The power to change

Stabilizing grids and enabling renewable power generation with PCS 6000 STATCOM

TOBIAS THURNHERR, CHRISTOPH G. SCHAUB – Our future energy mix will rely on the addition of a combination of renewable sources, such as hydro, wind, solar and tidal energy. This means the electricity grid must be adapted so that it can first cope with these additional sources of generation and second, use them in the most optimal way possible. On the distribution side, renewable power generation units must be modified so that the electricity they feed into the grid is as reliable as the electricity supplied by conventional power generators. To maintain efficient transmission and distribution, the reactive power balance in a system needs to be controlled. Inefficient reactive power management can result in high network losses, equipment overloading, unacceptable voltage levels, voltage instability and even outages. ABB offers a comprehensive range of reactive power compensation products and customized solutions to meet these challenges. One such solution, the PCS 6000 STATCOM (Power Converter System 6000 Static Synchronous Compensator), is proving to be a reliable, robust and efficient addition to a wind farm in the UK.

Living standards and energy consumption are growing from year to year. According to a MAKE Consulting market outlook, the worldwide demand for power will increase by 79.6 percent between 2006 and 2030. This demand must be met by clean and renewable energy sources, since conventional fossil fuel power generation plants contribute greatly to greenhouse gas emissions and global warming.

In 2006, 18 percent of the power generated was derived from renewable resources, mainly hydroelectric generation. The scale of future renewable power generation and its overall share of the energy mix are difficult to predict since this depends largely on the political climate. However, if currently planned political initiatives are implemented the total share of renewable power generation is expected to rise to 23 percent by 2030; more optimistic forecasts have even suggested a 62 percent share.

No matter the predicted size of the renewable power sector, wind power generation will play a significant part in the future supply of power. In some countries, wind turbines already play a significant role in energy production, and in some regions, there is still space for new wind parks. Unfortunately, it is becoming increasingly difficult to find new areas in which to economically harvest wind energy, ie, to find areas that are accessible, where the wind blows steadily and where the visual impact is acceptable. Nevertheless, the potential for offshore installations is particularly large. Here the wind generally blows more steadily than on land and access is less restrictive.

Wind power generation will play a significant part in the future supply of power and ABB's STATCOM can help support a stable power grid.

Connecting wind turbines to existing electricity grids presents quite a challenge. Because the environment determines the ideal location for a wind park, such locations tend to be far from existing transmission lines with sufficient spare capacity. Furthermore, windpower generators frequently behave differently to conventional generators, such as thermal or nuclear power plants, in terms of reactive power output capability, frequency control and fault ride-through capability (ie, the ability to remain connected, supplying power to the electrical system immediately after a network fault). In areas where wind generators comprise a large share of the generation capacity, this can have a negative impact on the entire network's stability.

For this reason grid operators are forced to introduce technical standards, so-called "grid codes," which must be fulfilled so that permission can be granted for a wind park to join the grid.

Reactive power and voltage control

Contrary to electric power frequency, which has to be the same at every point of an interconnected grid, the voltage is a local parameter that varies depending on the location and load flow in the grid. In a circuit where the load is purely ohmic, the voltage and current waveforms are in phase and transmitted real power is at a maximum. However, the inductive nature of the grid means that the flow of electric current is altered so that the voltage and current waveforms are out of phase. In a circuit powered by a DC source, the impedance equals the total resistance of the circuit. In an AC powered circuit, however, the electric devices in the circuit, ie, inductors (generators and transformers), capacitors and even the transmission cable itself, contribute to the impedance (see Factbox 2 on page 35 of *ABB Review* 3/2009). Inductors and capacitors generate or consume reactive power, thereby creating current flows. To reduce the affects of this reactive power, devices with matching impedance should be located carefully on the grid to maximize the transfer of real power.

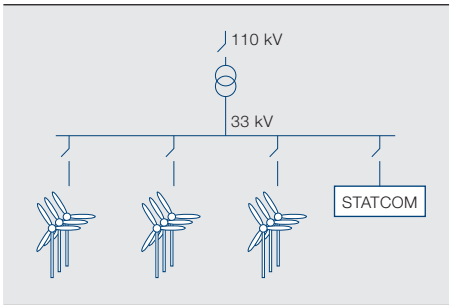
In areas requiring large amounts of reactive power, eg, areas of the grid with many asynchronous motors, the local voltage is reduced and a bank of capacitors should be introduced to match the impedance of the motors and maintain nominal voltage levels. Maintaining nominal voltage levels is important because most electrical components only tolerate small deviations in voltage. If the voltage is too low or too high the grid becomes unstable and components can malfunction or become damaged.

