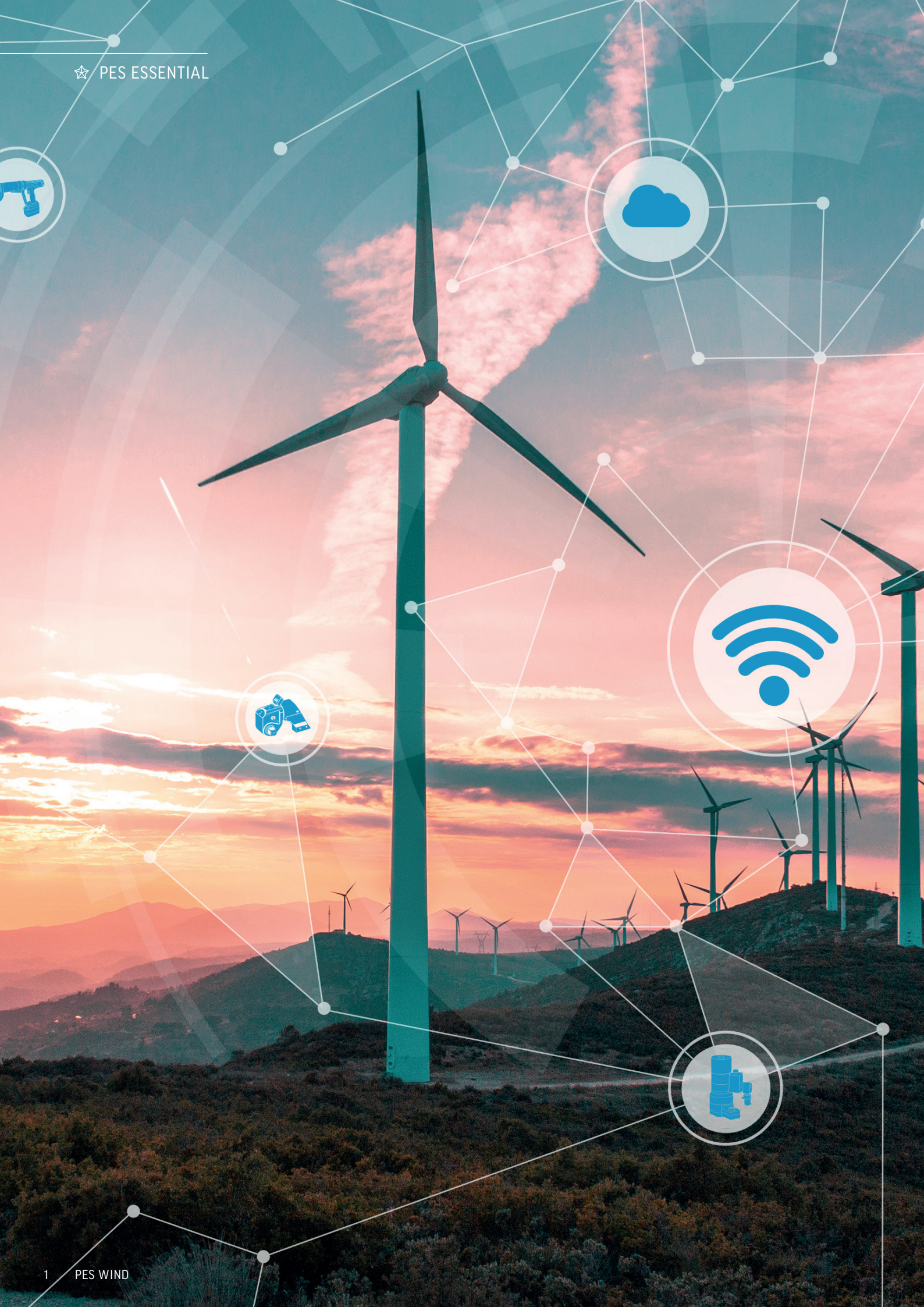

Smart connected bolting: taking the smart factory to the field

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The smart factory is a term we all know well and is used in reference to the implementation of Industry 4.0 in the manufacturing environment. Significant benefits such as improved quality, higher productivity and cost reductions have transformed industries such as automotive and electronics in recent years through implementation of smart connected assembly solutions. Wind energy is catching up. We now see the use of smart tooling with inbuilt intelligence for critical assembly in factories for nacelle and gearbox production, but what happens on work sites out in the field?

