assumptions on the module prices and targeting to achieve the EPC cost at even Rs. 2.9 Crores/MWp 5 months down the line when the construction of the plant will be required to start.
5. Some of the other assumptions are tabled below:

Cost of tracking system	0.50 Cr/MWp
O&M Cost	3 Lakhs/MWp
Interest Rate	9.30 % for 18 years
Equity IRR targeted	12%

1) *Calculation of Pitch*

Mod Capacity	310 Wp
Mod Size (in mm)	1956 x 992
Table Size	2 in portrait config
	3937 mm
Cos 24	0.914
Sin 24	0.407
Base	3596 mm
Height	1601 mm
Shadow Effect	2402 mm
Provisional Pitch	5998 mm
Plot Area available	4.5 Acres/MW
	18211 m^2/MW
Even for the highest DC AC of 1.3, area required	12,596m^2/MW
Pitch	8.67 m

The area required is much less than the area available that means we can increase the provisional pitch calculated at 5998mm and the same has been re-calculated at 8.67 m. The result of different energy yield for different technology combinations is given in Table 1.



B. Results

Table 1 represents the results from the analysis with different DC AC ratio and mounting structures.

Tracker Type	**DC AC Ratio**	**kWh/ kWp / Year**	**Tariff (Rs./kWh)**
Fixed	1.3	1764	3.248
Fixed	1.26	1767	3.262
Fixed	1.22	1770	3.276
Fixed	1.18	1771	3.296
Fixed	1.14	1771	3.319
Seasonal	1.3	Not Feasible	
Seasonal	1.29	Not Feasible	
Seasonal	**1.28**	**1830**	**3.140**
Seasonal	1.27	1832	3.141
Seasonal	1.26	1833	3.144
Seasonal	1.24	1836	3.149
Seasonal	1.22	1838	3.155
Seasonal	1.18	1840	3.173
Seasonal	1.14	1841	3.193
Tracker	1.3	Not Feasible	
Tracker	1.26	1840	3.511
Tracker	1.22	1846	3.519
Tracker	1.18	1847	3.538
Tracker	1.14	1848	3.558

The above table clearly indicates that the lowest bidding tariff should be Rs. 3.14/kWh which is realizable using a seasonal axis tracking system for given financial assumptions.

The combinations which are not feasible are due to the better insolation on the plane of array, leading to better generation. The higher current generated as a result is exceeding the inverter's operating range.

The PLF_{DC} and PLF_{AC} calculated for the above mentioned case are 20.89% and 26.80% respectively. The PR ratio for the same is 78.2

IV. Acknowledgment

The views and opinions expressed herein are those of the authors and do not necessarily represent the official views of the Feedback Infra Pvt Ltd, GIZ and Smart Roof Solar Solutions Pvt Ltd.

References

The paper represents the first hand views, market experience by stakeholder consultations and experience of the authors who have specific experience in the bidding activities. Some of the references used are:

[1] Solar cell and module manufacturing capacity, MNRE, Jan 2017
[2] Market Research and self analysis of the industry
[3] Bridge to India, Tender Reprt – Mar 2017
[4] GSEB Gujarat 150MW solar tender document, 2017