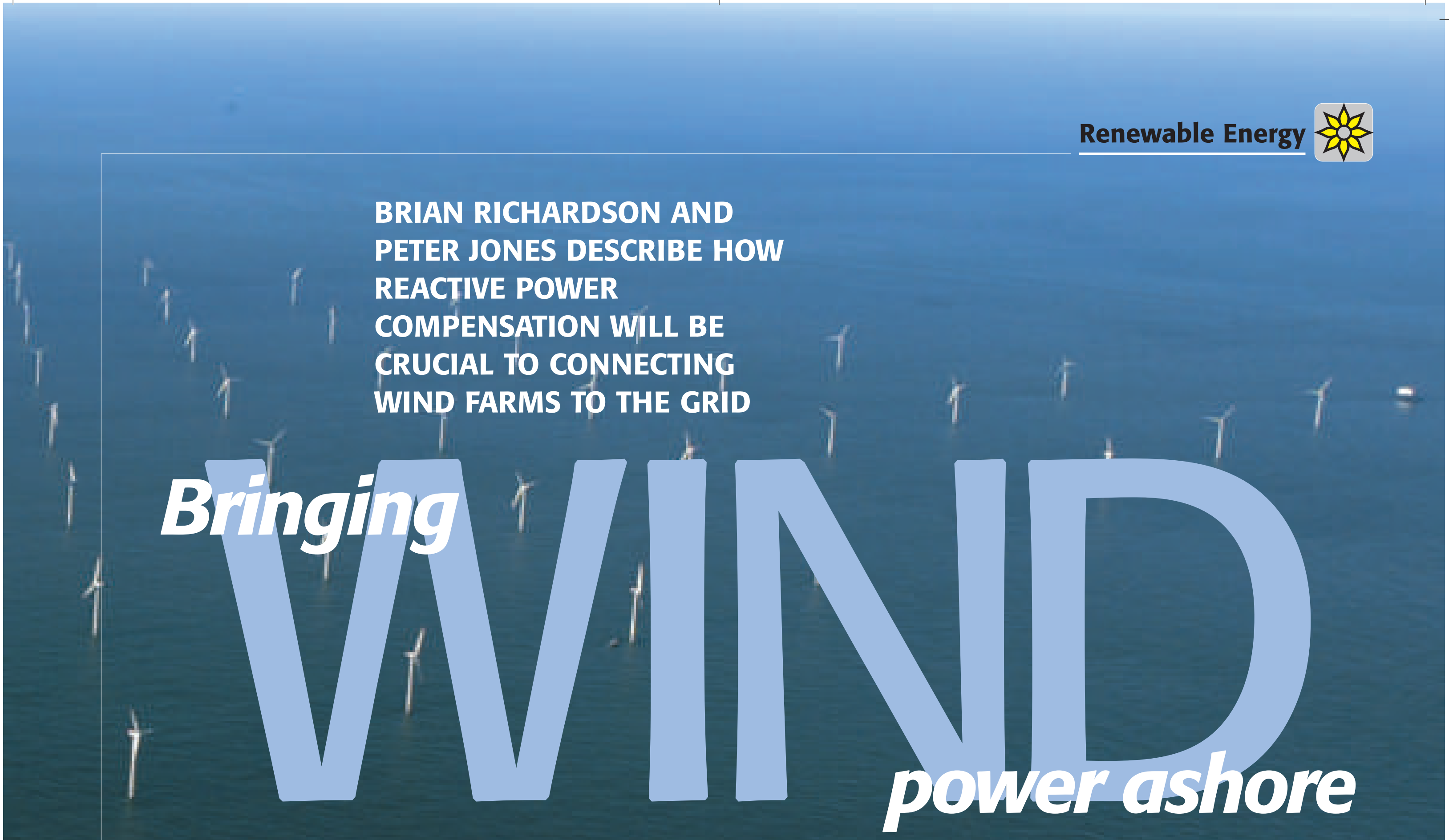

[Photograph of Horns Rev, Denmark. Credit: BWEA]

Bringing WIND power ashore

BRIAN RICHARDSON AND PETER JONES DESCRIBE HOW REACTIVE POWER COMPENSATION WILL BE CRUCIAL TO CONNECTING WIND FARMS TO THE GRID

After a slow start, wind power is finally being viewed as a serious source of sustainable and environmentally friendly energy. In Germany alone more than 12GW of wind power is already in operation while the UK is forecast to have more than 7GW of generation by 2010. Worldwide, more than 80GW of wind power is expected by 2008.

