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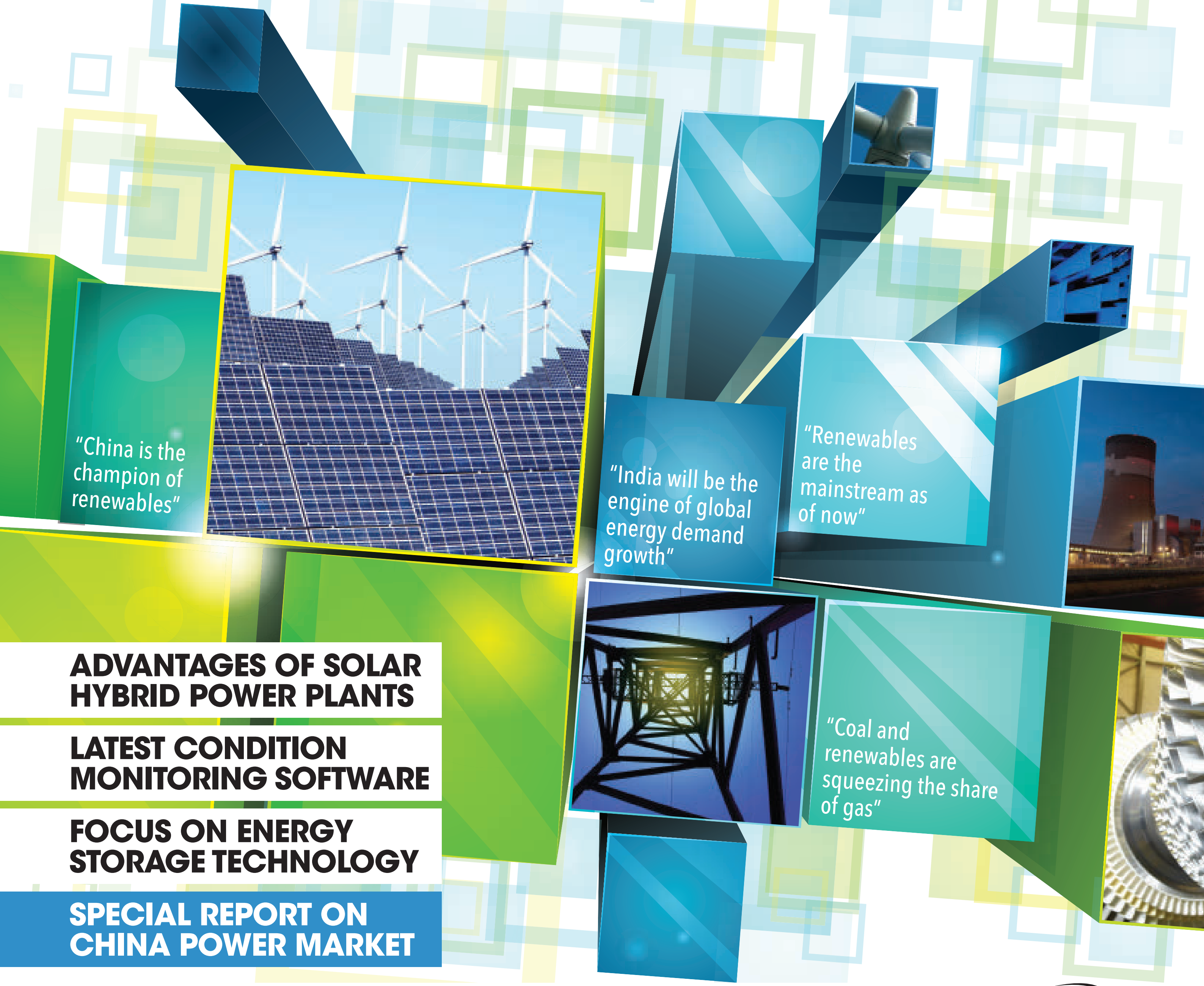

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Generators in Helsinki
Credit: ABB

Putting wind to the test

A changing power generation landscape has led to new challenges for both wind turbine manufacturers and makers of turbine components. Tildy Bayar travelled to ABB's electrical drivetrain testing centre in Helsinki to explore some of the ways component makers are responding

In response to the changing nature of power generation and distribution, many manufacturers of utility-scale wind turbines are moving away from electrical drivetrains based on doubly-fed induction generators toward those using full-converter technology. This potential paradigm shift could ultimately determine which wind OEMs will dominate in a changing energy market.

