Following the weld

Nowadays, due to the high demand of electricity and its high production price, Renewable Energy Resources (RERs) are considered as a viable solution. The penetration of renewables as a means of electricity production is expected to increase by up to 60% by 2050[1].

Introduction: wind turbine history

Wind turbine technology is one of the most reliable of the most-used resources in the past few years. The first wind farm in the world was inaugurated in 1981[2]. Since then, wind energy has experienced exponential growth.

On the other hand, due to the significant use of wind turbine technology for a number of years, 28% of European wind farms exceeded 15 years of operation in 2020[3], which shows the need for careful inspection of them before extending their useful lifetime. Moreover, these statistics are continuing to increase, as the wind energy market is growing rapidly every day. For this reason, many wind farm owners are dealing with the challenge of their assets' life extension.

Increasing the life term of a wind farm depends on the quality of maintenance that is carried out during its useful life. Inspection of each component is essential for a wind turbine to continue its healthy operation, not only to save costs, but also to reduce the environmental impact by delaying the recycling of the materials that make up the machine. In this context, the towers are a key component in a wind turbine, but specific inspections are only carried out if it shows a visible defect. Therefore, damage can harm the entire structure of the wind turbine, so it is vital to carry out regular inspections.

Typical tower inspections methods

One of the common Operation and Maintenance (O&M) strategies that is carried out on wind farms currently is manual UT Inspection. With this method, the operator climbs the tower to inspect the steel tower´s welds, using rope access or with the help of a lifting platform. This method is carried out manually, therefore, the inspection takes several days of work to inspect a complete wind turbine. There is risk for the operator due to the height, as well as the high costs of using lifting platforms.

TSR Wind offers robotic solutions to eliminate the risks for operators by proposing an innovative solution: Kratos robot.

Robotics at wind farms service

Kratos 200 executes weld inspection tasks Non-Destructive Testing (NDT) in wind turbine towers. This robotic platform is designed to be transported on steel surfaces or other ferrous material.

The solution features several highly complex proprietary technical innovations. These include the mechanical system, to guarantee an accurate omnidirectional movement while withstanding the pull force from the magnets and the perturbations caused by the gravity and weight of the robot and its payloads. Based on the same family of motors used for TSR robots, the team has designed a mechanical system to couple a motor with its reductor directly into the wheel, with a mechanical support that allows a rotation of 360 degrees, augmenting efficiency and reducing the weight of the complete assembly compared to the first prototype.

An ad-hoc probe holder visible to press the surface of the tower, adapting to different

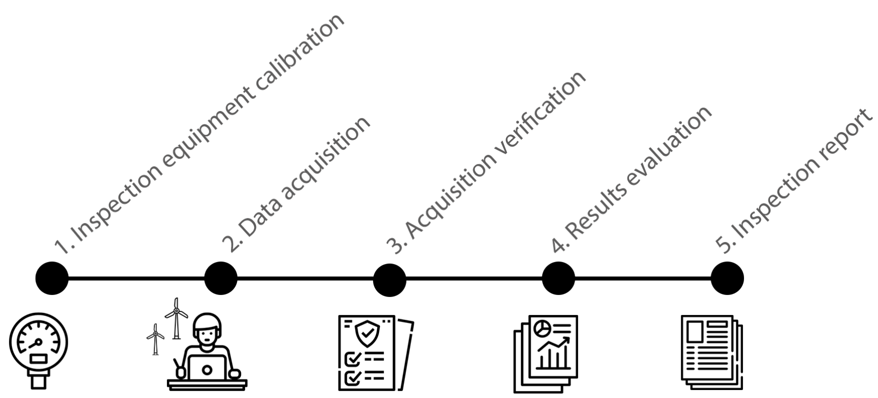

Figure 1. Weld inspection procedure carried out by a level II ultrasonic expert

1 International Renewable Energy Agency (IRENA), Global Energy Transformation. A Roadmap to 2050, 2018. http://www.irena.org/.

