Power Quality Issue HVDC Wind Power Plant Installation

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Abstract
The development of the system from a few tiny turbines connected right away to the low- Voltage grid to the current system with high entry on the medium the voltage distribution networks and two big offshore wind farms connected at the transmission level is presented in this paper along with a historical overview of the power quality problems of wind power installations. According to this viewpoint, the problems with power quality can be classified as either global or local, with the latter having to do with the stability and control of the power system and specifically pertaining to the power quality within the distribution networks. Measurements from wind farms are reported, and the power quality features of turbines and wind farms are defined in accordance with national and international standards.

Keywords: Grid Connection, HVDC Transmission, Measurement, Offshore Wind Farms, Power Quality.

Introduction

When compared to system load, the Danish electricity system has the largest installed wind power capacity in the world. Denmark had an exponential growth in wind power from the early 1970s to the start of this century. Initially, wind turbines were directly linked to the low voltage distribution grid. However, in the 1980s, when the rated power of commercial wind turbines surpassed 50 to 100 kW, the wind turbines were connected to the medium voltage distribution system through the use of specialized transformers. Most wind turbines in Denmark that are linked to the distribution grid are fixed speed wind turbines that have directly attached induction generators. Most of them are either standalone wind turbines or are connected in clusters, while a few wind farms with installed capacities under 50 MW have been created.

Two sizable offshore turbine farms were constructed in 2002 and 2003 and were immediately linked to the transmission network. The 160 MW Horns Rev wind farm, which used doubly-fed induction generator technology, was the first installation. The second construction used directly linked monkey cage induction generators to power a 165 MW wind farm located near Nysted. This change has affected how much attention is paid to power quality problems. Ensuring that the electrical current in the distribution grid is maintained within an acceptable range was the fundamental and primary issue for connecting to the distribution system. However, the influence on the distribution grid's voltage variations was also added shortly after. Initially, the strategy was to just restrict inrush currents in order to prevent voltage drops, but subsequently, less cautious techniques, such as flicker evaluation, were included.

Related Work

The first edition of the global norm IEC 61400-21 [1] for measuring and evaluating the power quality of grid-connected wind turbines was released by the IEC in 2001. The power quality parameters of wind turbines are defined by IEC 61400-21, which also suggests appropriate methodologies for evaluating the effect of one or more wind turbines on the grid's power quality. For instance, the definition of a flicker coefficient and the process for measuring it, as well as the techniques for estimating the flicker emission of one or more wind turbines based on their flicker coefficients, are provided. This influence on local power quality is addressed by the power quality criteria specified in the first version of IEC 61400-21.

Large-scale wind farm development has brought more attention to more worldwide power quality challenges pertaining to power system stability and control throughout the past five to ten years. The Danish transmission network operator Energinet.dk now has two grid identification numbers for wind turbines: one for connections below 100 kV [2] and one for connections over 100 kV [3]. The first grid code for connecting big wind farms to the grid was issued in Denmark in 1999.

Fault-ride-through is a major concern in both these two grid codes as well as in a number of other national grid codes. The controllability of reactive as well as active electricity is also emphasized heavily in the Danish grid rules, especially when it comes to connecting big wind farms with voltages exceeding 100 kV.

Based on measurements made on the 33 kV power collecting grid at the Nysted offshore wind farm, researchers are actively studying the approaches outlined in IEC 61400-21 to evaluate the effect of wind turbines on the local voltage quality. The observed voltage quality at the wind farm is provided in this article, and it will be compared in subsequent publications to the voltage quality that would have been determined using IEC 61400-21.

There are 72 SIEMENS turbines in the wind farm, each with a 2.3 MW rated power. Thyristor switching capacitors and directly linked induction generators are used by the wind turbines to compensate for reactive power on the low voltage terminals. Furthermore, the step-up transformer that is unique to each wind turbine is not included in the diagram. Wind turbines A 1 and A9 have had their power quality measured. Together with wind speed, which is supplied by a wind turbine controller register of wind speed on the nacelle, three phase currents as well as voltages are recorded at the wind turbines.

In addition, measurements of three phase currents and voltages are made at the offshore platform's transformer station (PF). In accordance with IEC 61400-21, the data collected will be used to give full electrical quality of A1 and A9.

Due to the wind farm's 72 wind turbines, which significantly affect the local voltage quality, the measurements offer a solid foundation for a comparison of the voltage quality as it is in real life versus that which can be determined by test results and evaluation techniques in accordance with IEC 61400-21. The voltage range, flicker, and harmonics will all be examined.