As these figures keep rolling in, one number at the top of operators' agendas is revenue. Studies have already revealed that the extra revenues from exploiting the higher wind speeds found further offshore outweigh the added cable costs and electrical transmission losses. And as a result more and more offshore wind farms – each generating several hundred megawatts – are likely to be taken further out to sea.

As these wind farms come online, one technology that is on the lips of many engineers is dynamic reactive power compensation. This technology promises to help stabilise voltage fluctuations and provide seamless grid interconnection. So what is it about this technology that makes it so critical to wind farms?

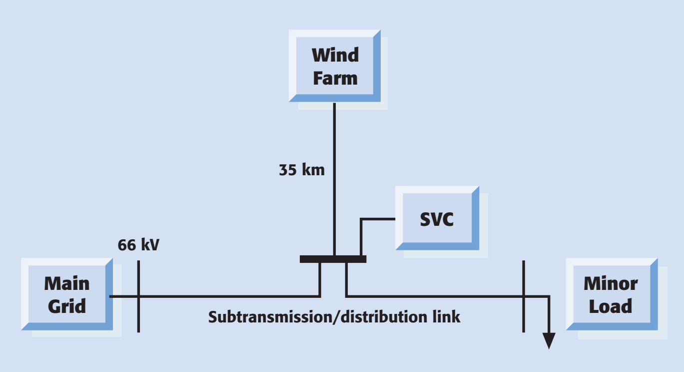

Fig 1: Typical grid connection layout of offshore wind farm

Today's most common wind power generator is based on a constant speed design. But while these induction generators are sturdy and cost-effective, they do not contribute to regulation of the grid voltage, and absorb reactive power.

As a result, these generators need to be connected to robust regions of the grid to maintain power quality. Unfortunately the remote location of windfarms means this isn't usually possible.

Doubly fed induction generators (DFIG) with a variable-speed design provide an alternative to the constant speed designs (see 'Turbine technology', p35). However, these generators can be expensive – rotor converter ratings must be limited to steady-state requirements – and may also be inadequate as a primary safeguard against grid transients.

The extent of these problems becomes clear when considered alongside the national grid codes, which highlight the importance of grid support from installed power generating devices. Indeed, a lot of regulatory authorities require generators to vary their reactive power output according to the grid voltage level in order to maintain voltage stability and limit dynamic voltage variations.

The need for reactive power control doesn't stop at individual generators. As power systems increasingly rely on wind power contributions, the resilience of the entire wind farm to network faults will become more critical.

When a fault occurs in a power system, a voltage drop occurs and the faulty component is typically disconnected from the system. But what happens if this fault occurs in an adjacent area of the network to which the wind farm is attached?

To prevent generation losses and even system collapse, the wind farm must remain connected to the grid even when the faulty component disconnects. To this end, the wind farm's turbines must be able to operate →

