

# Wind Generation Presents Interconnection Challenges

*New technical requirements for the interconnection of larger wind farms means more precision in integration planning.*

BY MICHAEL ROSS

Installing a wind farm can often generate unique challenges and problems for developers, owners and wind turbine manufacturers, particularly as they consider issues relating to transmission access. Major concerns and challenges that they face are typically associated with voltage regulation, low voltage ride through, system stability and aspects of potential turbine damage and maintenance.

Additionally, a number of federal and regulatory organizations are working together to create fair and uniform integration standards in order to improve wind farm transmission access. Therefore, in order for wind turbines to be properly integrated into the power system, a significant amount of research and analysis should be done to ensure that the wind farm is properly integrated and that the correct solution is installed to address each wind farm's unique challenge.

The wind generation has recently turned a critical corner in the U.S. While once considered an experimental technology, the U.S. wind community has set a target of having 100 GW of all U.S. generation derived from wind power by 2020 (see the Department of Energy's Report "Wind Energy Program Multiyear Technical Plan for 2004-2010").

This newly established bench-

mark, combined with steadily improving technology and a favorable tax environment, will result in the commissioning of thousands of megawatts of wind generation over the next several years.

Since the major challenge of wind

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farm interconnection versus interconnection of conventional generation sources is that the real power output (the power that is metered and sold) of the wind farm cannot be predicted or easily controlled, special precautions must be taken. Many of the standards and regulations regarding grid interconnection of conventional generation are not always applicable or may not be clear when applied to wind generation.

To address this issue, the Federal Energy Regulatory Commission (FERC) has been working with the North American Electric Reliability Council (NERC), the American Wind Energy Association (AWEA) and a number of U.S. utilities to es-

tablish uniform standards for wind generation access to the utility transmission grid.

FERC Order 661-A (released December 12, 2005) sets specific requirements for the interconnection of 20 MW or larger wind farms. Order 661-A addresses the important interconnection topics of low-voltage ride through (LVRT), power factor and voltage regulation. However, the order does not address the common interconnection concerns of system stability and wind turbine damage due to voltage transients, although often these issues are addressed by individual utility and wind turbine manufacturer standards.

Based on these criteria, it is critical that wind developers and transmission owners create an interconnection agreement regarding the rules and standards that will apply to the specific project, and also indicate who is responsible for each one of the individual issues that may arise. It is also critical that all parties involved with the interconnection agreement understand the potential problems that can arise during interconnection and the solutions that are available.

If the transmission owner or wind energy developer is not well versed in the details of the interconnection agreements, they could potentially agree to conditions or requirements which are tremendously

expensive, unnecessary or even impossible to achieve.

Since the real power output of the wind farm cannot be accurately predicted, this situation requires the utility to keep a greater amount of spinning reserve generation available. However, this is not a barrier to wind installations except at high wind penetration levels. A greater concern is that the varying real power output is often accompanied by significant variations in reactive power demand and consequently, variations in voltage.

Reactive power is what is required to counteract lagging currents and sagging voltage, and if it is not supplied in a quick and efficient manner, networks can crash, causing lost productivity and possibly equipment damage.

### **Power factor**

Most modern wind turbines have some capability to control power factor at the machine terminals. However, even if the power factor at the individual turbines is kept constant as real power varies, the reactive power consumption of the wind farm as a whole will continue to vary as a result of reactive losses on the collection system.

The full magnitude of the losses cannot be easily compensated by the individual turbines. Thus, wind farm reactive power consumption generally increases with real power output unless ancillary reactive support equipment is installed. Without compensation, this can cause significant voltage variation on the utility system, which can result in serious damage to expensive transmission grid equipment.

Requiring the wind farm to hold a reasonably constant transmission voltage, even as the megawatt output of the wind farm changes, is one of the primary goals of FERC Order 661-A. The order requires the wind farm to supply power with a power factor that is variable between 0.95 lagging (capacitive) and 0.95 leading (inductive) at the high side of the wind farm main transformer.

Often, the wind farm is required to use its reactive range to regulate its voltage to a specified level while incorporating complicated control characteristics. By requiring this level of reactive control, FERC is ensuring that the wind farm will be able to minimize system voltage variations and thus reduce any negative impact of the wind farm on the transmission grid's voltage performance.

Such specific voltage control requirements necessitate special reactive support equipment with voltage measurement capabilities and closed loop control. This degree of control is often beyond what can be provided by the individual wind turbines.

The ability of a wind turbine to survive a transient voltage dip without tripping is often referred to as the LVRT capability of the turbine. LVRT capability is an important part of wind farm interconnection because if the wind farm were to trip off when the voltage dips due to a fault on a nearby power line, that single fault could result in the loss of two major system components, i.e., the line and the wind farm. This would violate an important NERC standard (Reliability Standard TPL-002-0). LVRT is the other primary topic of FERC Order 661-A.

FERC Order 661-A essentially requires that the wind farm remain in service during any three-phase fault (when all three phases of a power circuit come in contact with the ground or each other) that is normally cleared as long as the clearing of that fault does not electrically separate the wind farm from the transmission system and the fault does not depress the voltage at the Point of Common Coupling (PCC) below 0.15 p.u. (15% of normal) voltage.

