Monitoring makes good sense

Competition among wind farmers to make winning bids in tenders for new generation contracts, while maintaining a healthy return on investment is spurring innovation in operating technology. PhotonFirst looks at how integrated photonics sensing can help operators improve return on investment.

Turbine operators are learning that advanced photonic sensing can provide more detailed, real-time wind turbine monitoring data, informing them about the behavior and performance of key components such as blades, towers, gearboxes and cabling.

This data will enable them to meet the highest safety standards, increase output, cut operating costs and extend operating lifetimes.

To date, the use of fiber optics for sensing has been limited to monitoring of load and temperature only at the root of a blade. This is because the early versions of the technology have been expensive to scale up for multi-point use in large turbines.

Now, a novel approach, Integrated Photonic

Sensing (IPS) pioneered by Netherlands-based PhotonFirst presents a roadmap, which will extend the scope and improve the performance of sensor systems at an affordable cost, giving turbine operators a more comprehensive, predictable and timely view of the behavior of turbine systems.

Photonic sensing: robust and precise

In all the main components of a turbine, measurement of physical parameters in real time allows operators to achieve higher output and longer lifetime. Photonic sensing is a known method for acquiring such measurements. A photonic sensing system can convert the minuscule changes in the light waves inside an optical fiber into an ultra-accurate stream of measurements of parameters, such as strain, temperature, pressure, shape, vibration and acceleration, refreshed thousands of times every second.

Photonic sensing systems are immune to various strong sources of interference in the turbine environment, can withstand natural phenomena such as lightning strikes which can damage or disable electronic systems, and are smaller and lighter than their electronic counterparts. Ultra-light optical fiber can also be extended over long distances, such as from a turbine's root to the tip of a blade, without degradation of the signals even at the farthest reaches of the system.

But today, the full capability of integrated photonics sensing is barely being used in wind turbine installations. The current generation of fiber optic measurement technology is expensive when scaled up to provide detailed, multi-parameter measurements. So wind turbine installations are restricted to the monitoring of load and temperature measurements provided by cheap, low-performance fiber optic sensing systems which are mounted at the root of the blade.

Existing higher-performance systems, which are much more expensive, have been deployed by turbine developers to study the performance of prototype designs. The higher performance comes from multiplying the number of sensor points, and extending them out from the root along the length of the blade, all the way to its tip.

This provides extremely accurate measurements of the blade's shape and the loads it is subject to throughout its length. Turbine developers can use these detailed measurements to optimize the design of the blade, extracting the maximum power output while ensuring that the blade does not hit the tower.

Detailed multi-point measurements can provide similarly valuable information about the inside of the gearbox, providing an accurate log of the loads imposed on gearbox components over time, and enabling operators to arrange maintenance and repair in response to the actual condition of the mechanism, rather than on a predetermined schedule. There is equal scope to deploy fiber optic sensing in the tower, cables and tethers.

This detailed operational monitoring data is only available to developers of prototype turbines because of its prohibitively high cost, and not to operators of installed turbines.

It's no surprise, then, that turbine operators are excited about the potential to apply high-performance fiber optic sensing at scale, and affordably, in production units. This is the promise of integrated photonic sensing.

The problem of scale: discrete vs integrated modes of photonic sensing

Solving the problem of scale has involved the development of a new, highly integrated method for handling the optical signals in a fiber optic sensing system.

Today, fiber optic sensing technology uses a discrete approach, in which the Fiber Bragg Grating (FBG), an important optical component at each passive sensing point, is connected to a central, complex electronics circuit which performs all the system's other functions, such as signal routing, amplification, processing and conversion. So the optical signal processing is a discrete, separate function from the electronic signal processing.

This original implementation of photonics sensing can be effective in terms of raw measurement output, but is expensive, inflexible and bulky when scaled up to provide the high number of measurement points and to monitor the multiple parameters required to perform functions such as blade monitoring, shape sensing, ice detection, gearbox monitoring or cable monitoring.

This is why the world's leading turbine manufacturers are now turning to IPS, the next generation of photonics sensing technology based on the use of photonics integrated circuits (PICs). In the integrated mode, the optical measurement signals are handled by a PIC, the optical equivalent of the familiar silicon IC used in the electronics world, avoiding the need for multiple complex optical-electrical-optical conversions. Compared to a discrete system, a PIC is smaller and simpler, and cheaper to produce at scale.

And because a PIC is fabricated with similar materials and production equipment as electronics ICs are, the devices benefit from the same forces, known in the electronics world as Moore's Law, which produce an exponential decline over time in unit cost-per-chip combined with a similar rate of improvement in performance.

And just as in the semiconductor world, there is an ecosystem for the production of PICs which drives the Moore's Law process forward. In the case of PhotonFirst, this ecosystem is supported by The Netherlands' PhotonDelta (photondelta.com), which recently received a €1.1bn investment from the Dutch government and the Dutch industry to support the development and manufacturing of a new generation of PICs.

This means that turbine developers which commit to the use of IPS can expect to enjoy a progressively more attractive payoff year after year, as the cost of PICs, and of a complete IPS systems, fall while offering continually higher measurement precision, accuracy and speed.

How to plan to implement IPS in new turbine installations

IPS, a technology pioneered by PhotonFirst, is highly applicable to the wind power sector for many reasons.

Firstly, it is scalable; as with silicon ICs, the unit cost per sensor falls dramatically as production is scaled up from a few hundred units, while maintaining high performance. Secondly, it is flexible. IPS systems may be used to measure any physical parameter of interest, including a blade's torsion, shape and load, or a gearbox's vibration, load and temperature. And it is high performing. Handling measurement signals in the optical domain enables systems to be optimized for each customer's application, whether that calls for the ultimate in accuracy, high sampling rates, or a high number of sensing points

Already, PhotonFirst has engaged with manufacturers and engineering companies in the wind industry in the development of prototype turbine measurement systems based on IPS technology. To support the development of complete sensing systems, PhotonFirst provides a complete, vertically integrated photonics sensing solution. This includes not only packaged PICs: PhotonFirst also assembles the photonic chips into its interrogators, which convert the optical signals into data.

Evaluation of the technology and the implementation of IPS-based turbine monitoring systems are facilitated by the provision of Modular Photonics Systems, standard measurement building blocks which the developer can configure to meet the needs of their application: these building blocks may be optimized for speed, accuracy, number of sensors, or any combination of these factors.

Turbine manufacturers can begin today to develop new sensor systems which benefit from the cost and performance advantages of IPS technology. But crucially, the Moore's Law effect of IC fabrication means that these advantages are set to grow exponentially over time. Companies that begin to master the design and manufacturing of IPS-based sensing systems today will thus be in pole position to win in the competition for energy generation tenders as the industry continues to ramp up generation capacity through the rest of this decade.

The production capacity, systems expertise and application tools available from PhotonFirst will be on hand for those pioneering manufacturers which choose to take advantage of the promise of integrated photonics sensing.

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