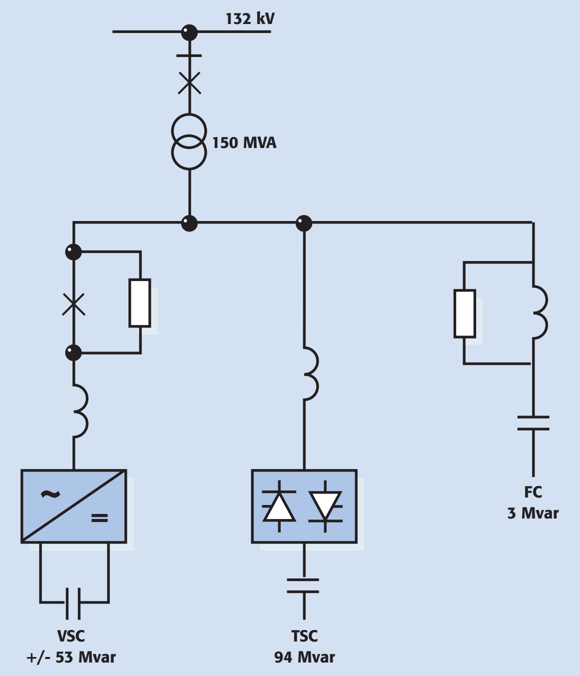

Fig 2: Combined voltage source converter and thyristor-switched capacitor

continuously – without interruption – during the faulty component's protection clearance times.

The need for reactive power control doesn't stop at the turbines. Undersea cable networks – that link individual wind turbines and bring power ashore – also require reactive power compensation. If all of these issues are not addressed at an early planning stage, the wind farms will never achieve the same level of performance as other large generators serving the grid, and could even initiate a cascading power outage.

POWER CONTROL

Using reactive power control to address these reliability issues can be achieved in different ways, depending on the type of generator in the system. Looking at synchronous generators, reactive power control is achieved by over- or under-exciting the generator. By allowing this, the synchronous machine can supply as well as consume reactive power.

Such an approach is not possible for basic induction generators as these machines take their magnetising power from the grid and consume reactive power. Instead, a Static Var (volt-amp-reactive) Compensator (SVC) positioned at the grid connection point can be used to act as a central exciter system, which means that that reactive power can be controlled, even when power isn't being generated, (see fig 1 on p33).

SVCs are solid-state thyristor-based devices, typically used in AC transmission systems to eliminate voltage fluctuations and rapid changes in reactive power caused by line switching, faults, non-linear components and rapidly varying reactive loads. The SVC regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power, and when system voltage is high, it absorbs reactive power.

SVCs are not the only devices that can deal with voltage level problems. In the past mechanically switched capacitor banks (MSCs) have been used, but when it comes to wind farms, these devices can prove inadequate.

This is because the power production and reactive power consumption in a wind farm varies with wind speed. The resultant frequent switching of the MSC deteriorates power quality and decreases the MSC's lifetime. However, an SVC offers continuously variable susceptance, and so makes a cost efficient alternative to several small MSC units.

Another key problem with the power produced from wind farms is voltage flicker on the connecting node, typically caused by generator start and stop, wind speed variations or tower shadow effects. However, connecting an SVC at the grid connection points relieves the network from flicker.

So if SVCs herald an end to wind farm-initiated grid problems, how can engineers integrate them to the network?

Today's SVCs are available in two different versions. The first SVC approach is based on using conventional capacitor

banks with parallel thyristor-controlled inductive branches. These inductive branches consume the excess reactive power generated by the capacitor bank.

This type of equipment can be directly connected to an intermediate voltage bus, which interconnects the wind farms (up to 36 kV). It is also possible to connect the SVC to the high-voltage network via a dedicated transformer, if required.

A second approach makes use of a voltage source converter (VSC) that can inject or consume reactive power to or from the bus where it is connected. This application of VSCs is usually referred to as STATCOM (static compensator) and has a relatively small footprint as large air-cored inductors are not used. In addition, a smaller parallel capacitor bank can be used, to offset the overall control range in a capacitive direction.

These two schemes can be combined to give a cost-effective dynamic compensator that is rated for a high dynamic yield during a short time and a lower yield during steady-state operation. For example, a VSC rated at -/+53MVAr can be combined with a 94MVAr thyristor-switched capacitor (TSC) and a 3MVAr harmonic Filter to give a variable output range of -50/+150MVAr (see fig 2).

Such a scheme would provide dynamic VAr compensation in a large offshore wind farm. Here, the TSC will only operate for short time periods – such as during potential voltage collapse – until the fault has been cleared, which means it can be rated in a very economical way.