There is a significant amount of critical bolting operations take place in construction, commissioning and maintenance which have a direct impact on the turbine performance, reliability and cost. However, the reality is that in many cases conventional bolting methods are still being used in the field due to old processes remaining in place, outdated tool fleets, and a general lack of awareness exactly how smart factory thinking can really be applied in the field with the technology and solutions available on the market today.

The energy transition is happening, but the wind sector must drive a transformation in critical bolting across the full value chain to truly benefit from the possibilities smart connected bolting solutions can bring.

Digitization of manufacturing

The fourth industrial revolution or the digitization of manufacturing has arrived.

A key enabler is the emergence and use of

Data collection

technologies for connecting people, equipment and machines, and with it the capacity for integrated analysis and use of large amounts of data across value chains.

Manufacturing companies have been implementing sensors and automation for decades, but seamless connectivity and communication have been missing for establishing fully connected production network in factories where data is exchanged in real time.

The data and information can be used to improve productivity and quality, reduce defects and costs, and offer opportunities to introduce new or enhanced services to customers.

Benefits to the wind energy industry

Smart tools for bolted assemblies with integrated sensors and intelligence that can document and distribute process data are already used in some manufacturing facilities of the wind industry today. Automation, process control and traceability of data such as torque and angle tightening results, tool maintenance cycles or error logs which are connected to specific parts, components or persons is used just as it is in other industries such as automotive, aerospace or electronics.

Going forward the bolted assembly process is expected to be further digitized. Even if we assume the process needs to be performed by humans, the move towards robots is happening even in the wind industry, which can be beneficial when applications require high loads or are in extreme locations such as offshore.

Bolted assembly work in the factory or the field, today and in the future can benefit from new technology in many areas including quality, process performance and overall cost efficiency.

We have identified **3 key areas**:

1 The assembly process

The quality of assembly will be guaranteed within narrow tolerance due to sensors in the tools for torque, speed, load, angle, acceleration, temperature and more. Sensors in the tool will control the process and secure that there is a documented record of the assembly process showing what has been done, when, and by whom. Benefits to operators will include interfaces that are intuitive and self-instructing. This will reduce training demands and enable fast efficient assembly processes independent of operator influence.

2 Maintenance of all tools and equipment

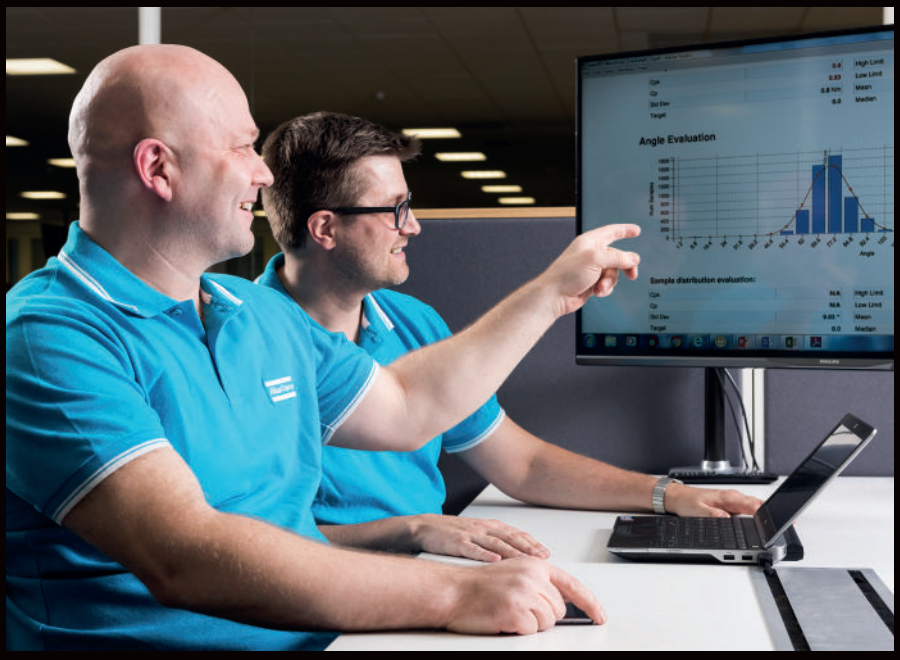
It is well known that preventive maintenance is better than unplanned, but the use of sensors and big data shifts the trend to predictive maintenance which uses multiple sources and parameters to model the likelihood of failure. Early indications of deviations can be identified through analysis and the accuracy of prediction can be improved by sharing results across multiple users, or even sites. This results in costs being significantly reduced and equipment maintenance schedules optimised.