Below the OEM level, but working symbiotically toward the same efficiency and profitability goals and subject to the same market factors, are the companies that manufacture and supply wind turbine components. One such firm is ABB, which makes both types of drivetrain package. On a recent visit to the company's electrical drivetrain testing facility in Helsinki, I spoke with ABB about how they test the different components, why they need to, and what's in store for the future.

A wind turbine's electrical drivetrain is composed of the generator, converter, transformer and medium voltage switchgear. The difference between doubly-fed and full converter drivetrains lies primarily in the type and size of the generator, and that in the full converter type, all the power is fed through the converter. Full converter drivetrains are offered in low-speed (also called direct drive), medium-speed, and high-speed versions.

The electrical drivetrain sits between mechanical and electrical forces, says Teijo Kärnä, Wind Market Manager at ABB Finland. It must withstand both types of interactions, and also fulfil grid code compliance requirements at the turbine and power plant levels. It is perhaps not surprising, then, that electrical drivetrain components are responsible for one-third of all wind turbine failures, resulting in 37 per cent of annual turbine downtime. According to Kärnä, the high number of failures is due to how the different components within the drivetrain interact with each other. If one component is optimized, he asks, how well does it operate with a different supplier's converter? In other words, he says, it's about how well you can optimize your overall design to maximize reliability and minimize downtime.

While the doubly-fed drivetrain model has traditionally dominated the market, full converter drivetrains are catching up fast. Drivers for this trend include the need for compliance with new and more demanding grid codes and a growing need to optimize power generation at lower wind speeds. Increasingly, today's wind turbines need to produce higher-quality output more reliably, as well as be able to help stabilize the grid by feeding in reactive power.

According to Timo Heinonen, content manager at ABB Motors & Generators, the full converter concept "multiplies all the benefits of the doubly-fed system and much more. It offers a full speed range, full grid compliance with the most advanced grid fault support and ride-through function, full control of the generator and the grid, and total grid de-coupling of mechanical parts".

ABB notes that an OEM's choice of electrical drivetrain will result in different wind turbine weights, sizes and eventual maintenance needs. Thus, the company cautions that selecting a drivetrain must be undertaken with care, weighing the turbine's requirements against the necessary certifications and grid code specifications. In addition, because where the turbine will be installed – and thus which grid codes will apply – is not always known ahead of time, sometimes the OEM is forced to estimate, which can lead to extra costs. Testing can eliminate this, the company says.

The importance of grid codes

Grid codes define the technical specifications that a grid-connected power-generating installation has to meet to ensure the safe, secure and economic functioning of a regional or national electricity network.

In Europe, many grid codes have recently been modified to cope with the increasing penetration of renewable energy sources, bringing new challenges for OEMs and component makers.

Kärnä notes that in Europe, power plant operators "are not allowed to disconnect anything [in the event of a grid failure] – the plant must be online at all times and be in a position to support the grid." And individual wind turbines, he says, can no longer operate as "conventional units, but must operate in the same way as a power plant".

ABB is given requirements by OEMs, but the grid code requirements are first set by the transmission system operators or distribution system operators.

"The OEM is just happy if they are able to comply with the requirements for the turbine," Kärnä notes. While a wind turbine can't comply with all of the grid code requirements on its own, as these are typically applied at the point of common coupling for an entire wind farm, the quality of the power that the turbine produces is nevertheless increasingly important, as electrical problems such as flicker, harmonic distortion and fault ride-through will all affect the grid.

In addition, says Kärnä, the challenge for OEMs and component manufacturers is often not to fulfil the grid code requirements as such, but to understand their intended functionality and the details of the technology requirements, as the grid codes themselves can be moving targets.

Jari-Pekka Matsinen, Account Manager and Area Sales Manager at ABB Oy BU Drives & Controls, PG Wind Converters, says that "at the moment, OEMs are satisfied" with today's European grid code requirements. However, "there have been discussions, specifically in Germany," where some OEMs using full-power technology were actively promoting its capability to support the grid under different kinds of fault conditions.

"How the turbine should operate under symmetrical and asymmetrical faults, however, is more or less questionable," Matsinen says.