Looking to the future, SVCs are going to have an increasingly vital role to play in ensuring that networks with large amounts of wind farm connections remain resilient. As very large offshore wind farm arrays become more commonplace, small-scale local network faults must not be allowed to escalate. Who would want to see more serious, widespread transmission power blackouts? ■

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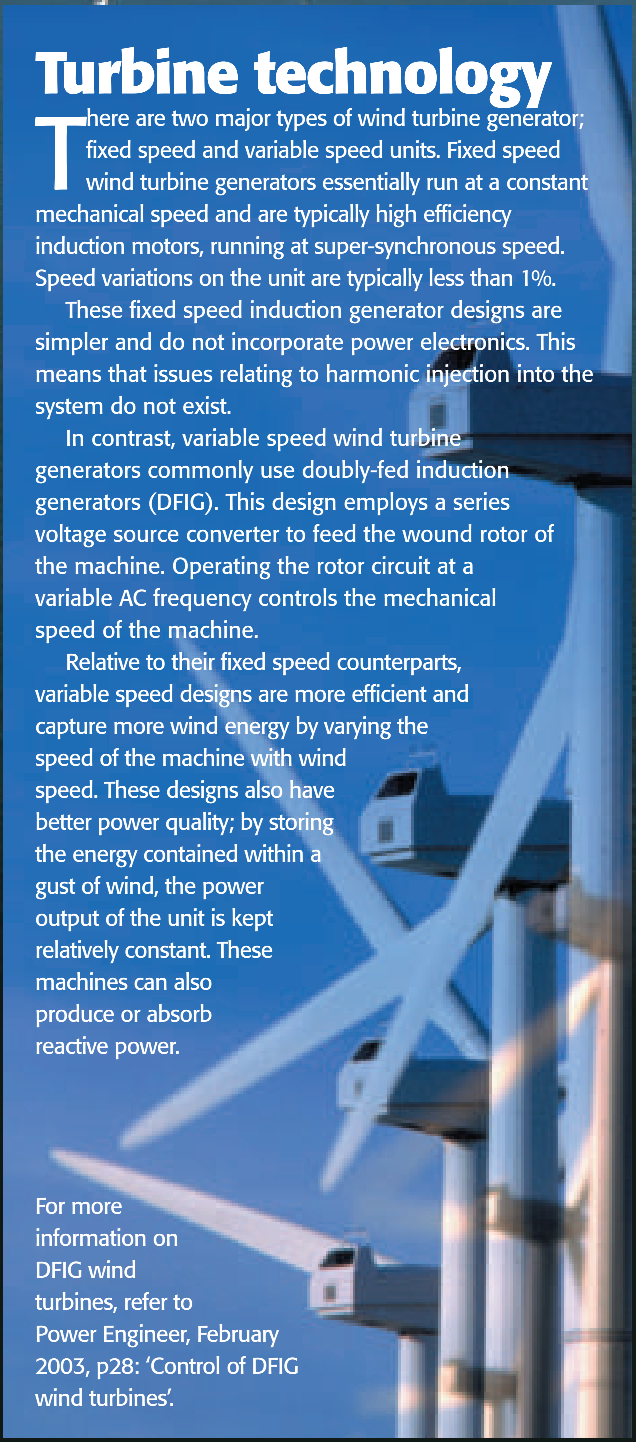

Turbine technology

There are two major types of wind turbine generator; fixed speed and variable speed units. Fixed speed wind turbine generators essentially run at a constant mechanical speed and are typically high efficiency induction motors, running at super-synchronous speed. Speed variations on the unit are typically less than 1%.

These fixed speed induction generator designs are simpler and do not incorporate power electronics. This means that issues relating to harmonic injection into the system do not exist.

In contrast, variable speed wind turbine generators commonly use doubly-fed induction generators (DFIG). This design employs a series voltage source converter to feed the wound rotor of the machine. Operating the rotor circuit at a variable AC frequency controls the mechanical speed of the machine.

Relative to their fixed speed counterparts, variable speed designs are more efficient and capture more wind energy by varying the speed of the machine with wind speed. These designs also have better power quality; by storing the energy contained within a gust of wind, the power output of the unit is kept relatively constant. These machines can also produce or absorb reactive power.

For more information on DFIG wind turbines, refer to Power Engineer, February 2003, p28: 'Control of DFIG wind turbines'.