2 ABC Science, The world's first wind farm. 2015. https://www.abc.net.au/science/articles/2015/07/30/4282474.htm

3 Lisa Ziegler, Elena Gonzalez, Tim Rubert, Ursula Smolka, Julio J. Melero. Lifetime extension of onshore wind turbines: A review covering Germany, Spain, Denmark, and the UK. Renewable and Sustainable Energy Reviews,v 82, Part 1, 2018, p. 1261-1271. https://www.sciencedirect.com/science/article/pii/S1364032117313503

diameters, weld geometries, projections and impurities, while moving with a millimeter precision.

Finally, a control system is designed especially for acting over the inclination and altitude of the robot while it moves following the weld on an inspection, avoiding the gravity drift while it moves horizontally.

The powerful neodymium magnets allow it to climb a tower up to 100 meters high at a speed of 5 meters per minute.

Although the robot is prepared to work autonomously, an operator reviews the inspection process by observing its location with a device connected via optic fiber to provide high speed connection between the robot and the operation station.

The welds are inspected by attaching an intelligent probe holder device to the robot, equipped with motorized probes that can be controlled independently, with adjustable pressure to the surface and a weld detection system based on computer vision to aid the robots to follow the weld automatically, using ultrasonic testing methods that complement each other during the acquisition, Time of Fight Diffraction (TofD) and Phased Array (PAUT).

A small amount of water is applied as a coolant, instead of other chemical liquids, which the robot dispenses and is used both in the calibration process and in data acquisition.

The information of the Kratos can be collected and reviewed in real time by a level II ultrasound expert or downloaded for a later inspection.

In addition to collecting ultrasound data, Kratos utilizes a high-quality video camera to record the entire process, which allows any other visual defect in the tower to be monitored and to assess whether it needs any type of maintenance.

It depends on the height of the wind turbine and the number of welds to check, but the inspection process can take a day to inspect an entire tower of a wind turbine.

The level II ultrasound expert analyses the results obtained during data collection and prepares a report that will be incorporated into the TSR Inspector platform. In this self-developed application, the client can see the results on any device with an internet connection and conveniently