"At least so far," he explains, "the current trend in grid code development has been that grid support shall always be conducted as a positive sequence current, regardless of the type of fault. It is a well-known fact that, under symmetrical failures, the conventional synchronous generators often used in, e.g., large hydro plants will offer positive sequence reactive current support to the grid, but what happens in the case of asymmetrical failures is another story."

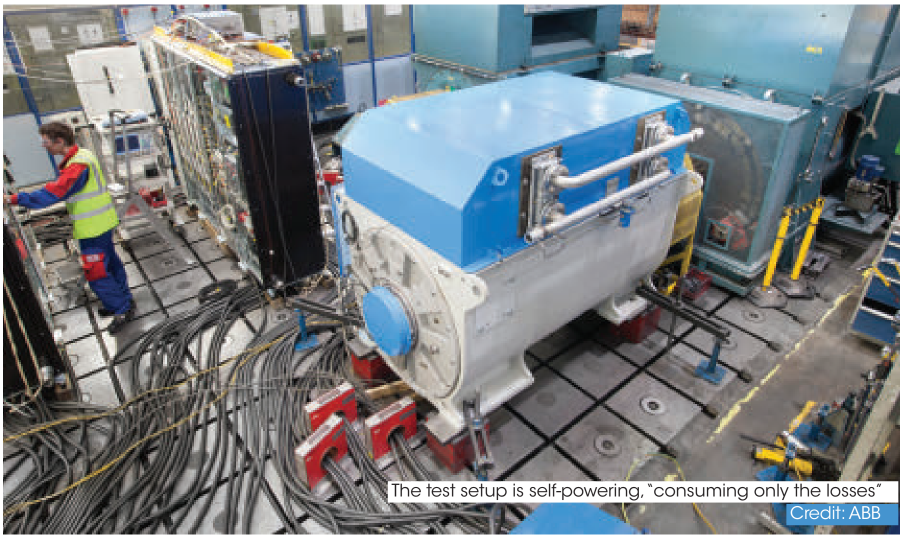
He notes that the "price tag" for this grid code development was that OEMs using doubly-fed drivetrains were "suffering" because of the advantages offered by the full-power types. For example, a doubly-fed generator can operate similarly to conventional synchronous generators, but only if the grid code requirements do not ask for something different. The grid code requirements of today are perhaps less favourable for doubly-fed technology, and have "cost a lot of money for these turbine makers," Matsinen says, noting that the doubly-fed technology is both feasible and able to comply with current grid code requirements.

Today, because of the high penetration of renewable energy on the German grid, instability is increasingly likely. And grid code requirements are not only about avoiding failures, Matsinen notes; they also work to guarantee power quality. "We need to know how to support the grid to survive under normal load consumption conditions, and how to balance with renewable energy to stabilize it," he says.

In terms of coming grid code developments, ABB has focused its testing where it expects change. As the system monitors grid voltage for faults, if it notes a drop in voltage that might have previously triggered a fault, it will cut out – but under today's grid codes the voltage can fall as low as zero and still not trigger a fault. Thus, the current concern is with the duration of fault events. Matsinen says that "the failure modes are more or less there; the voltages cannot go any lower than zero – and now we are already there. The only variable that can be extended is duration."

Grid codes differ throughout Europe, presenting further problems for OEMs. One of the strictest codes, if not the strictest, is the UK's, Matsinen says. ABB has extended its testing even beyond the average range to explore whether the equipment will stand up to failures lasting 500 milliseconds, a number that is "fully compatible with all known international grid codes" (and then some). "Some customers have asked whether ABB is using over-rated converters to comply," he says (the answer is "Of course not"). "It's all about how you control the converter and the generator during the fault event," he explains. "They must operate in perfect sync, and you can achieve enhanced performance without oversizing the system."

Significant changes such as China's revisions to its grid code can mean that OEMs may have to retrofit their previously commissioned turbines, representing huge costs, in order to comply with the new requirements and take advantage of higher feed-in tariffs. With ABB components these OEMs "can take advantage of our lab-test results and simulation tools beforehand," Matsinen says, "so they really know what to do. For example, in the case of China's latest



The test setup is self-powering, "consuming only the losses"
Credit: ABB

LV drives factory
Credit: ABB

grid code revision, only the converter's control software needed to be upgraded in order to comply with the requirement."

