Turbine Market Needs Tech Upgrade

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With the aim of generating 20% of all energy from renewable sources by 2020, the European Union is relying heavily on the contribution of wind power. Such targets can only be met with a two-fold strategy of energy-saving incentives and large-scale exploitation of renewable energy.

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Medium Voltage IGBTs Harness More Energy, Less Heat

Several European countries have impressive plans for installing large amounts of wind power generation in the coming years. Some governments support these actions by providing tax or investment incentives. For example, in northern Europe with its windy coastal waters and fine-meshed but strong electric grid, there are plenty of opportunities for powerful, efficient, land-based turbines (5MW) as well as offshore wind farm developments.

For large wind farms, though, maintenance challenges are enormous. Experience shows that up to 25% of the costs of energy produced by wind energy converters or turbines can be attributed directly to maintenance. Weighing in at more than 300 tonnes and standing over 90 metres tall, some turbines have suffered failed electrical systems, cracked blades, turbine gear teeth wearing prematurely and gearbox malfunctions. As a result turbines have often been subject to repair/refurbishment, a very expensive proposition that includes the cost of electrical component replacement and human safety requirements (the climb on the turbine's internal ladder requires mountaineer-style safety harness and can take 10 to 15 minutes), as well as the loss of production. It may be necessary to multiply these expenses ten-fold when turbines in extreme, often remote, offshore or inhospitable areas have to be repaired.

Building equipment robust enough to survive all weather conditions without undue maintenance would seem a simple task, especially when considering the backing it has received from the EU's technological initiatives, and the 'green' energy stimulus worldwide. Certainly, advances have been made in reliability and efficiency of rotor/mast design, yet the actual power conversion technology has not kept pace.

According to a 2007 European Commission-funded study, Project Upwind, many operating wind farms are experiencing problems with the electrical equipment (both power and control electronics), which clearly could be categorised as built-in weak points or simply inadequate designs. Further burdening the electrical controls are impacts related to climate, vibrations and intermittent operations. Electronics failure rates have been considerably higher than previously anticipated, necessitating costly maintenance and replacement. But there are new, highly reliable developments on the horizon.

Current Technology Usage

Wind turbines generate electricity in variable voltage and frequency; the electric utility grid, which distributes energy to our factories and homes, is at a local distribution voltage and fixed frequency of 50Hz. This requires the generated power to be changed, cleaned and conditioned before it can be fed into the grid. Each process of changing or cleaning the generated power creates losses, and the more times it is changed the more inefficiency is introduced into the system. As a result, in almost every position in the supply chain for wind-generated electricity, there is a need for power semiconductors for efficient power conversion.

The IGBT (insulated gate bipolar transistor) is a semiconductor switch used as a control method for electricity. Switch the IGBT on and power flows, switch the IGBT off and it stops – much like the light switches in our living rooms but much faster. It was developed in the late 1980s for

Figure 2. Examples of the press pack IGBTs

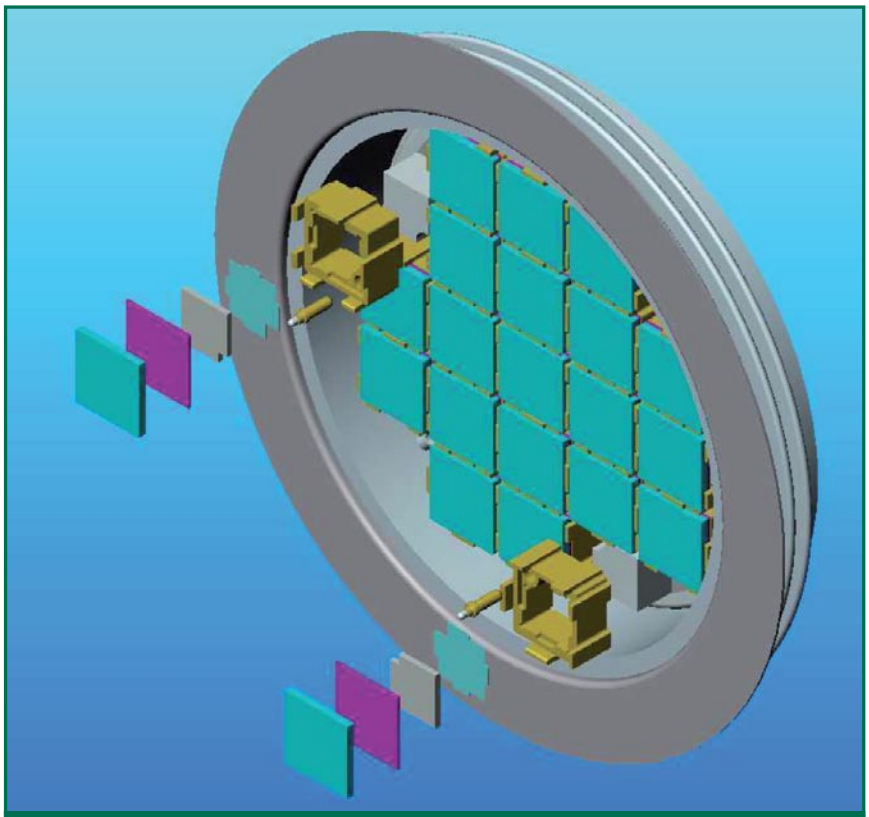


Figure 1. Internal construction of the bondless, solderless IGBT capsule

controlling the omnipresent electric motor and refined in the 1990s to reach the higher voltages required for transport applications such as trains, trams and heavy duty electric vehicles. IGBTs are commonly produced by a large proportion of power semiconductor manufacturers in the USA, Europe and Japan. Only on a more recent timeframe have higher voltages been available to harness wind energy.