3 Big data analytics

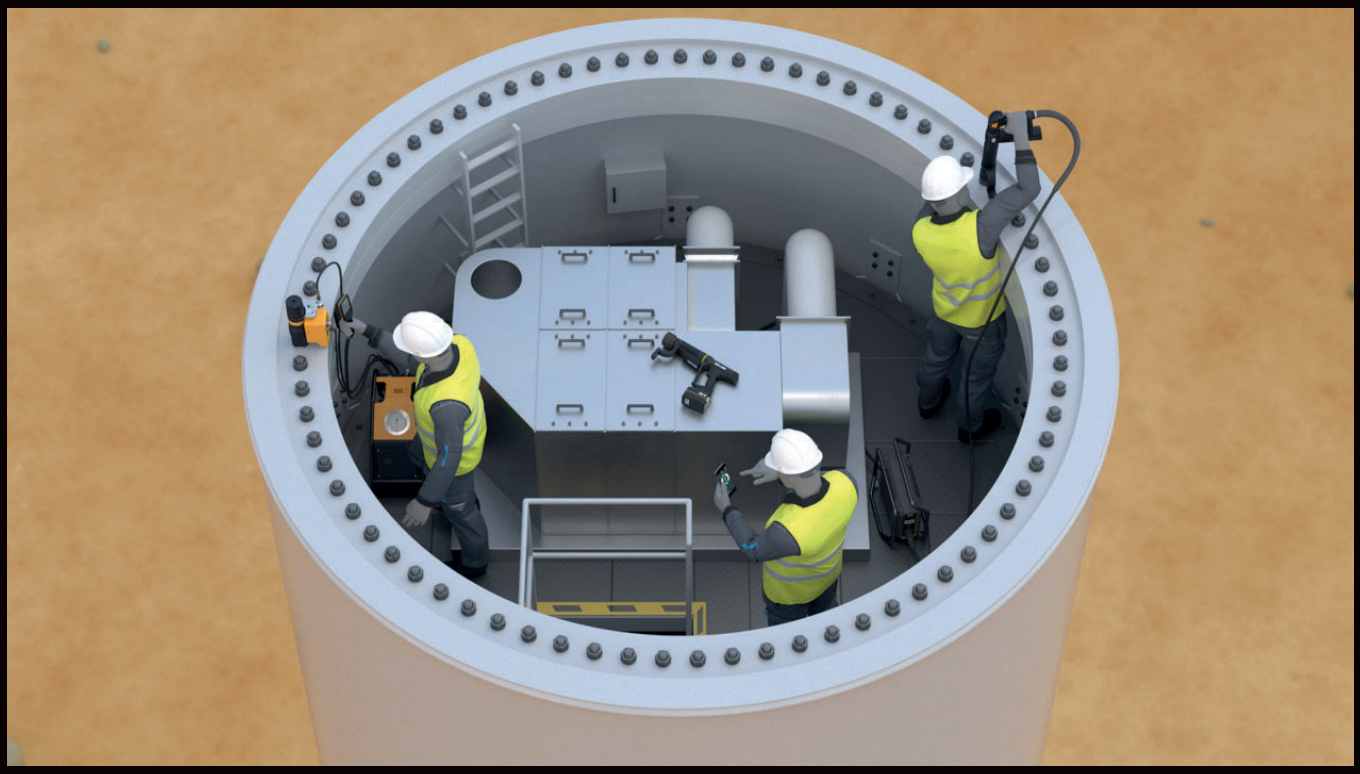
Highly relevant where the cost of downtime is high. Rework and downtime result in high costs both financially and in reputation. Big data can be collected from all bolted assembly operations whether it be in a factory or in the field, at any time during the product life cycle. This information can be shared across sites or locations performing the same types of operation. This will drive early identification of potential problem areas and enable rapid knowledge transfer and best practice implementation.

Adding value across the value chain

Harvard Business Review (October 2015) stated we will see a whole new era of 'lean' as smart, connected products will help make people, materials, energy, plant and equipment more productive. Data flowing to



Predictive maintenance



Smart Connected Bolting: all bolting technologies, 1 user experience

and from products will allow product use and activities across the value chain streamlined in countless new ways.