As was said in the introduction, maintaining an appropriate range for the distribution grid's voltage is the primary problem while connecting wind turbines. According to the European voltage standard EN 50160 [4], appliances should not be damaged or malfunction, and a range of ±10% of the 10 minute average voltage at the customers is permissible. According to IEC 61400-21, load-flow studies should be carried out to determine how wind turbines affect steady state voltages. As part of the wind turbine test method, the maximum power and corresponding reactive power are measured to give input for such load flow simulations.

The observed PQ relation yields the equivalent reactive powers Q60 and Q0.2, whereas the maximal powers P60 and P0.2 are measured with 60 s and 0.2 s average times, respectively. A wind turbine's maximum output often drops with longer average durations. The 60-second average duration was chosen as a modest, conservative number that may be used to evaluate power system component thermal overloading, for example. P60 for a wind farm may be computed as the total of P60 values for each wind turbine, per IEC 61400-21. This analysis is cautious as it makes the assumption that the maximum happens at every wind turbine at the same time.

The average time of 0.2 seconds is chosen to suggest that brief bursts of high power flow might cause a relay to trip. The calculation of P0.2 for a wind farm is outlined in IEC 61400-21. This technique accounts for the fact that the rapid changes in power of individual wind turbines are uncorrelated, so that the P0.2 for the wind farm is smaller than the total of the P0.2 for the individual wind turbines.

We recorded the voltages and wind speeds on wind turbine A9 (whose p.u. base is 33 kV) in the Nysted offshore wind farm for ten minutes on average. Despite considerable dispersion, it is seen that the voltage rises with wind speed. The wind speed variance across all wind turbines and the fluctuating voltage at the wind farm connection point are the primary causes of the dispersion.

Because of the increasing active power delivered into the grid, the voltage generally increases with wind speed. But occasionally, the voltage drops as a result of the wind farm's reactive power consumption. Standard load flow investigations for varying wind speeds will yield the effective power resulting from these contrary influences.

A person's level of discomfort when exposed to light of a bulb lamp powered by a changing voltage is measured in flicker. There are other causes of the voltage variations, including as variable loads and generators, transformers tap changers, etc. In a flicker evaluation, the various time scales of voltage fluctuations are given varying weights since the eye is primarily irritated by relatively quick voltage changes (8.8 Hz is the rate with the highest sensitivity).

The effect of wind turbines to fluctuations in voltage is split into two categories in IEC 61400-21: switching operation and continuous operation. Due to variations in wind speed, flicker is caused by the continuous operation's oscillations in reactive and active power. Wind turbine blades rotating in an enormous rotor disk with varying winds causes the electrical power to vary with three times the speed of the rotor [5], also known as the 3p effect. The wind speed shifts in a fixed point are fairly gradual and do not contribute much to flicker. 0.5 to 2 Hz is the typical figure of three times rotor speed, depending on the wind turbine's size.

The 3p effect typically only applies to wind turbines with fixed speeds. The 3p impact of the aerodynamic torque is often absorbed by variable speed wind turbines as tiny rotor speed variations, but this depends on the wind turbine's speed control. Flicker is also caused by switching processes including generator cut-in, cut-out, and switching between generator windings. Flicker is the result of sudden changes in power levels, and inrush currents that activate the generators can exacerbate this effect. A variable speed wind turbine may also efficiently lower the flicker contribution during switching operations. This is accomplished for switching operations by lowering the ramp rate during startup and shutdown.

Another source of the voltage waveform's harmonic distortion might be wind turbines. According to the currently in effect first edition of IEC 61400-21, harmonic testing is only recommended for wind turbines that have power converters. This will likely change in the second edition, though, with all wind turbine types being required to monitor their harmonic currents.

Power System Control and Stability

Owing to the surge in wind power growth, attention has turned to how wind power affects system security. The capacity of turbines to maintain connectivity, or "ride through," when the voltage drops as a result of a system malfunction is a crucial security concern. The primary worry with fault-ride-through is the potential impact of a transmission system failure, since it may greatly affect voltage across a wide region. It is crucial that these turbines can maintain their connection if a transmission system malfunction causes a voltage dip that affects a large number of them.

If not, a large loss of generating capacity may result, which would lead to issues with power and frequency regulation in the system following the failure. After a grid failure, the fault-ride-through demand presents another difficulty for voltage recovery. The wind turbines had to disconnect in order to prevent big inrush currents when the voltage recovered, for example in electrical substations shared by distributed power plants and consumers, in order to prevent the inrush current from tripping a system protection relay, before fault-ride-through demands became pertinent to avoid loss of significant generation. Therefore, recovering the voltage after a dip becomes more difficult due to the fault-ride-through requirements, particularly for wind turbines that use directly coupled induction generators.

