Wind power development in India

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India has been making rapid strides in the addition of wind power supported governmental policies and regulations by the central and state regulatory commissions. Although it is widely recognised that wind energy is the cleanest form of energy, there are some perceptions in some quarters, which often puts hurdles in quick addition of the wind power into the power system. The paper attempts to state some of those perceptions and the realities with the support of data collected over a years’ time at one major wind farm in India.

The development of wind power in India began in the 1990s, and has significantly increased in the last few years. The power sector in particular has seen a paradigm shift in recent years. The Indian Electricity Act 2003 and power sector reforms have changed the scenario, emphasizing the performance and efficiency of power utilities. The principles of merit order dispatch and introduction of power trading are some drivers of change. The entry of private sector in generation, transmission and distribution sectors, as well as a promotional tariff and incentives for renewable sources of energy, have changed the power sector. The generation mix consisting of different fuels, different technologies, and different forms of renewable energy has brought new operational challenges.

Although the emphasis is still on the coal based power plants, attention to the clean development mechanism has necessitated that energy planners consider development of clean energy sources. India is the first country in the world to establish a separate Ministry of Renewable Sources, which underscores the importance given to the development of renewable sources of energy. In terms of the installed capacity of wind India has the fifth largest wind generation capacity in the world. Out of an identified potential of wind power of 48 560 MW in the country, installed capacity of 14 000 MWs expected to be achieved by March 2011.

The installed capacity of power from all sources and the share of wind power are given in Table 1. A large potential and sites still remain to be harnessed. To achieve efficiency and economy there needs to be a clear perception of the issues involved in the planning and operation of wind farms in respect of power evacuation systems. Some of the common myths in this arena and the facts are described in the succeeding paragraphs.

Perceptions and facts

Perception 1: Wind power generation suddenly dips to zero as and when wind stops blowing.

Wind power generation from a large wind farm never dips suddenly to zero owing to the geographical dispersion of the several wind turbine generators (WTGs). The wind could stop blowing at a single wind turbine and not at the entire wind farm site. Therefore, as the wind blowing across a wind farm drops, WTGs would experience slowing down sequentially, and there will be a steady decline in power production spread over a considerable time period. This time should be sufficient for the system operator to take remedial actions.

Fig 1, which shows the variations in generation over a day and over a period of few days in high wind season at a major wind farm, would explain the above phenomenon.

If you consider the larger picture with more wind farms in a state power system, the rate of decline in power output could be even less. Thus, wind can be harnessed to provide near reliable electricity even though the wind is not available 100% of the time at one particular site. If at any time the lines emanating from the wind farm trips, there could be sudden loss of power, which is identical to loss of generation. Such a contingency is not an alien one to power system operators who always deal with uncertainties.

Variations in wind energy are smoother, because there are hundreds of WTGs in a wind farm. When there are thousands of such units in a state power system the variations would be further smoothened out. Apart from the above, the system will not notice the shut-down of few WTGs of 2,1/1,5 MW capacity, but it will have to respond to the shut-down of a 500 MW coal fired plant or a 500 MW nuclear plant instantly.

Perception 2: Wind power generation occurs only when it is needed and is not there when it is needed.

Since sustained high wind speeds are predominant during the south west monsoon season (from May to September), generation from wind farms would be maximum during this period. While it may rain in few parts of the state where the wind farm is located, there may be several parts of the same state which are not covered by monsoon. In other words there will be low demand (mainly due to lack of demand from agriculture loads) in those rainy areas, while in other parts of state, load demand will not vary much. The data collected at one of our wind farms (Installed capacity of 250 MW) over a long period indicates that the wind energy has been assisting the grid in times of low frequency (high demand). For the study, a time frame of about 18 months is chosen. The above period is split into two periods viz. prior and post the Indian electricity grid code (IEGC) (May 2010) periods. In the pre-IEGC period, the percentage time the frequency was below 49.5 Hz was 36%. In both the periods it can be seen that the wind energy has been assisting the grid in times of low frequency (high demand). For the study, a time frame of about 18 months is chosen.

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![Table 1: Installed generation capacity.](image)
the total energy from the wind farm was generated below 50 Hz in the pre-IEGC period and post IEGC period respectively.

Perception 3: Wind farm operation always causes severe voltage dips in the grid.

The WTGs of Suzlon are of the induction generator type operating with soft start facility. They are equipped with reactive power support, which varies automatically to ensure that the WTGs operate near unity power factor and therefore do not draw reactive energy from grid while operating. During start up of WTGs, all of them are not taken into service simultaneously but in a phased manner so that the grid voltages are not affected. This ensures a stable voltage profile near to the wind farm. The actual measurements of voltages in one of our wind farms (250 MW capacity) are shown in Fig. 5.

It can be seen that the voltages are normal throughout the high generation as well as low generation periods. It may be appreciated that the time voltages were beyond 103% (of rated) are much more than periods of low voltage (Less than 97% of rated). The above readings were obtained through deployment of ABT based metering system at these substations. Since the WTGs do not draw reactive energy from grid, the reactive power drawn from the grid at a wind farm would solely cater for the requirements of the interconnecting transformers at the wind farm substation. However, Suzlon conducts power system studies on the grid to which the wind farm is proposed to be connected for ascertaining the voltage profile in two scenarios viz. without the wind farm connected and with the wind farm connected and arrive at the compensation to be provided at the wind farm substation. The study results will be compared with the actual field conditions and the study will be revised appropriately, if required. Services of reputed consultants in the field are taken.

Perception 4: If a wind farm has interconnecting transformer capacity of 300 MVA, the connected generation should be 90% of the transformation capacity.