The addition of a large wind farm on a power system can alter the flow of power on the system. In some instances, the wind farm's effect on system flows can make certain fault and outage events on the transmission system more severe than they would have been prior to the wind installation and in some cases result in a violation of system stability requirements.

To protect against system stability degradation, utilities often require that the addition of the wind farm does not degrade system stability or result in violations of stability criteria. In these cases software simulations must be run to determine the wind farm's influence on the system. If it is determined that system stability has been unacceptably altered by the wind farm installation, it may be necessary to add auxiliary equipment to address the issue.

### **Interconnection concerns**

Often, wind farm developers attempt to address interconnection concerns by installing switched shunt reactors and capacitor banks. Switched shunts are capable of introducing blocks of reactive power to regulate voltage and are widely used on virtually all power systems.

The major concern in utilizing switched shunts at a wind farm is that they cause sudden step changes in voltage. While often the voltage change is small (1%-2% or less), any sudden change in voltage causes a sudden change in torque within the gearbox of the wind turbine. Because the voltage at a wind farm tends to vary significantly, many switching events are required every day. Over time, the events (and resulting torque changes) can accelerate the wear and tear on the turbines resulting in high maintenance costs.

In most cases, the wind farm developer will work with the turbine manufacturer and the transmission owner to determine what ancillary equipment, if any, will be required to meet the transmission access requirements. A detailed study of the system is normally required.

These studies require a software model of the transmission system from the transmission owner and a model of the turbine and generator step-up transformer from the manufacturer. Most often the layout of the wind farm – including details of the cables or lines that connect the individual turbines to each other and the main transformer – is also required as well as details of the main trans-

former from the developer.

With all these pieces, an engineer can create an accurate model of the wind farm and surrounding power system, and determine if ancillary equipment will be needed in order to meet the power factor, voltage regulation and LVRT requirements without adding to turbine maintenance.

A variety of solutions exist to help solve interconnection issues. Many wind turbine manufacturers are able to mitigate some problems with advances internal to the turbines themselves, but external solutions often are required.

Because of their low cost, shunt-connected mechanically switched capacitors (and to a lesser extent, reactors) are often installed at the collector bus of a wind farm to provide voltage control. As described earlier, switched shunts, while effective, have the potential to create maintenance problems in the wind turbines. In addition, shunt devices alone cannot provide the desired continuous voltage regulation similar to a conventional generator.

It is also important to note that switched shunts are only a solution to power factor issues and are not complete options to solve voltage regulation, LVRT or system stability problems.

### **Possible solutions**

Static VAR compensators (SVCs) utilize thyristor (an older power electronic technology) controlled components to create an infinitely adjustable reactive device. A typical SVC will have maximum leading and lagging reactive power limits, and is capable at operating at any point between those limits.

An SVC can be installed at the main bus of the wind farm and be programmed to hold a certain voltage or power factor at that point. The SVC will adjust its reactive output to regulate the system voltage, effectively solving most steady state voltage problems. In addition, SVC can be programmed to respond quickly in order to address LVRT

and stability concerns.

SVCs are limited by their ratings and must be sized appropriately if they are to address transient events. In addition, since they are capacitor-based, they are less effective in addressing deep voltage dips than other technologies. This often is a factor when system stability is a concern.

STATCOMs are power electronic devices that use newer IGBT, IGCT or GTO-based converters to generate

+/- 24 MVAR. In order for a typical STATCOM or SVC to match the transient output capability of the D-VAR device, those devices would have to be rated at the full +/- 24 MVAR, which would be much more costly.

Other advantages of D-VAR systems include their inherently mobile design and comparatively quick installation.

Synchronous condensers provide another potential solution. A syn-

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reactive current. These devices utilize advanced controllers to regulate their output in order to maintain steady state voltages and mitigate transient events. Compared to SVCs, STATCOM devices tend to have faster response times, smaller footprints and better performance at reduced voltages.

The dynamic VAR (D-VAR) power electronic device is a type of STATCOM that has properties that are effective in addressing wind farm interconnection issues. Like all STATCOMs, this device has a continuous dynamic reactive rating that can be used to address voltage regulation issues.

It can also control the switching of nearby shunts to further assist in voltage regulation. D-VAR systems also mitigate the sudden voltage change that normally results from shunt switching, thereby eliminating any potential gearbox damage.

An important aspect of the D-VAR device is its ability to operate in an overload mode. For short periods of time (1-2 seconds) this device can inject up to three times normal current output. This overload is ideal for addressing transient voltage problems and for meeting the LVRT requirement in a cost-effective manner.

For example, an 8 MVA D-VAR device has a steady state rating of +/- 8 MVAR, but an overload rating of

chronous condenser will strengthen the system and always act to stabilize voltages at nominal levels, and is effective in mitigating virtually all wind farm interconnection issues.

SuperVAR machines are dynamic synchronous condensers with a rotor wound with high temperature superconductor (HTS) wire.

Wind farms commonly give rise to various interconnection issues, and it is critical that the wind energy developer, turbine manufacturer and transmission grid operator understand these issues early in the planning phase so that the cost associated with the solutions are thoroughly understood. By balancing the demands of the contract between the players, and clearly understanding the regulations, challenges and responsibilities early in the process, participants in the project can prevent unnecessary delays and enjoy the benefits of a successful wind farm grid interconnection. **SNP**

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