Grid integration of wind turbines: What happens when the wind stops blowing?

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POWERED BY WIND

The ‘intermittency’ myth

Wind power is sometimes incorrectly considered as an intermittent energy source. This, however, is misleading. Intermittent means ‘on or off’. Even in extreme conditions, such as storms, it takes several hours for wind turbines in a system area to shut down. Moreover, periods with zero wind power production can be predicted and the transition to zero power is gradual[1].

The term ‘intermittent’ is therefore inappropriate for system-wide wind power and the term ‘variable-output’ should be used instead .

Because the wind resource is variable, this is sometimes used to argue that wind energy is not reliable per se. No power station or supply type is completely reliable; all system assets fail at some point. In fact, large power stations that go offline do so instantaneously, whether by accident, by nature or by planned shutdowns, causing loss of power and an immediate requirement to restore power. When a fossil or nuclear power plant trips off the system unexpectedly, it happens instantly. That is true intermittency. Power systems have always had to deal with these sudden output variations of large power plants as well as the variable demand. By contrast, wind energy does not suddenly trip off the system. Variations in wind energy are smoother when there are hundreds or thousands of units rather than a few large power stations, making it easier for the system operator to predict and manage changes in supply as they appear within the overall system.

The system will not notice the shut-down of a 2 MW wind turbine. It will have to respond to the shut-down of a 500 MW coal fired plant or a 1,000 MW nuclear plant instantly[1].

European experience

The main conclusions are that the capacity of European power systems to absorb a significant amount of wind power is determined more by economics and regulatory rules than by technical or practical constraints1. It is more accurate to state that larger scale penetration of wind does face barriers; not because of its variability, but because of

a series of market barriers in electricity markets that are neither free nor fair, coupled with a classic case of new technologies threatening old paradigm thinking and practice. Already it is generally considered that wind energy can meet up to 20% of electricity demand on a large electricity network without posing any serious technical or practical problems1.

Since wind energy is a technology of variable output, it needs to be considered as just one aspect of a variable, dynamic electricity system. At modest penetration levels, the variability of wind is dwarfed by the normal variations of the load. It is impossible to analyze wind power in isolation from other parts of the electricity system – and all systems differ. The size and the inherent flexibility of the power system are crucial aspects in determining the system’s capacity to accommodate a large amount of wind power[1].

Cost of variability

Three reports on the wind variability in the UK, issued in 2009, generally agree that variability of wind needs to be taken into account, but it does not make the grid unmanageable; and the additional costs, which are modest, can be quantified[2].

Several options exist for ‘smoothing’ and lowering the cost of wind variability:

- Improved methods of wind prediction are under development worldwide and could potentially reduce the costs of additional reserve by approximately 30%.
- Geographic diversification and inter-connection of renewable energy sources and generation connections.
- The use of Smartgrids and Supergrids, delivering system-wide benefits and aid the assimilation of variable renewables.
- Electric cars hold out the prospect of reduced emissions for the transport network as a whole and could act as a form of storage for the electricity network.
- Pumped Storage. Although pumped storage power systems are only about 75% efficient and have high installation costs, their low running costs and ability to reduce the required electrical base-load can save both fuel and total electrical generation costs[3].

Capacity credit of wind power in South Africa

South Africa is facing severe generation capacity constraints. Power stations need to be upgraded and new ones built to cope with the growing South African economy in a world where climate change and its predicted impact, such as water scarcity, will increasingly impact on the choice of energy sources and technologies. Wind power generation does not need water and by its nature is a clean source of energy.

Questions are rightly being asked regarding the potential contribution of variable-output wind power to system security, which is defined as the capacity credit of wind. The capacity credit of wind is estimated by determining the capacity of conventional plants displaced by wind power, while maintaining the same degree of system security. In other words, it is an unchanged probability of failure to meet the reliability criteria for the system. Alternatively, it is estimated by determining the additional load that the system can carry when wind power is added, maintaining the same reliability level.