As the wind farms are distributed over large geographic area the maximum generation at any given time depends on geographical spread. As the size of the wind farm goes up, the WTGs do not produce peak power at the same time and the peaks of individual machines get distributed over different periods of time. Therefore the capacity factor for a wind farm of a large size of say 150 MW and above, the capacity factor of about 80% would be touched during high wind season. Where the wind farm size is smaller, following can be considered for planning of infrastructure.

- 100% capacity factor for wind farms connected below 66 kV (up to 50 MW)
- Minimum 90% capacity factor for wind farms connected at 66 kV or 110 kV or 132 kV For large wind farms connected to 220 kV system minimum of 80% capacity factor need be considered for planning the power evacuation.

This is based on the available data and the experience world over. The data acquired in one of the major wind farms by us confirms the above observation. Some of the utilities have accepted the above consideration for planning and do allow connecting WTGs of capacity (MW) more than the transformation capacity of the substation.

Perception 5: In wind farm substations the interconnecting transformers should have 100% redundancy.

It would be appropriate to consider the group of WTGs connected to the grid as a consolidated unit and the interconnecting Transformer at the wind farm substation should be treated identical to a generator transformer (GT) for the purpose of assessing reliability requirements. The transformers which are used in wind farm substations are available in standard sizes.
As the average capacity factor is very low (in the order of 20%) and only during very short periods the capacity factor touches 80%, the required transformation capacity is achieved by providing two or more transformers depending on the size of the wind farm. This will also ensure that during low wind season one or more transformers could be switched off judiciously without affecting the power evacuation to reduce the reactive power consumption by the transformers in the wind farm substations.

Perception 6: The inter-connecting line from the wind farm to the grid should have redundancy similar to conventional power stations.

CEA's manual on transmission planning criteria that was brought out in 1994 does not deal with the requirements of transmission system for evacuation and grid connectivity of wind farms and thus need to be updated to include various requirements specific to evacuation of power to the grid. As wind generation has low capacity factor in the range of 15 - 20% (unlike conventional power stations who have more than 80% capacity factor), transmission planning for wind projects should be different from conventional power projects. N-1 reliability criteria for the power evacuation line at 220 kV from conventional power stations means redundancy in the tower. In other words if a 220 kV DC line is sufficient to evacuate power, another double circuit line is to be provided for redundancy. Same criteria should not be applied to power evacuation from wind farm substations due to the low capacity factor. When one 220 kV Tie line is sufficient for power evacuation, insisting on a redundant tower is not justified. A redundant circuit could at the most be sufficient. Above was proposed in the draft IWGC also.

Some more facts that need consideration

Ampacity of conductors

The norms for selecting the conductors for the lines connecting the wind turbine generators (WTG) to the wind farm pooling substation are not uniform across the country. Different practices are followed in the states. For example, the ACSR panther conductor is permitted for evacuating 25 MW (at 33 kV) in one state while in another state the limit is up to 10 MW for the same length of line. The rationale, based on technical considerations is often ignored. The guidelines on conductor current carrying capacity applicable for power evacuation from conventional power stations under conservative conditions of high ambient temperature, zero wind or low wind speed and high solar irradiation (as per CEA's transmission planning criteria) are applied to wind power evacuation also. The wind energy generation depends on the velocity of wind. The WTG would give its rated output at wind speeds of 12 m/sec to 14 m/sec and the same wind blows in the vicinity where the 33 kV lines for power evacuation from WTGs are laid. There is no wind energy generation below speeds of 3.5 to 4 m/s.

Therefore the conservative norms for evacuation of conventional generation should not be applied to wind generation. Even at 4 m/sec speed of wind the current carrying capacity of the conductor goes up substantially as compared to still wind, because of the cooling effect on the conductors. The high wind generation is generally associated with low ambient temperatures (late evening/night) and this factor allows loading of the conductors to a much higher value than the values arrived at from assumptions of...
conservative conditions. As an example, the current carrying capacity of ACSR panther conductor is 500 A at wind speeds of 1 m/s while the same conductor could easily carry 780 A at wind speeds of 4 m/s, because of the cooling effect of wind.

These calculations are based on the IEC 61597. IEEE 738 also recommends similar approach, which was suggested in draft IWGC for adoption for deciding the wind power evacuation infrastructure. The above methodology need be standardised for arriving at the design of the lines from the WTGs to wind farm pooling Substation. This would lead to uniform practices among states. Due to lack of uniformity, presently there are delays in approval and consequential delays in execution of work.

Wind energy installations are generally at remote areas and could feed the local loads similar to distributed generation. Therefore, to a certain extent, it can reduce transmission and distribution (T&D) losses of the state power network. For this reason, Power evacuation scheme for the wind power need to be part of the long term plan (5 years) and annual budget exercises of State Transmission Utilities (STU).

Wind power generation with increased penetration may require evacuation systems at 220 kV, 400 kV in some states. Therefore the regional power system planning committee of CEA should also be appraised of the plans and the committees' approval sealed within a reasonable time frame, commensurate with the execution time frame of the wind farm. This should be part of Annual Revenue Requirement (ARR) of STU or a separate transmission tariff should be available to investor.

The metering location for billing and meter specification differs from state to state and these need to be standardised pan-India.

Conclusions

The CERC has already mandated the Central Electricity Authority (CEA) to issue regulations pertaining to grid connectivity of wind turbine generators and wind farms. But the aspects pertaining to planning issues are apparently not being reviewed. In view of perceptions (described above) that are prevalent in the technical community, it is time that the CEA comes out with a separate power system planning criteria for the wind power evacuation.

There should be uniform technical regulations pan India for deciding the ampacity of conductors and metering at state and regional level. The planning process for wind power planning at state and regional levels should involve the developers.

Power system studies for connectivity of wind farms should be entrusted to independent and reputed organizations which do not have stakes in the power system to be developed, but are guided by principles of overall economy and efficiency of power sector.

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References


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