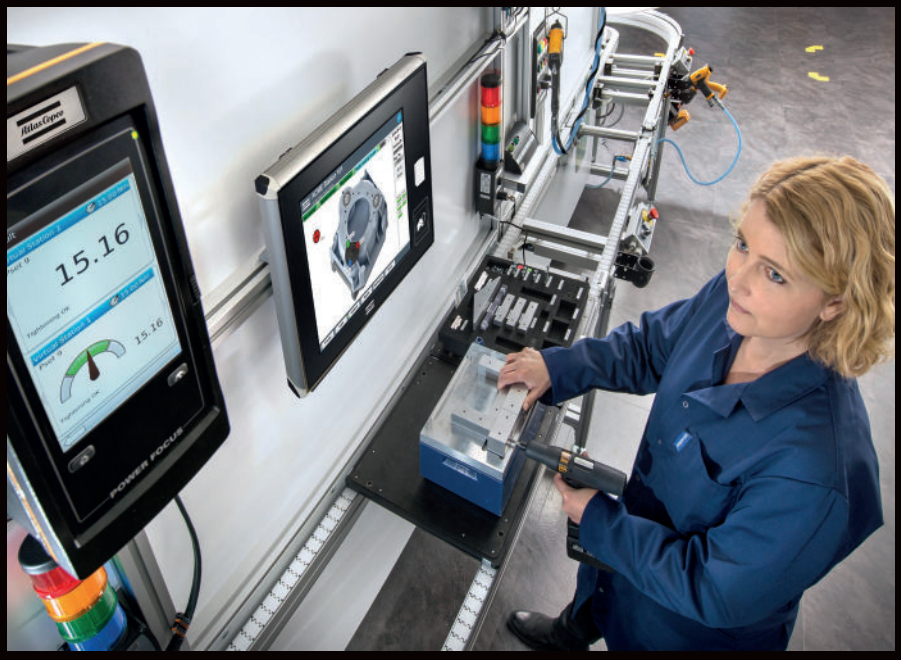
Inspired by lean manufacturing we see **'4 pillars of value'** that can be applied to the Wind industry to illustrate potential value, all based on real cases on other industrial sectors.

1 Reduction in defects by >15% by integration of parts verification, operator guidance and documentation.

2 Improved productivity > 15% through less rework and increased 'right first time' quality.

3 Reduced training by >30% due to operator guidance integrated into tools and solutions.

4 Increased tool availability by >75% due to data driven predictive maintenance



Process control and guidance

Taking the smart factory to the field.