1 LARGE SCALE INTEGRATION OF WIND ENERGY IN THE EUROPEAN POWER SUPPLY: analysis, issues and recommendations, EWEA Report, December 2005
2 Jo Abbess (2009-08-28). “Wind Energy Variability and Intermittency in the UK”. Claverton-energy.com
3 The Future of Electrical Energy Storage: The economics and potential of new technologies 2/1/2009 ID RET2107622

The Department of Energy, and Eskom, with the assistance of Windlab and GIZ funding, collaborated and undertook two studies[4]:

1. **Impact of Wind Generation in South Africa on Capacity Planning**
2. **Impact of Wind Energy in South Africa on System Operation**

The studies presented in this report are based on three scenarios:

- Scenario 1: Year 2015, 2000MW installed wind generation capacity
- Scenario 2: Year 2020, 4800MW installed wind generation capacity
- Scenario 3: Year 2020, 10000MW installed wind generation capacity

For each of the three scenarios, the average loss of load probability (LOLP) at the daily peak load has been calculated and has been used as the relevant reliability index for assessing the capacity credit of wind generation in South Africa. (LOLP Is a measure of expectation that system demand will exceed capacity during a given period, often expressed as the expected number of days per year. E.g. one day in 10 years.)

The resulting capacity credit (CC) figures for the different scenarios are:

- Scenario 1: Year 2015, 2000MW installed wind generation capacity, CC=26,8%
- Scenario 2: Year 2020, 4800MW installed wind generation capacity, CC=25,4%
- Scenario 3: Year 2020, 10 000MW installed wind generation capacity, CC=22,6%

From Scenario 3 it follows that 10 000 MW installed wind capacity by 2020 would result in a capacity credit of 22,6%. This mean that the generation capacity online which can be attributed to 10 000 MW wind installed, while maintaining the same system reliability, would be 2260 MW (22,6% of 10 000 MW)

With increasing wind penetration levels, the capacity credit of wind generation will drop.

Based on Scenario 3 (year 2020, 10 000MW of installed wind capacity), an assessment has been carried out by scaling the 67 modeled wind farms up to a totally installed wind capacity of 25 000MW. The resulting capacity credit is equal to 17,6%.

Comparing these figures with the availability indices of newly planned coal-fired power stations in South Africa that have a combined planned/unplanned outage rate of approximately 11%; the contribution of an average wind farm in South Africa to the equivalent firm capacity of the system will be in the following range:

- Scenario 1: CC=29,8%
- Scenario 2: CC=26,1%
- Scenario 3: CC=25,1%

When comparing the capacity credit of wind generation to older coal-fired power stations with a combined planned/unplanned outage rate of around 20%, the capacity credit of wind generation will be around 33,5%, 31,7%, and 28,2% for Scenario 1, Scenario 2 and Scenario 3 respectively.

The second part of the presented studies analyzes the impact of wind generation in South Africa on the residual load, which is the remaining load that must be supplied by thermal and hydro power plants.

The analysis mainly focused on:

- Worst case situations with regard to wind and load variations, and
- The impact of wind generation on dynamic performance requirements.

The results of the corresponding studies lead to the conclusion that:

- Hourly ramp-up and ramp-down rates of the residual load are comparable to the corresponding ramp rates of the system load (without wind generation), and
- There are no increased dynamic performance requirements for the existing thermal power plants in South Africa.

The main impact on system operation will be a result of the limited predictability of wind speeds and not of absolute wind speed variations. The limited predictability of wind generation will result in an increased forecast error of the residual load compared to the present load forecast error.

Several factors will have an influence on the accuracy of wind prediction: some of them are related to the spatial distribution of wind generation and some of them to the actual wind prediction system that will be put in place for supporting the operation of the South African power system. Therefore, additional studies are required that simulate the behavior of a wind prediction system in order to obtain indicative values for the required increase of the load following reserve.

In conclusion, it can be stated that the capacity credit of wind generation in South Africa will be between 25% and 30% for installed wind generation of up to 10 000MW. In the case of higher wind penetration (25 000 MW), capacity credit of wind generation in South Africa will drop below 20%.

Based on part 2 of the presented studies it can further be concluded that it is very likely that it will be possible to operate the system safely without increased dynamic performance requirements for the conventional power plants of South Africa. However, the use of state of the art wind prediction tools for assessing the required load (and wind) following reserves will be important. This second aspect requires further, more detailed studies that model the dynamic performance characteristics of the South African power plants in more detail for ensuring the safe operation of the South African power system under all credible operating conditions.