The criteria for fault ride through vary greatly throughout TSOs; for example, refer to Jauch et al. [7]. The wind turbine business finds it difficult to comply with these many demands [8]. In order to replicate the dynamic behavior of the wind turbines during faults, the TSOs require models from the owners in addition to the faultride-through functionality of the wind turbines. It is evident that the wind turbine business bears the brunt of the model requirement.

The research community has also been quite active as a result of the demand for such dynamic models. In his thesis [9], Akhmatov developed an extensive collection of models for various kinds of wind turbines, which are frequently cited. In the IEA Wind Annex 21 on "Dynamic models of wind farms for power system studies," more recent research endeavors have collaborated [10]. In this regard, the participants have created a database containing pertinent turbine and grid data, measurements, and benchmark testing of wind turbine and wind farm simulation models.

It is measured on a 180 kW fixed speed wind turbine's low voltage terminals. The conventional model for a wind turbine that has an induction generator linked directly. The simulated response exhibits oscillations with somewhat larger amplitudes at the same frequencies as the observed response.

Power control

Only a few grid codes demand power control features, although fault-ride-through requirements for turbines and other distributed energy sources have become standard practice in TSO grid codes. The Danish grid code provides highly strict standards for active power management and slightly more generic rules for reactive power control when it comes to connecting big wind farms to the transmission system [3]. The controllers used in the two major offshore turbines in Denmark that are now in operation match the current specifications for the power management of new large wind farms.

The Horns Rev wind farm is the first of them, and according to Kristoffersen et al. [11], power regulation is incorporated in the wind farm main controller there. Automatic frequency control or a power set point can be used to directly or indirectly regulate the power of the wind farms. The Danish grid code specifies balancing regulation, stop oversight, power gradient constraint, absolute output constraint, delta output constraint, and combinations of these as direct power control measures.

While the delta production constraint guarantees that the actual production is less than the possible production, offering a constant reserve that is especially helpful when combined with automatic frequency control, the total production constraint, balance regulation, and stop regulation seek to maintain a constant power level. Wind farm power control was additionally modeled. Hansen et al. [12] offer a model for a wind farm controllers integrated with variable speed management of wind turbines, whereas [13] describes a more generic model and uses proactive wind turbines to show it.

Power fluctuations

Wind farms generate the most electricity possible when they are operating normally, and as a result of the wind's erratic behavior, the power generated varies accordingly. As per the findings of Akhmatov et al. [14], Energinet.dk has discovered that, despite Horns Rev's installed power being relatively small in relation to the system's total wind power installation, the active power supplied by this system's first large 160 MW offshore wind farm exhibits more intense fluctuations in the minute range than what was previously observed from the scattered wind turbines on land. Energinet.dk is worried about how the 200 MW Horns Rev B wind farm, a second nearby wind farm, may affect the system's future need for power regulation. The wind farm is already planned for completion in 2008.

Large offshore wind farms can reduce power swings by requiring management, but this reduction is only truly effective when wind speeds and available power rise quickly. Demand side control, storage, or conventional power plants must maintain the power balance when wind speeds and available wind output drop. Variability affects a wide variety of time intervals. It affects flicker as previously said on a short time scale and the power exchange hour by hour on a longer time scale. TSOs have long employed wind power forecasting technologies to manage the hourly variations.

Wind power fluctuation also affects power balance on a shorter scale, albeit it doesn't seem to become a problem until the system has noticeably greater wind power content.

It is separated into two categories: variations in the output of "Onshore" wind turbines with equivalent installed capacities and variations in electricity from the Horns Rev wind farm. The weather on the chosen day is incredibly erratic, which is why the power variations from the Horns Rev wind farm are particularly high. In addition, there are far less variations in "Onshore" wind turbine manufacture. These variations have an impact on the system's necessary reserves.

Even if the power control's ramp rate limitation might lessen fluctuations, having a better understanding of them is still helpful for power system planning and operation. The onshore turbines are dispersed across a far broader region than the Horns Rev turbines in Fig. 6, which explains why the variations of the power produced by various turbines are significantly less correlated onshore.

It is helpful to be able to model predicted wind power variations, depending on the installed capacity and where this capacity is situated, for the planning of future system growth incorporating a continuously expanding capacity of wind power. These simulations can be used as an input for cost-benefit analyses of various sites, taking into account the effect that the decision will have on the amount of regulating power that is needed. By Sørensen et al. [15], a method for simulating wind power changes in a large wind farm is given.

