GE

ATTRACTIVE: GE's 4MW direct-drive transmission system with Switch permanent-magnet generator

Fair wind blows for permanent magnets

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Whether the world's major wind turbine manufacturers will ultimately make the move to direct-drive transmissions is a subject of debate. But the shift towards permanent-magnet generators (PMGs) is looking more certain. Even developers of hybrid reduced-gearing drivetrains are now rushing to integrate PMG technology into their designs.

PMGs promise drivetrains with greater efficiency and reliability, particularly under "partial load" — the state in which turbines usually operate. Compared with the currently dominant double-fed induction generators (DFIGs), PMGs have been shown to have efficiencies as high as 98% in gusty conditions and, in tests of a 2MW turbine, energy production yields 8.5% higher than DFIGs.

Finland's The Switch has been riding the upswing in interest in PMGs. Its recently unveiled SwitchDrive unit is being used by GE as part of a drivetrain package that combines a 4.25MW synchronous PMG and a full power converter (FPC) for the direct-drive offshore turbines the US giant is developing in western Norway.

A 3.7MW direct-drive PMG with a full-power, liquid-cooled converter package and built-in redundancy previously developed by The Switch for ScanWind — the Norwegian turbine maker bought by GE in 2009 — hit operating availability levels that averaged 97% in high wind speeds typical of the North Sea.

The Switch has also supplied PMG drivetrain packages for turbine developers including China's Goldwind and Dongfang, as well as Germany's PowerWind.

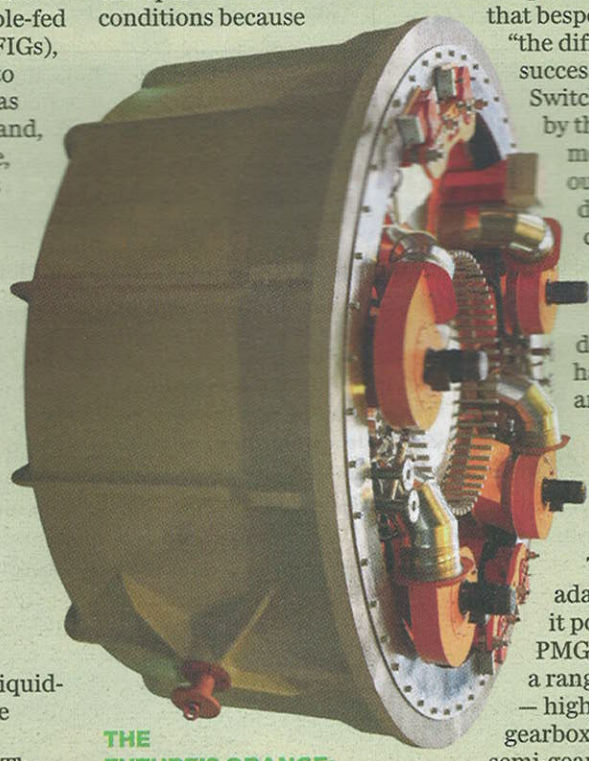
"It had been felt for some time within the company that PMGs would be the way of the future, but the decision to move forward on the technology was prompted by ScanWind, who had this 3MW direct-drive turbine ready to go but was not happy with the performance at start-up in low wind speed, where there was a great deal of vibration and noise," states The Switch PMG product specialist Panu Kurronen.

"Still, we had to scale up from very small PMGs that we had developed to that point to extremely large ones to meet their needs as a customer," he adds, noting that the latest version of the PMG for the 4MW GE direct-drive turbine weighs almost 90 tonnes and measures 6.4 metres in diameter.

The technology has swiftly evolved far beyond making a smooth-running PMG.

The SwitchDrive makes it possible for active power to be harnessed from the turbine at the same time as reactive power — the background energy in an electrical system — with both being precisely controlled over the full spectrum of operating speeds.

This means a PMG turbine can operate even in windless conditions because it can draw off the stored energy in the permanent magnets (PMs) to stablise energy output. DFIGs are more efficient in high, steady winds but have to have electrical current injected into the rotor at low speeds, resulting in lower efficiencies.



THE FUTURE'S ORANGE: The Switch's SwitchDrive permanent-magnet generator

"With a PMG design you have theoretically no losses — which is not strictly true because there are some losses due to harmonics in the air gap — but if you compare it with DFIGs, the difference is hugely in favour of PMGs," says Kurronen.

The SwitchDrive PMG also benefits from better fault ride-through during grid disturbances. Coupled with the FPC, the unit can balance the flow of active and reactive power to maintain stability when power voltages are erratic.

Fewer moving parts in the PMG — no slips or associated brushes — translate into lighter maintenance regimes and reduced chances of induced shaft voltages and bearing currents that are behind many bearing failures in wind turbine drivetrains.

Neodymium-iron-boron (NeFeB) magnets favoured for their "super-strength" by The Switch have been honed for greater corrosion resistance and temperature tolerance — key to preventing demagnetisation of a PM — using coating technologies developed in-house and proprietary hybrid air-and-liquid cooling systems.

However sound the concept, Kurronen stresses that bespoke design is "the difference between success and failure". The Switch puts great stock by the "finite element method" in fleshing out accurate loss distributions, short-circuit forces, and voltage waveform and harmonic frequencies in devising PMGs that have special magnet arrangements, purpose-built cooling systems and mechanically robust supporting structures.

This attention to adaptablilty makes it possible to build PMGs that are suited to a range of "topographies" — high-speed three-stage gearboxes, medium-speed semi-geared and direct-drive drivetrains.

As wind turbine designs continue to get bigger, cooling systems become increasingly crucial, since the PMs will overheat in temperatures higher than 100°C. In manufacturing the drivetrains for GE, a key lesson learned by The Switch was that hot spots on the rotor needed to be cooled to keep losses low. For this it designed an air-cooled system with a liquid-cooled secondary circuit.

Despite mainstream media reports to the contrary, delivery of the rare-earth materials used in the PMs bought by The Switch has not presented any pinch-points, says Kurronen, "apart from price, which has been climbing".

Any shortage of supply of neodymium, central to the NdFeB magnets, he reckons, is unlikely given the estimated eight million tonnes of the material still unmined around the world.

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