Inspection free bolting

Nuts and bolts are one of the most simplistic components on a modern wind turbine, but their inspection is often the single largest maintenance expenditure. Inspection-free bolting is a revolutionary new maintenance approach, which is now available in the offshore wind industry through the adoption of bolt load monitoring technology.

A wind turbine consists of over 10,000 bolted connections, with around 1,000 to 1,400 being classed as critical from a safety and/or performance perspective. Failure of bolted connections can have a significant impact on the structural integrity of the asset, lead to asset damage and incur significant lost production and repair costs.

To identify failed fasteners and prevent catastrophic failure of the asset, periodic manual bolt inspections are currently conducted in the wind industry. Whilst this varies between OEMs, this typically involves an annual torque or tension check on 5 to 15% of critical fasteners. The existing maintenance regime presents significant health and safety risks as a result of using heavy and cumbersome tools, as well as the typical risks of working at height in offshore environments.

The existing practice is also very costly, with annual bolt inspection often costing in excess of £200,000 for an offshore wind turbine. This represents almost a third of the annual maintenance budget, with annual bolt inspection being the largest single planned maintenance activity. To drive down the cost of offshore wind energy, operators are actively seeking alternative maintenance regimes.

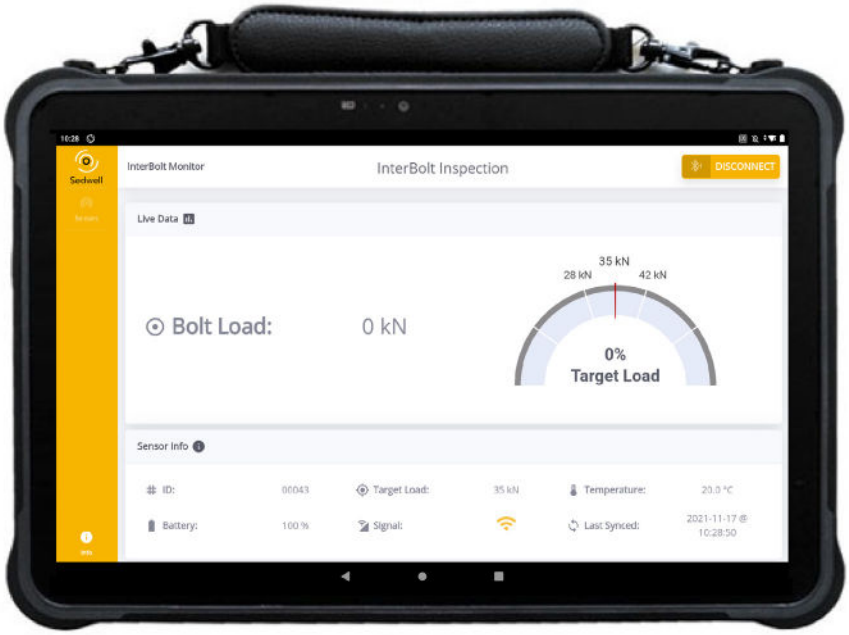
A technological solution

Sedwell's innovative InterBolt technology is the first commercially available bolt load monitoring technology that can eliminate the need for manual inspection of bolted connections. Partnering with TensionPro, the bolt tensioner specialists, for mechanical design aspects and international sales functions, it brings together a team with expert knowledge in sensors and Industrial Internet of Things (IIoT), and large diameter bolt tightening technology.

The solution consists of a novel IIoT bolt load sensor integrated into the standard bolts or studs used on wind turbines. The sensor measures bolt load through detecting minute changes in bolt length. Although it may seem counterintuitive to many, a bolt acts like a spring and is designed to stretch a small amount as it is tightened. The relationship between force and elongation is linear over the proof load range of a fastener. The unique bolt load sensor converts this elongation to an accurate measure of bolt load. Each InterBolt is calibrated over its full operational load and temperature range so no on-site calibration or setup is required, completely eliminating the probability of user/ human error.

Onsite monitoring

When technicians are on site during installation and retightening, the LED



indicator in the end cap will illuminate red or green to notify the technician whether the connection has been tightened to the correct preload. With a clear line of sight, the super bright LED indicator is visible at a distance of 50m.

The bolt load can also be displayed on the InterBolt Inspect app, which features two main screens, list view, where you can view the data from multiple InterBolts in a table; and single view, where you can view data from an individual InterBolt in more detail.

The single view pictured is particularly useful during tightening to ensure that bolts aren't stretched beyond their yield point at installation and the achieved preload is close to its target.

The app can be hosted on a client's handheld device or can be supplied on the special ruggedised tablet solution. The 10in android based device is perfect for harsh operating environments and features ingress protection to IP65, impact resistance to IK07 and an anti-glare coating.

The local monitoring features of InterBolt ultimately enables simple and accurate monitoring of bolt load on site, ensuring that technicians can demonstrate that all bolts have been correctly tightened before they leave site.