Besides affecting the voltage, reactive power flows also increase the load on transmission lines and transformers, thereby restricting their active power transmission capacity. By lowering the reactive current in transmission lines, capacity is increased and losses are reduced. This solution is faster and more cost effective than building additional transmission lines.

ABB offers a comprehensive range of reactive power compensation products and customized solutions to meet these challenges.

One such solution is the Power Converter System 6000 Static Synchronous Compensator, better known as the PCS 6000 STATCOM. The system meets the most stringent dynamic response requirements and is able to deliver full reactive current even during voltage dips, making it the perfect add-on solution for wind parks. It allows wind parks to meet highly demanding grid codes, stabilizes both positive and negative sequence voltages in industrial plants and provides

1 Schematic overview of the wind park



2 ABB STATCOM in a container version

reactive compensation for motor starting and dynamic voltage control in weak transmission grids.

ABB STATCOM

One of the first countries in which the grid operator introduced a grid code specifying the reactive power requirements for wind parks was the United Kingdom. Here several ABB STATCOMs are already in operation, statically and dynamically supporting the grid. Recently, a 24 MVAr STATCOM was installed and operates successfully to ensure that the Little Cheyne Court wind park, located near Rye in Kent in the southeastern part of the United Kingdom, fulfills the National grid code.

A typical wind park setup is shown in ➔ 1. The STATCOM in Little Cheyne Court is connected to the secondary side of the 110 kV / 33 kV wind park transformer. Here the STATCOM stabilizes the local voltage in the wind park by creating a voltage drop across the transformer.

> ABB's STATCOM is controlled by an AC 800PEC (power electronics controller) high-performance control unit, providing fast and precise closed-loop control and protection functions.

However, depending on the customer requirements or the grid code, the STATCOM could have been connected directly to the transmission level on the primary side of the wind park's main transformer.

Contrary to passive components, such as capacitors or inductors, the STATCOM can output its full reactive current even at low voltages and is limited only by the need for active power to cover its losses. The reactive power output capability of the system decreases linearly with the voltage, whereas for passive components, the reactive power output is proportional to the square of the voltage.

The PCS 6000 STATCOM consists of a voltage source converter, connected to the grid through a transformer. The converter contains so-called power electronic building blocks with integrated gate-commutated thyristors (IGCTs). Developed in the 1990's, IGCT's combine the advantages of insulated-gate bipolar transistors (IGBTs) and gate turn-off thyristors (GTOs), ie, low switching and conduction losses, fast switching capability and robustness. The same IGCT platform is used for medium-voltage drives, frequency converters feeding railway grids and full-power converters for large wind turbines. The IGCT allows high power density within a compact space, thereby reducing the overall footprint of the unit.

All STATCOM units are water cooled, with either an external water-to-air heat exchanger or a raw water cooling circuit. The water-cooling unit makes fans unnecessary, and thus reduces or even eliminates air exchange with the environment, preventing dust, sand particles and salt entering the converter. This in turn results in lower maintenance requirements.

The ABB STATCOM can be installed either in a building or in a cost-effective outdoor container ➔ 2. The container includes a cooling unit, a control system with a human machine interface (HMI), air conditioning for the control room and a heater for the converter room. It is fully wired and tested prior to delivery to reduce installation and commissioning time.

STATCOM control

ABB's STATCOM is controlled by an AC 800PEC (power electronics controller) high-performance control unit. This controller provides fast and precise closed-loop control and protection functions and coordinates slower processes, such as the supervision and control of the cooling unit and communication via a customer interface, all within a single unit.

The control system is setup in Switzerland before shipping. A downscaled hardware simulator allows extensive tuning and testing of the software before delivery, so that only minor fine-tuning is required during plant commissioning.

STATCOMs used for wind parks or in transmission grids usually run in a U-Q control mode. This means the grid operator specifies a certain set point voltage U0 and a slope N, as shown ➔ 3. The STATCOM measures the grid voltage and injects reactive power when appropriate,

which varies linearly with the difference between the measured voltage and the set point voltage. If the measured voltage is below the set point voltage, the STATCOM acts like a capacitor bank and injects reactive power into the grid to support the grid voltage. If the measured voltage is greater than the set point voltage, the STATCOM acts as an inductor and suppresses the grid voltage. The slope defines the proportionality between the STATCOM output and the difference between the set point voltage and the measured voltage.