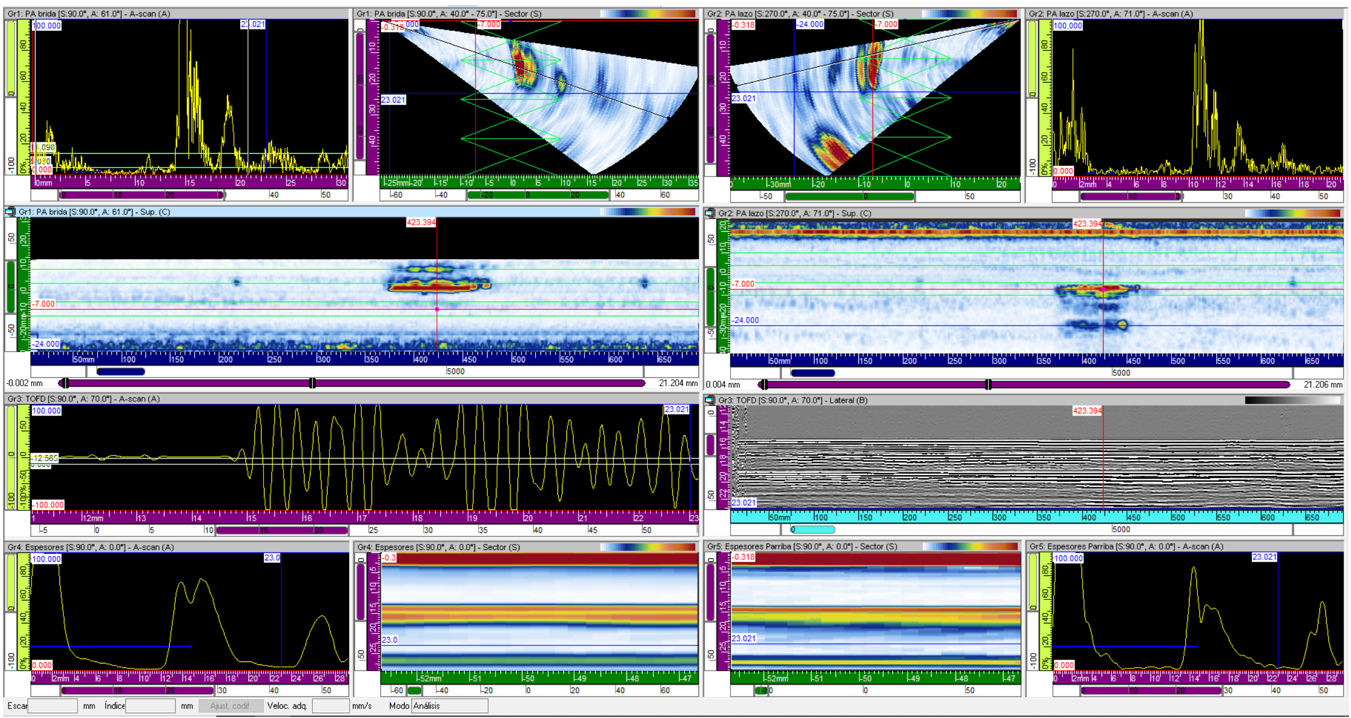

Figure 2. Damage example. Materials analysis by ultrasound (Phase Array and TOFD technology)

download the reports to check them at any time.

During the first phase of this project, the Kratos 150 was used to inspect more than 200 welds.

Ultrasonic inspection for life extension

As mentioned above, the wind turbine´s tower is a key component of the system, therefore inspections of the tower's welds are highly related to the life extension of the turbine. Welds status directly affects the integrity of the tower and maintaining periodic inspections is a way to be sure that there isn't any damage in the structure. Some examples of serious damage that Kratos can detect in welds are cracks, fissures, and manufacturing defects with depths greater than 2mm. It is clear that time can extend these damages until they become a big problem for the towers.

In addition, the robot is also capable of detecting smaller defects, such as pores or lack of fusion before they became something worse.

Having all the inspections kept in TSR Inspector keeps all the useful information in one platform. The storage of this data involves the creation of an important database, where the client can consult at any time and observe the damage evolution over time.

Savings for owners and O&Ms

By using this robotic inspection method, the wind farm owner can optimize and reduce the budget of weld inspection of the turbines by a minimum of 50%. Moreover, the time of inspection can be reduced by a third, which means shorter inspection time, longer production, and in-use time of the turbine.

Another key feature of using TSR robots, is if the safety regulations of the park allow, the robot is able to inspect the tower of the turbine while it is in operation mode. So during the inspection period the turbine can still produce power to avoid the loss of income.

A robot with many possibilities

Kratos provides many possibilities for wind farm operators. Its probe system, where the ultrasound monitoring is performed, is just one of the functionalities of Kratos. It is also able to lift heavy loads and move in any direction through the tower. The robot could help maintenance technicians who are working at heights to lift certain heavy tools, attach another type of ultrasound system, perform paint stripping, repaint the wind turbine, carry out non-destructive tests, install sensors or antennas, and many other complementary functionalities.

Apart from the wind industry, the TSR Wind vision is widely open to apply its solutions in other industry sectors. Although it has inspected more than 4,400 turbines, TSR Wind solutions has been examined in some industrial storage tanks, providing excellent results. Typically, these kinds of inspections are carried out by assembling large scaffolding. However, Kratos provides an optimal inspection solution for any structure with steel surfaces or other ferrous materials.

The perspective for offshore structures

The weld inspection on the deep waters or in shallow waters with strong waves is a hard task and dangerous for the operator comparing to those carried out in onshore structures. Consequently, for offshore wind farms, Kratos provides a solution to check the welds of the wind turbines with floating platforms or other infrastructures in port before the installation.

Ultimately, Kratos is prepared to respond to the great demand that exists all around the world. The complexity and multi-functionality feature of Kratos makes it a unique solution for a reliable welding inspection process using ultrasound technology. Kratos is considered as a fundamental solution for wind farm life extension processes.

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