The focus initially was just to harvest the wind energy, but as our world becomes more environmentally minded it has become increasingly important not to waste this energy. A wind turbine on average can operate at a peak efficiency given optimum conditions of around 20%. With an abundance of wind hitting the turbine, the focus is on retaining the majority of captured electrical energy that, in traditional inefficient turbines, would be lost in heat. This is where the higher efficiency IGBT comes into play. Every cycle of power you can save whole percentage points of power. Multiply these cycles by the average 20–24 year lifespan of a turbine and you can appreciate the environmental/energy improvements better IGBTs allow.

European turbine manufacturers have already adopted newer technologies, using medium voltage solutions with higher voltage IGBTs, which enable better power conversion (in the 5MW range), better power control behaviour, and smaller offshore constructions. More wind power stays in the form of electricity and is not lost in the form of heat.

However, much of current European technology use focuses on high voltage IGBT plastic modules, which must be de-rated (used at lower power) due to reliability issues inherent in a module solution. As weaknesses persist, European turbines experience less than the optimal 20% efficiency and are subject to higher outages due to breakdown and service requirements.

New Technologies Promote Higher Power, Higher Efficiency

The most recent improvement comes in the form of medium voltage inverters using press pack IGBTs. Many power semiconductor companies have committed R&D to this market, seeking to harness more efficient energy with less heat loss. Utilised in the wind turbine application, either as the mast head converter/inverter or the ground-based synchronisation element, a medium voltage 4.5kV IGBT is basically a switch used to control electrical current and voltage. Once an IGBT chip is integrated

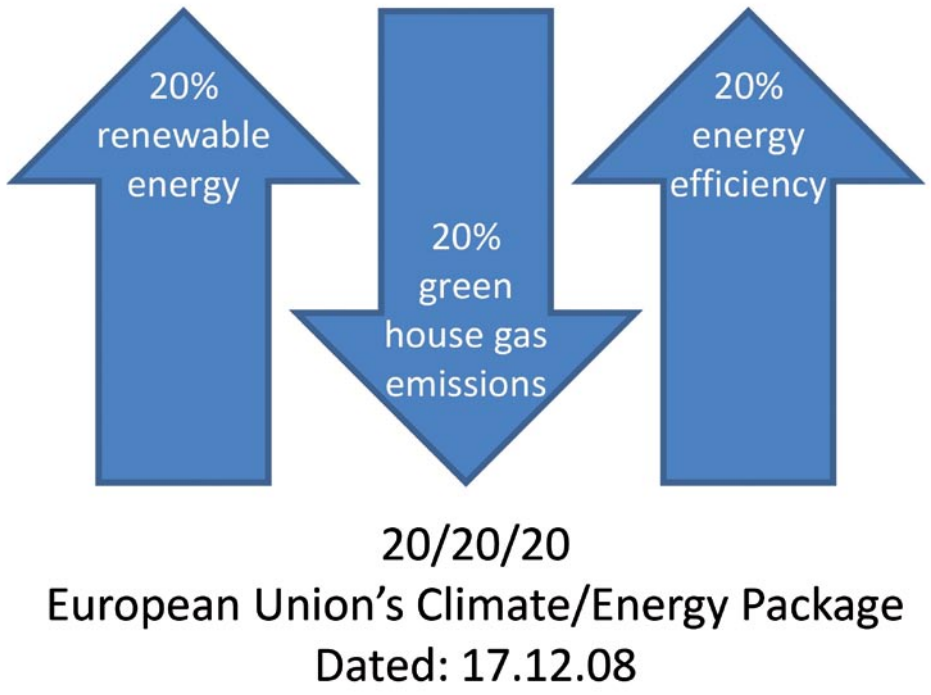


Figure 3. 20/20/20 Europeans Union's climate/energy package

into a hermetic ceramic capsule, it removes the weak points of die soldering and wire bonding that are found in the currently used plastic module design.

The 4.5kV ceramic IGBT capsule basically solves the problems inherent in the current turbine inverter design: (1) it does not need to be de-rated and so the maximum power densities are reached (over 5MW power), (2) the higher voltage design will reduce the number of stages of changing and cleaning the generated power that are needed, thus improving efficiency (at nearly 20%), and (3), the new IGBT technology offers the highest reliability necessary for remote/offshore wind farms, reducing downtime and repair/refurbishment costs. An additional benefit of a ceramic IGBT capsule is that it has a shortcircuit failure mode that allows for a redundancy to be built into any medium voltage inverter without the need for additional components.

Medium voltage inverters have other important benefits:

Due to the trade-off between voltage and current for power, a medium voltage generator inverter set will need to control smaller amounts of current, which means the conductors may be a lot smaller for the same generating capacity.

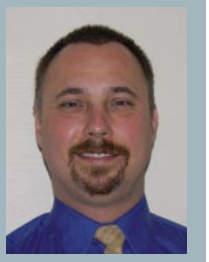
A medium voltage turbine will use a lot less copper, making it lighter, which is important during installation.

If commodity inflation returns as expected, the cost of commodities like copper and aluminium will make a medium voltage system less expensive for a given megawatt rating.

Since a medium voltage turbine will be producing electricity at or near the distribution voltage any transformers will be smaller and have lower losses, making the entire system more efficient.

Over the last decade, the European Union has witnessed new developments in harnessing wind power, becoming the clear leader in renewable energy. Turbines have become larger (5MW and more), with improved efficiency and availability, and wind farms have become bigger. However, to ensure the maximum efficiency of these ever-larger turbines, power and control electronics must advance. ■

Biography of the Authors



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