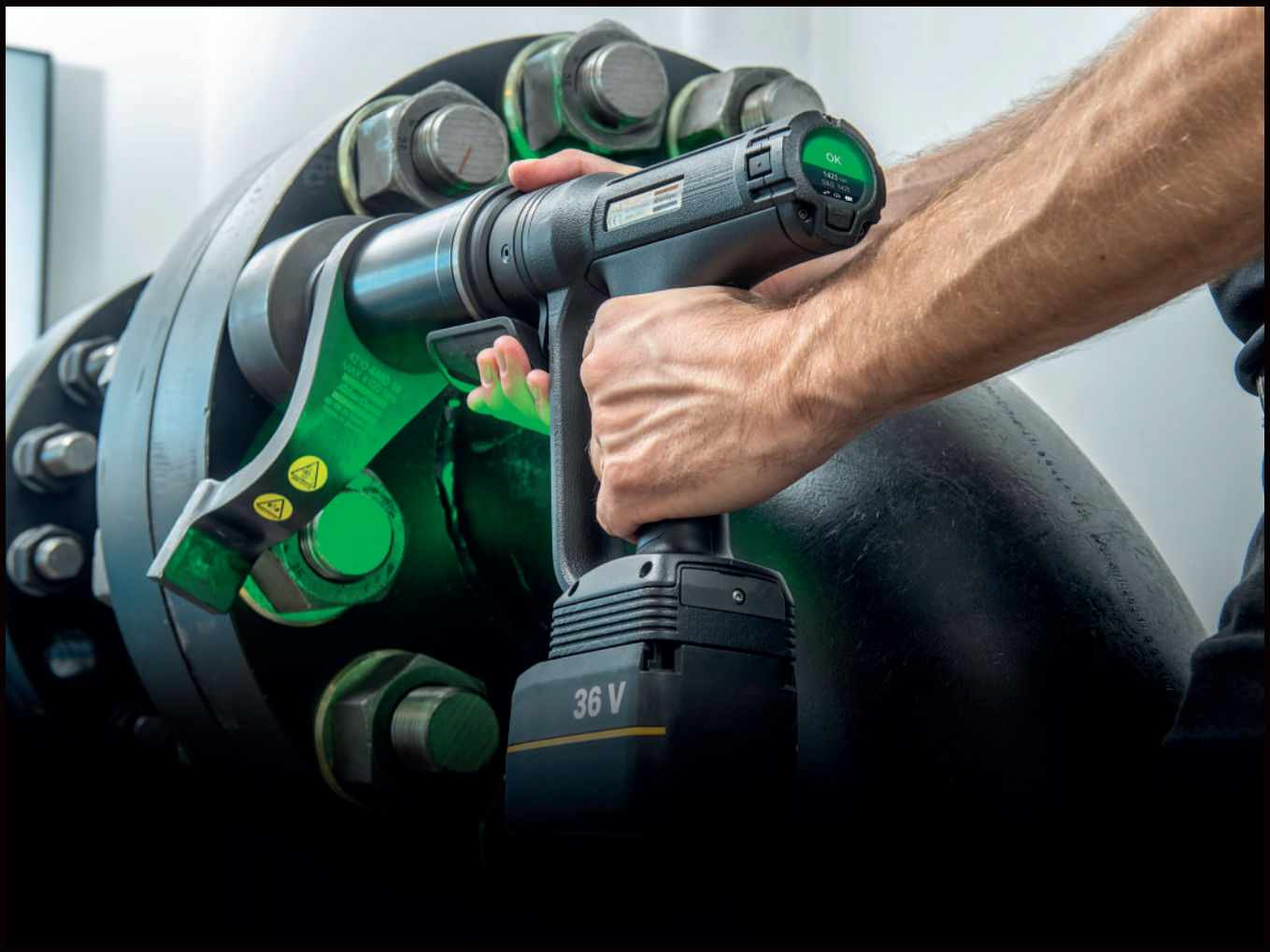
Securing bolted assembly processes, collecting data, and tool management is standard practise in factories in many industries today including Wind. However, in the wind turbine construction, operations and maintenance sector there are additional factors which make implementation of these solutions a challenge.

Extreme work environments, time pressure, high demands on safety and the need for documentation are challenges that face the construction, operations and maintenance sector every day and are not easy to handle.

Furthermore, the wide variety of bolted joint design today results in many different types of bolting tools being used by the workers. Hydraulic torque wrenches, bolt tensioning, electric nutrunners, battery tools, and even manual torque wrenches can all be found in use on site at the same time. For all these tool types there is a requirement for appropriate operator training, calibration process, and maintenance cycle monitoring, and for the most part documentation becomes a time consuming and manual process.

These challenges can result in mistakes being made, and corners being cut, and the ultimate impact can be dangerous and costly equipment failure or rework required. Even worse catastrophic failure in the field.

‘Smart connected bolting is not only a vision, but in 2020 a reality, enabling increased operational productivity and efficiency while reducing risk and cost’



If the process control and documentation capability used in production facilities today were to be deployed in the construction and maintenance environment, this would have significant positive impact for OEM’s, contractors and wind Industry as a whole relating to higher quality delivered work, cost reduction, and improved operational efficiency.

This was not possible in the past; however, the new availability of mobile connectivity, cloud and smart devices are enablers that make this very much a reality today. The availability of these solutions now makes it possible to take the ‘smart factory’ into the field based, operational, work environment.

Shaping the future

The wind industry is becoming more global and more competitive every day. Wind turbine assembly and construction is getting more complex. Larger bolts, in more extreme environments and with longer product life cycles means there is a need for new bolting solutions that support the goal of maintenance free bolted assembly.

To address these demands, the implementation of smart factory technology in the field-based environment is a critical path to take that will ensure the best quality products are manufactured, installed and operated for the full product life cycle with reductions in both risk and cost.

Furthermore, this will enable the interconnectivity and data analytics to be applied through the full value chain of OEMs, from manufacturing to operations and even beyond to partners and service providers all of which drive faster product development, quicker problem resolution, and rapidly deployed process improvements across multiple sites or locations.

Technology enablers are allowing this to happen today and products exist on the market that support the vision for smart connected bolting in all environments. Atlas Copco will, together with other eco-system partners continue to help the wind industry to navigate and speed up this exciting journey ahead, and make customers process and operations quicker, safer and smarter.

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