The testing labs

"Officially," Kärnä says, ABB is "not a turbine manufacturer, and will not be. We do component and system supply – this was a strategic decision." On the other hand, he notes, "if you look at just the electrical drivetrain there are a lot of things to do still, starting from standardization – but also optimization, the grid codes changing, the energy market changing, the interface with the grid connection, and also how turbines can be operated in a wind farm, and as a wind farm. This is system optimization – and for that we need real verifications, real models, real simulations, not estimations or assumptions." Thus, ABB's electrical drivetrain testing centre at its Helsinki production facility.

The test setup is self-powering: "We are consuming only the losses," Kärnä says, "driving motors downstairs that run [the testing rigs]" on the upper level. The setup is isolated from the grid and can use different frequencies. According to ABB, it serves four primary functions: electrical drivetrain dynamic performance requirement fulfilment evaluation (as related to grid codes); electrical drivetrain optimization (modelling and converter dimensioning); validation of simulation models against full power testing; and electrical drivetrain technology development for ABB converters and generators. The facility is connected to the Helsinki grid, "ensuring that our customers have an ideal and realistic testing environment for multi-MW and full power drivetrain testing".

Matsinen explains that the testing facilities offer design verification via full-scale, full-power testing in two different ways: first, full power testing of generators, converters, transformers and switchgear under different dynamic and static operational conditions, and then testing under transient grid conditions. The drivetrain lab and the grid testing facility also test for grid code compliance. The testing lab does not test to external standards, "just requirements from customers – we are setting the standards here," Kärnä says.

The advantage of this process, Matsinen says, is that components are tested together rather than singly. "When we do new turbine components or a system, of course that process starts with some kind of base design that we already know, and we develop it from there. If we just test as single components, we never get verification of how it all works as a system," he says. "First we verify our own design, then we build up the validated simulation models that can be used for the grid studies, and that is the value for the customer."

The tests simulate the different kinds of fault conditions that could happen on a real power grid, he explains, through circuit tests in multiple combinations. They test "short-circuit failures, safety breaker interactions, any combination of these". Asked how many sequences are in a typical test run, Matsinen describes a recent test for a customer that featured over 60 different combinations. This testing can significantly reduce costly on-site validation time, he notes, as well as avoiding "surprises" during on-site validation tests.

A week before our visit, he adds, a new electrical drivetrain package was put under extreme full-power testing at the Helsinki facility. The full-scale test configuration used a 3.25 MW permanent magnet generator (PMG) and an appropriately rated full power converter. "This electrical drivetrain package enables a wind turbine to generate and deliver 3 MW of power into the grid and meet even the strictest international grid code requirements," Matsinen notes. "All tests were carried out with full power, covering temperature rise testing, efficiency, power quality and excessive dynamical tests such as low voltage ride-through testing, just to mention a few."

Looking to the future

Kärnä says he does not particularly prefer one drivetrain concept. "There are advantages and disadvantages with any concept: direct drive, medium speed or high speed." In the offshore wind market, he says, ABB approaches the issue "client by client".

"I don't comment on concepts like that because so many things need to be evaluated," he explains. "All technologies are equal, but it depends on your perspective – manufacturing, installation, operations and maintenance – all are different flavours. There is still a place for all of these in the market for the foreseeable future." For him, he says, the foreseeable future is "maybe five years – and I don't believe that direct drive will be a major concept [during that period]. Globally, mainly due to the Asian market, doubly-fed will prevail onshore." For offshore wind installations, he says, it will be "PMGs and induction generators (direct drive or medium-speed)".

And the next step? Beyond PMGs, he says, the industry should expect not big changes but "further refinements – around dimensioning and magnet materials, but of course also differences in medium speed, high speed, direct drive – mainly because of the manufacturing processes and technology."

The challenge for direct drive turbines is the larger dimensions of all of the components, he notes, especially in terms of where to manufacture and how to transport them. "Going up to 8 MW," he says, "you have a huge generator manufactured on the shore in the harbour because you can't transport it anymore." For this scale of production, he says, "you have to have a sustainable market".

Looking to the future, Kärnä says which technology will dominate "remains to be seen". Today there are "more or less three or four players in the offshore market in Europe," he says. "Two have medium speed, two have direct drive, and one of those has an option for high speed… so from that I could not draw any conclusions."

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