Capacity Value of Wind Generation in India - An Assessment

Executive Summary

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Executive Summary

A two fold increase in the conventional generation capacity over last decade in India is accompanied by an eight fold increase in the installed renewable energy (RE) capacity. Today, India stands at the 5th position globally in the wind power generation installed capacity. The officially estimated wind power potential at 80m hub height is 102 GW[1]. However, a number of recent independent reports suggest that this potential could well be beyond 1000 GW. Further, solar is regarded as a resource with unconstrained potential. With the launch of Jawaharlal Nehru National Solar Mission (JNNSM) launched in 2010, the installed solar capacity has increased multi-fold reaching 1.8 GW in July 2013. The ever increasing power demand in the country coupled with energy security, energy access and environmental concerns strongly suggest increasing the contribution of renewable energy sources in the overall generation mix. It is noteworthy that in the year 2013, installed wind and solar capacities constitute about 13% of the total electricity generation capacity in the country and are expected to hold significant share in future too. In 2012-2013, RE plants in the country contributed 4.7% to the overall generation mix.

The renewable energy markets in India can be transformed if we work to solve issues such as unstable policy environment, absence of land procurement frameworks, inadequate transmission network and its planning, absence of supportive grid integration rules, and limited state-centre coordination.

Motivation for the study

Even though wind and solar power contribute significantly to India's electricity generation mix, these resources are not attributed a capacity value in the capacity addition plans of the Government of India. The 12th five-year plan targets to add 15,000 MW of wind capacity over 2012-17. It also recommends of a National Wind Mission to accelerate tapping the huge wind potential of the country. The JNNSM aims to add another 9000 MW of solar in the second phase of the mission, that is, 2013-17. Above all these, Government of India's National Action Plan on Climate Change (NAPCC) envisages to achieve 15% RE in India's electricity generation mix by 2020. However, these targets are additional to the required capacity and are only valued in energy terms. Attributing a capacity value to RE sources assume importance primarily because of the following reason: if the capacity value of wind generation is estimated at say 15% in a particular region (for 100 MW of installed wind capacity), this implies that instead of 1000 MW of base load capacity required to be installed; now 985 MW will need to be deployed as 15 MW will be met through wind.

Looking at the increasing contribution of RE sources to the national energy mix, and their potential to solving India's environmental concerns, it is essential that these sources, particularly wind and solar, be ascertained a capacity value while formulating our power sector plans. While this phenomenon is common in several other countries, it still needs to make place in India's planning framework.

Therefore, this analysis focuses on assessing capacity value of wind generation mainly because it is considered to be more variable than solar. However, a similar analysis is equally imperative case for solar as well.

[1] At 80m level, source: http://www.cwet.tn.nic.in/html/departments_ewpp.html

Objective

The study aims to address the following major objectives:

- To estimate the contribution of wind power in meeting the base load requirement and electricity shortages
- To attribute “certainty” value to wind generation so that capacity addition plans can be optimized by substituting appropriate percentage of installed and planned wind capacity with equivalent conventional capacity
- To facilitate integration of RE with India’s power sector planning by mainstreaming RE into the power sector

Methodology

Understanding the variability in power generation from RE sources and accounting for the contribution of RE generation in meeting the peak demand is becoming important in developed countries as the installed capacity of RE based power plants is increasing. The methodology followed in this study for estimation of capacity contribution of wind power is an adaptation of the methodologies used internationally for this purpose and is considered appropriate, given the data constraints. This study assesses the capacity value of wind generation in India to quantify its contribution in meeting the peak power demand. It is noteworthy that a similar term ‘capacity factor’ is the ratio of the actual energy produced by a generator in a given period, to the hypothetical maximum possible, i.e. running full time at rated power whereas capacity value implies a different meaning as already explained.

The approach followed for the study involves determining correlation between wind generation and the state’s peak power demand in six key wind-rich states over three financial years (FY10, FY11 and FY12). The analysis has been carried out in various scenarios[2] differing in methodology for calculating the critical hours of power demand in these three years. Hours in power demand is highest or is needed the most have been referred as critical hours.

Further, capacity contribution of wind generation for the overall wind resource base in the country and wind capacity planned at the end of each five-year planning period has been estimated. Also, the planned conventional generation capacities (as per the targets laid down in NAPCC) that could potentially be replaced by the estimated capacity value of wind at the end year of 12th, 13th, 14th and 15th planning period have been estimated.

Modelling Assumptions

For the study, it is assumed that in all the selected states – Rajasthan, Gujarat, Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu, there is 100% power evacuation from wind plants. It is assumed that all inter-state transmission constraints will be resolved in the coming years (by end of 12th Five Year Plan) thus no such constraints between states have been incorporated in the modelling. ToD definition of peak hours represents the best estimate of critical hours for system reliability under scenarios considered for calculation of capacity value of wind. Average hourly generation of wind plants for all three years (FY10 to FY12) has been computed using wind resource data obtained from AWS Truepower. The

[2] explained in detail in the main report

wind frequency distribution and density has been converted into potential power generation for each wind area by using the power curve of G97 Gamesa wind turbine as it represents the wider turbine installation base in India. However, other turbines similar in capacity, hub-heights and size could also be used to carry out this analysis. Hub-height of 90m has been considered for the calculation. Representative sites in each state have been assumed to represent average wind capacity value of all the wind plants in the state.