4 Capacity Credit of Wind Generation in South Africa, Final Report, DoE, GTZ, Eskom, February 2010

Grid integration of wind power in South Africa

Having demonstrated that wind farms could contribute to firm capacity, the question arises whether a potentially large volume of wind turbines can technically be integrated with the electricity network.
The Western Cape is one of several South African regions with a particularly high wind regime. The Western Cape Provincial Department of Environmental Affairs and Development, in collaboration with Eskom and GIZ undertook, with GIZ funding, high level feasibility studies for analyzing the impact of up to 2 800 MW of wind generation in the Western Cape on the 400 kV transmission grid[5].

The results show that no considerable impact on the transmission grid has to be expected and that it will be possible to accommodate such a high level of wind generation without any major upgrades of the 400 kV transmission grid.

At the same time it is understood that the transmission capacity of sub transmission and distribution grids (voltage levels <=132 kV) will be limited in some cases and that major network upgrades at these lower voltage levels will be required.
In order to confirm the results of these initial feasibility studies, additional, more detailed studies will be required, especially on the basis of well approved low load scenarios.

Furthermore, studies looking at operational aspects such as additional spinning reserve requirements, stability aspects, and dynamic performance requirements for peak load power, for example, have to be carried out in order to confirm the feasibility of wind generation of up to 2800 MW in the Cape.

However, many general aspects of the Western Cape system, such as the availability of peak-load power plants (gas turbine) in the Cape; generators allowing for synchronous condenser operation, and the fact that wind generation in the Cape will reduce power imports into the Cape, can lead to the conclusion that the Western Cape transmission system is generally very well suited for the integration of high amounts of wind generation, definitely even if some of these aspects still have to be confirmed by additional, more detailed studies.

Eskom Generation Connection Capacity Assessment of the 2012 Transmission Network (GCCA-2012)

Eskom, in an effort to assist developers of new generation regarding clarity on available connection capacity, produced Generation Connection Capacity Assessment of the 2012 Transmission Network (GCCA-2012)[6]. The GCCA shows connection capacity on existing networks which will assist developers in their own evaluation of project viability and timing.

Figure 1 shows how much generation could be connected at each substation based on the expected 2012 network:

Fig 1

Area	Level 1	Level 2
Western Cape Zone	2 988 MW	4 100 MW
Eastern Cape Zone	1 042 MW	1 600 MW
Northern Cape Zone	129 MW	1 000 MW
Total	**4 159 MW**	**6 700 MW**

Level 1:
(As quickly as possible – e.g. REFIT, 2013)

Connect generation at 132 kV level or lower as soon as possible with no transmission reinforcement. This is the only possible way to connect large amount of renewables before end 2013.

Level 2:
(Targeted projects: 2014 - 2019)

Target medium-term large generation projects that can be connected directly to the existing 400 kV transmission substations and corridors with relatively minimal localized transmission work.

Grid Code requirements for wind turbines in South Africa

'Grid Code requirements for wind turbines connected to distribution or transmission systems v4.4', published by NERSA[7], sets the technical connection conditions for Wind Energy Facilities (WEFs) connected to the South African electricity transmission or distribution networks. It sets out the rules and obligations to which participants must comply in order to connect WEFs to the South African electricity networks.

Conclusion

Wind energy, being primarily a variable source of electrical energy generation, also contributes to South Africa's growing capacity generation needs. Significant volumes, connected as per the Grid Code requirements for wind turbines, can be integrated into the electricity network within a relatively short space of time, with minimal upgrading of the electricity network and with no impact on water usage.
(Sources cited: Wind Energy The Facts, EWEA, March 2009; Wind Power and Variability, Renewable UK, June 2010)

5 Grid Integration of Wind Energy in the Western Cape, Final report, GTZ, Eskom, DEADP, December 2009
6 Generation Connection Capacity Assessment of the 2012 Transmission Network (GCCA-2012), Eskom, December 2010
7 GRID CODE REQUIREMENTS FOR WIND TURBINES CONNECTED TO DISTRIBUTION OR TRANSMISSION SYSTEMS IN SOUTH AFRICA, NERSA, rev 4.4, March 2011