Other bolt load measurement or verification techniques exist, including ultrasonic measurement, and smart or integrated tensioner and torque systems that incorporate the bolt tightening method, plus sensors to give the operator feedback that the bolt is tightened correctly. However, these methods are only valid for the particular bolt being tightened, at that moment in time.

Bolted joints have considerable elastic interaction between different bolts as the flange is completely loaded, with the flange itself compressing and bending to conform to the mating flange. This means that the initially correctly loaded bolt may not still be at the target load once all the other bolts are loaded. This solution allows for full, 100%, verification that all bolts in the flange are at target load. A critical thing to ensure the integrity of that bolted joint in service.

Remote monitoring

The real value of the technology comes in the form of its remote monitoring capabilities. This means that bolt load measurements can be captured autonomously and visualised in real-time from operational control rooms.

To enable remote monitoring, a wireless gateway is placed on the turbine, typically in the nacelle. The gateway connects the InterBolts, which operate on a LoRa wireless network, to a remote network through an ethernet, cellular, Wi-Fi or SCADA connection. They have a communication range of up to 1km so only one gateway is typically required to get full wireless connectivity for a wind turbine.

The InterBolts periodically sample and transmit the measured bolt load. This data is forwarded to a cloud system where it is stored. Abolt load samples from installation to decommissioning are stored in a database so that the whole life performance of the fastener can be viewed on demand.

It is then analysed, with each incoming sample subjected to an inbuilt analysis engine. Using a combination of threshold and trend analysis, alerts can be generated when the reported bolt load is outside a specified range, i.e., too loose or too tight. These alerts are displayed on the cloud UI or can be sent to operations teams using SMS or email. Through using alerts, technicians don't need to periodically check every individual bolt in the Cloud UI to detect a fault.

Then it visualised. The bolt load from a single bolt or a complete wind farm can be viewed through the Cloud UI. The InterBolt Cloud UI is an asset centric system meaning that the

measured bolt load is associated with a specific location on the turbine. This ensures that there is a location context to any fault so intervention is targeted. The Cloud UI features various graphical widgets to display the data: from a graph showing the bolt load history of a single bolt, to a 3D model of the turbine with the data overlaid.

Ultimately, the remote monitoring capabilities eliminate the need for periodic manual inspection. Instead, operators and asset owners can adopt data-driven maintenance strategies. A general industry trend to use predictive and prescriptive asset-management strategies are gaining traction as companies discover the benefits of applying data and analytics to maintenance. The potential cost savings of a predictive maintenance program for a large array of offshore turbines can be very high. Such programs for bolting require the availability of the reliable bolt load data that InterBolt provides.

Through work with the Offshore Wind Growth Partnership, the OREC Levenmouth demonstration turbine has been equipped with the InterBolt technology on the two lower tower flanges. Live data from this site can be seen at https://dashboard.interbolt.co.uk/login, using email demo@sedwell.co.uk and password Interbolt.

How does the system differ from other products on the market?

Whilst there are several mechanical and electronic load indicating bolting solutions entering the market, the InterBolt technology offers superior performance. Specifically:

- Wireless connectivity with a 1km range. InterBolt uses a LoRa wireless network which offers superior power efficiency and range over other technologies. This minimises the number of wireless gateways and repeaters required for full network connectivity on a turbine.
- Battery operated with a 15-year battery life. The novel bolt load sensor is an order of magnitude lower power than other solutions and with its high efficiency electronic circuitry and clever low power sampling regimes, it offers the best in class battery life. The battery forms part of the end cap and can be replaced in less than 30 seconds in the field without the need to remove the bolt.
- Accuracy: InterBolt offers a 97% accuracy and each unit is supplied with a calibration certificate. The sensor features ageing and temperature compensation circuitry and algorithms so is calibrated for life.
- Robustness: unlike other technologies, this has been specifically designed for harsh operating conditions. It has ingress protection to IP68, has a temperature range of -40 to 850C, been impacted tested to IK07 and has the ability to withstand vibration and shocks to 1000g.
- Inbuilt LED indicators for simple and fast verification of bolt load on site as well as connectivity to the Inspect app.
- Supported by a fully functional remote cloud system.

Where can it be used?

The technology can be used on any critical bolt or threaded stud which is prone to failure and/ or troublesome to inspect. For a wind turbine this includes tower segments, transition piece, blades, yaw bearing and gearbox bolting.

How will it help our operations?

InterBolt enables operators to achieve more accurate bolt tightening and eliminate the need for periodic manual inspection. This will help with cost, through eliminating manual bolt inspection, the single most costly planned maintenance task can be removed from the maintenance schedule. In terms of health and safety, this method eliminates the need for heavy and cumbersome tools to be used to confirm bolt load and eliminates the need for technicians to be deployed offshore unless there are bolts that require tightening. And it helps reduce downtime, as it monitors bolt load whilst the turbine is in operation so there is no requirement for the asset to be shut down for bolt inspection.

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