Limitations

Met load data has been used as substitute to unrestricted demand data for all states except Tamil Nadu, for which load shedding data for one year is available. For the estimation of critical hours under scenario 1 as defined in the section below, Time of Day (ToD) tariff hour definition by respective DISCOMs has been considered. For states where ToD tariff is unavailable, peak hour definition from respective Regional Load Dispatch Centre (RLDC) has been considered. In addition, the results derived in the analysis are limited by some factors listed below[3]:

- Long term monthly power demand pattern and overall demand scenario
- Long term power supply scenario
- Daily load profile or change in peak hour definition as per ToD
- Transmission or power evacuation constraints
- Size and efficiency of turbine
- Wind farm site selection
- Additive effect of wind generation within a wind farm
- Curtailment of wind energy
- Wake effect in wind farm
- Scenario with firming up of wind power with other sources
- Impact of grid integration

Scenario Definitions

The analysis has been undertaken under four scenarios, which differ mainly on the method of critical hour calculation. In the **first scenario**, critical hours were estimated based on time periods having lowest system reliability by taking ToD tariff definition of Peak hours from respective states while in the **second scenario** critical hours were estimated by considering top 10% hours in Load Duration Curve (LDC) plotted using Met Load data. The **third scenario** could be worked out only for Tamil Nadu because of data constraints. In this scenario, critical hours were estimated by considering top 10% hours in LDC plotted using Met plus Un-Met demand data.

In addition to these, a **fourth scenario** was also analyzed to understand the contribution of wind power from each of the six states to the national-level peak power demand. The pan India demand constituted demand of 14 states (Maharashtra, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat, Karnataka, Rajasthan, Madhya Pradesh, Punjab, West Bengal, Haryana, Delhi, Orissa and Kerala) which accumulate to 90% of national demand. The critical hours were estimated based on common ToD hours of above mentioned 14 states.

[3] explained in detail in the main report

Results

Based on the above assumptions and scenario definitions, capacity values of wind for the sites under study in the six key wind rich states have been calculated through MS Excel based model. The table below summarizes the results:

Table 1 Capacity Value of Wind Generation for six key wind states

S. No.	State	Site	Capacity Value Scenario 1	Capacity Value Scenario 2	Capacity Value Scenario 3	Capacity Value Scenario 4
1	Tamil Nadu	Muppandal	24-31%	21-28%	18-19%	~24%
		Coimbatore	19-24%	20-23%	15-16%	~22%
2	Gujarat	Kutch	22-23%	~25%	-	~29%
		Saurashtra	25-28%	~26%	-	~30%
3	Andhra Pradesh	Ramasagaram	25-27%	~17%	-	~25%
		Anantapur	20-29%	~18%	-	~26%
4	Maharashtra	Satara	18-36%	~18%	-	~25%
		Somnath Nagar	14-28%	~26%	-	~21%
5	Karnataka	Chitradurg	30-31%	~25%	-	~29%
		Gadak	18-19%	~17%	-	~19%
6	Rajasthan	Jaisalmer	16-17%	~20%	-	~22%
		Ludurwa	13-15%	~17%	-	~19%

Wind power plant capacity addition as per National Action Plan on Climate Change (NAPCC) targets for 2020-2030 and its contribution that could potentially replace the conventional capacity at the end year of 12th, 13th, 14th and 15th planning period is shown in Table 2 and Table 3 below. Wind power contribution has been calculated based on the capacity value of wind estimated in Scenario 4 analysis.

Table 2 Wind capacity at the end of each planning period (in MW)

Capacity (Wind)	2011*	2012	2016	2021	2026	2031
NAPCC Complaint	14,986	17,986	35,266	75,266	1,40,266	2,25,266

* ending year of the corresponding National Five Year Plan

Table 3 Wind capacity contribution at the end of each planning period (in MW)

Capacity Contribution (Wind)	2011*	2012	2016	2021	2026	2031
NAPCC Complaint	3,583	4,323	8,668	18,536	33,928	54,373

* ending year of the corresponding National Five Year Plan

Thus, the potential contribution of wind power to national generation capacity has been estimated to be about 54 GW by 2031.

The Way Forward

This study lays a foundation for developing an understanding of the Wind Capacity Value concept in the Indian scenario. In view of the emerging RE sector, the study explains the importance of quantifying wind power share and estimates the wind capacity value range for various wind rich sites in the country. It strengthens the role of wind power in meeting national peak power demand and hence establishes the need to incorporate wind power to India's National power capacity planning. However, this analysis is developed with some assumptions and power shortage data limitations as mentioned above. Thus, a more detailed study through pertinent probabilistic models is recommended for determining the accurate capacity value contribution of the installed and planned wind generation capacity in the country. Such a comprehensive study would involve significant data requirement and stakeholder's involvement. Data on a number of parameters such as unrestricted demand, shortage, and unrestricted load profile for each state at hourly level, monthly forced outage rate of generators, conventional and non-conventional plant average monthly availability etc will be needed. The resulting extensive analysis would aid in realizing higher capacity value of renewable energy resources and avoiding larger conventional generation capacity through a number of policy and regulatory measures.

About the study

The study has been supported by Shakti Sustainable Energy Foundation and carried out by ICF International (www.icfi.com).

About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to secure the future of clean energy in India by supporting the design and implementation of policies that promote both the efficient use of existing resources as well as the development of new and cleaner alternatives. Shakti's efforts are concentrated in four specific areas: power, energy efficiency, transport, and climate policy. The organization acts as a systems integrator, bringing together stakeholders in strategic ways to enable clean energy policies in these fields. It also belongs to an association of technical and policy experts called the ClimateWorks Network. Being a member of this group further helps Shakti connect the policy space in India to the rich knowledge pool that resides within this network.

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