The model's capacity to forecast at necessary reserves has been verified by applying data gathered from Horns Rev's operational wind farm. Using estimated 1% percentiles of reserves required to counteract power variations from wind farms across various power ranges. Based on both simulated and observed power, the reserves have been computed. Using prediction techniques for the inter-hour variations would also be beneficial in the operation of a power system with a high wind power capacity.

A variety of prediction models, all of which are time series models that need real data for training, have been examined by Pinson et al. [16]. Pinson concluded that the most promising model type is the Markov-Switching AutoRegressive (MSAR) model since it works best based just on observed power and may be further developed by including variables from weather models.

Conclusion

The influence on local voltage quality has been the primary focus of power quality research throughout the first 20 years in wind power growth. Currently, 18% of the electricity consumed is generated by wind energy. With such a high penetration rate of wind power, system-related concerns including power regulation, fault ride through, and the requirement for reserves are receiving greater attention.

References

[1] IEC 61400-21. Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines. First edition, 2001-12.

[2] Wind turbines connected to grids with voltages below 100 kV. Technical regulation for the properties and the regulation of wind turbines. Elkraft System and Eltra. English version of Regulation TF 3.2.6. Doc. No. 225056. January 2005.

[3] Wind turbines connected to grids with voltages above 100 kV. Technical regulation for the properties and the regulation of wind turbines. Elkraft System and Eltra. Regulation TF 3.2.5. Doc. No. 214439v3. Dec. 2004.

[4] EN 50160. Voltage characteristics of electricity supplied by public distribution systems. CENELEC, Nov. 1994.

[5] P. Sørensen, A. D. Hansen, P. A. C. Rosas, "Wind models for simulation of power fluctuations from wind farms," J. Wind Eng. Ind. Aerodyn, vol 90, pp. 1381-1402, Dec. 2002.

[6] IEC 61000-4-15. Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 15: Flickermeter – Functional and design specifications.

[7] C. Jauch, J. Matevosyan, T. Ackermann, S. Bolik "International comparison of requirements for connection of wind turbines to power systems," Wind Energy, vol 8, pp. 295-306, 2005.

[8] S. Bolik, J. Birk, B. Andresen, J. G. Nielsen, "Vestas handles grid requirements: advanced control strategy for wind turbines,", in Proc European Wind Energy Conference (EWEC), Jun. 2003, Madrid, Spain.

[9] V. Akhmatov, "Analysis of dynamic behaviour of electric power systems with large amount of wind power," Ph.D. thesis, Technical University of Denmark, Apr. 2003.

[10] J. O. Tande, E. Muljadi, O. Carlson, J. Pierik, A. Estanqueiro, P. Sørensen, M. O'Malley, A. Mullane, O. Anaya-Lara, B. Lemström (2004) "Dynamic models of wind farms for power system studies – status by IEA Wind R&D Annex 21", in Proc European Wind Energy Conference (EWEC), Nov. 2004, London, UK.

[11] J. R. Kristoffersen, P. Christiansen, "Horns Rev offshore wind farm: its main controller and remote control system," Wind Engineering, vol 27, pp 351-360, 2003.

[12] A. D. Hansen, P. Sørensen, F. Iov, F. Blaabjerg, "Centralised power control of wind farm, with doubly fed induction generators," Renewable Energy, vol 31, pp. 935-951, Jun 2006.

[13] A. D. Hansen, P. Sørensen, F. Iov, F. Blaabjerg, "Grid support of a wind farm with active stall wind turbines and AC grid connection," Wind Energy, vol 9, pp. 341-359, Jul 2006.

[14] V. Akhmatov, H. Abildgaard, J. Pedersen, P. B. Eriksen, "Integration of Offshore Wind Power into the Western Danish Power System," in Proc. Copenhagen Offshore Wind 2005, CD

[15] P. Sørensen, N. A. Cutululis, A. Vigueras-Rodríguez, L. E. Jensen, J. Hjerrild, M. H. Donovan, H. Madsen, “Power Fluctuations from Large Wind Farms,” Submitted to IEEE Transactions on Power Systems, Special Section on “Power System Performance Issues Associated with Wind Energy”.

[16] P. Pinson, L. E. A. Christensen, H. Madsen, P. Sørensen, M. H. Donovan, L. Jensen, J. R. Kristoffersen, ”Regime-switching modelling of the fluctuations of offshore wind generation ,” submitted to J. Wind Eng. Ind. Aerodyn.