Harmonic characteristics

A grid-connected converter has to fulfill certain grid harmonic requirements, such as IEEE 519 or IEC 61000-2-12. Depending on the size of the unit, the multilevel topology allows the PCS 6000 STATCOM to fulfill these requirements without a harmonic grid filter. If desired, a suitable optional filter can be supplied,

> The STATCOM acts like a capacitor bank when the measured voltage is below the set point voltage and like an inductor when the measured voltage is above.

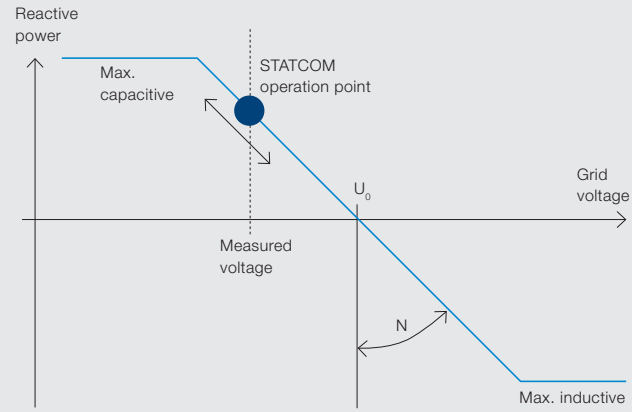
either to offset the reactive power output of the STATCOM or to filter certain harmonics already present in the grid.

A very valuable benefit of the ABB STATCOM is that its input impedance can be adjusted for a certain range of harmonics. This is extremely helpful for damping resonating systems. A sister installation of the Little Cheyne Court STATCOM is controlled such that the input impedance of the STATCOM is resistive for a given range of multiples of the fundamental frequency. This means that for this range of frequencies, the STATCOM absorbs energy from the grid and re-injects the energy back into the grid at the fundamental frequency. In this way, resonance in the wind park can be mitigated. A high-frequency oscillation would cause a harmonic fault in the turbine control and result in the immediate disconnection of turbines. ABB's STATCOM allows the wind park to generate clean power without having to wait for the delivery of passive components to solve the problem, as shown in ➔ 4. The grid voltage, which is measured when the STATCOM is disconnected, is shown in ➔ 4a. It is observed that a harmonic voltage is superimposed with the fundamental frequency voltage. ➔ 4b shows how this harmonic voltage can no longer be seen when the STATCOM is connected.

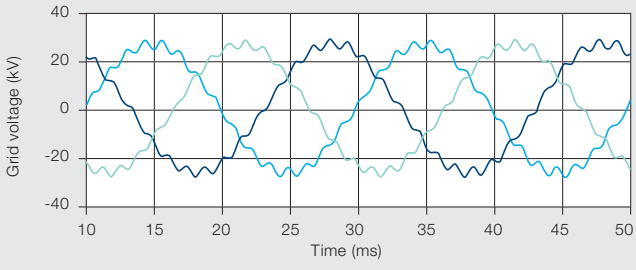
A successful solution

ABB's PCS 6000 STATCOM is a robust, reliable and efficient solution that is suitable as an add-on for wind parks to make them compliant with grid connection rules or as a fast and dynamic reactive power compensator for utilities. The demand for ABB's STATCOM will remain strong in a climate where the continuous and steady supply of electricity will have to be met through the expanded use of wind-powered turbines and other less reliable power sources, especially when the electricity grids of the future are extended into developing countries.

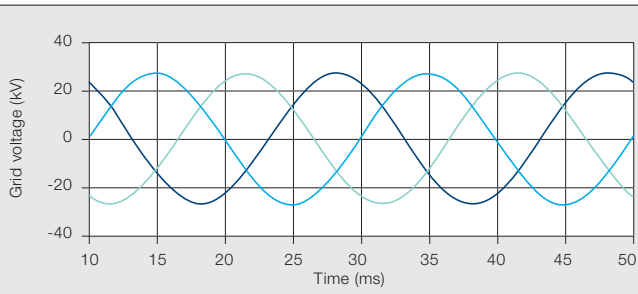
3 Typical control mode of the STATCOM



4 33 kV bus voltage in the wind park



4a without the STATCOM



4b with the STATCOM

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Further reading

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– Linhofer, G., Maibach, P., Umbricht, N. The railway connection: Frequency converters for railway power supply. *ABB Review* 4/2009, 49–55.