Plant geometrical digital twin and its application to complex maintenance activity

The implementation cutting-edge technologies in existing plants has become an essential mission

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To operate continuously for decades, a plant needs constant routine maintenance, effective extraordinary maintenance when it is necessary, and repeated machinery upgrades to keep it up to date with technological developments. With the ambitious, and necessary, objectives of reducing pollutants that these years offer us, being able to implement cutting-edge technologies in existing plants has become an essential mission.

An industrial plant can be seen as a complex organism, in which we find many different systems that interface and work together. It is evident that to carry out a major improvement or maintenance intervention, such as the replacement of a gas turbine module in an offshore platform, you need to know perfectly how the plant is made and have a team of specialists who develop dedicated and specific solutions to install those new technologies in that specific plant, with all its peculiarities and criticalities. We define this type of activity as upgrade or complex extraordinary maintenance, precisely because it cannot be understood as a standard or "catalog" activity, but each time it is necessary to analyze the existing system and develop specific solutions to be able to maintain or install a machinery, a system or, more generally, a technological product.

Nuovo Pignone is an Italian company with headquarter in Florence that, since 2019, has been part of Baker Hughes. Baker Hughes is one of the largest companies in the world that provides services and technologies for oil and gas sector, with a portfolio of solutions that cover all areas, from well exploration to transportation and refining.

Maintenance and Installation Engineering team, within Service Engineering division of Nuovo Pignone (has been part of Baker Hughes since 2019), takes care of these complex extraordinary maintenance and upgrade activities. One of the team's tasks is to produce manual documents called "Field Modification Instructions". These are operating procedures that describe disassembly and modification activities that must be carried out on the system, up to the installation and commissioning of the new technology. When a procedure is not enough, the team also develop and designs "Smart Tools": special equipment specifically developed to install a specific product in a given system, or to carry out specific maintenance interventions.

To create Field Modification Instructions and Smart Tools, it is first of all necessary to know the system in detail. This can be very complicated in case of very old systems, for which it is difficult to retrieve documentation, or for third parties' plants. Since 2015, team has begun to make use of Laser Scanning to create a digital copy (Geometrical Digital Twin) of the plant.

Laser scanning is a method for detecting three-dimensional objects of any type

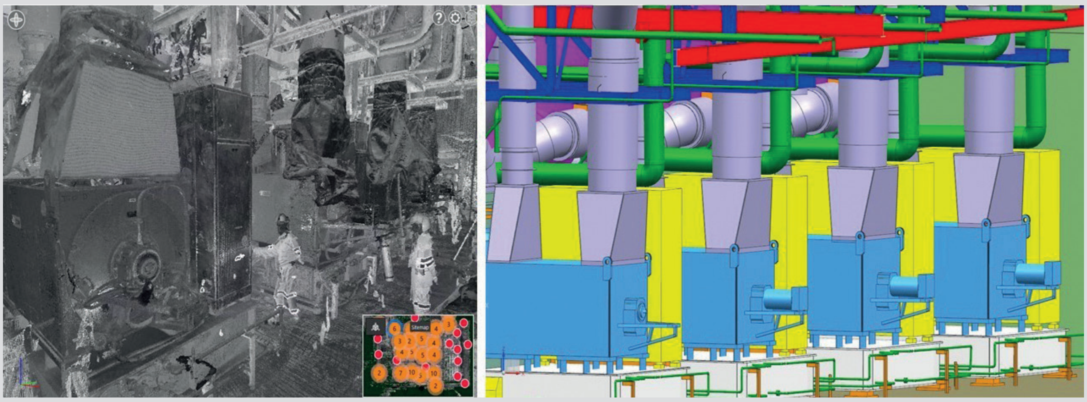


Figure 1: on the left – point cloud; on the right – 3D modeling

(buildings, machines, industrial plants...). The scanning tool emits laser pulses in succession, radiating from the center of the scanner, and acquires the spatial coordinates of the points on which laser beams are reflected. The set of these georeferenced coordinates is called "points cloud".
Clearly if an object is not visible to the scanner's optics, it will not be scanned; to perform the complete scan of an object or a portion of system, the scanner must be placed in various, rational and strategic positions depending on the geometry to be acquired, to avoid blind spots.
All the point clouds acquired during the various scans must then be joined and aligned using specific software, creating an overall point cloud, summation of the individual ones, which does not have blind angles, and which fully represents the geometry we want to acquire.
In case of very complex geometries, such as plants, to be sure to align the clouds correctly, it is necessary to apply "targets" inside the plant; these are nothing more than physical markers that function as absolute reference points for the clouds. These targets must be acquired during the scan. To perfectly align two clouds, they must share at least three targets.
In terms of time, it takes between 10 and 30 minutes to perform a single scan, depending on the type of instrument, resolution of the scanner and working environment. As a reference, to scan the turbomachinery deck of an LNG plant, in which there are gas turbines and centrifugal compressors with relative auxiliaries, 90 to 100 scans are required, setting an accuracy of 1.9mm at 10m with a measurement error less than 1mm.
Once the point cloud that depicts the plant at the time of scanning has been acquired, the same is processed and translated into surfaces to create a single 3D model, manageable by the most common CAD software, which represents the geometric Digital Twin of the plant. 3D model developed by this cloud can weigh a few GB *(Fig. 1)*.
Having a digital duplicate of the plant ge-

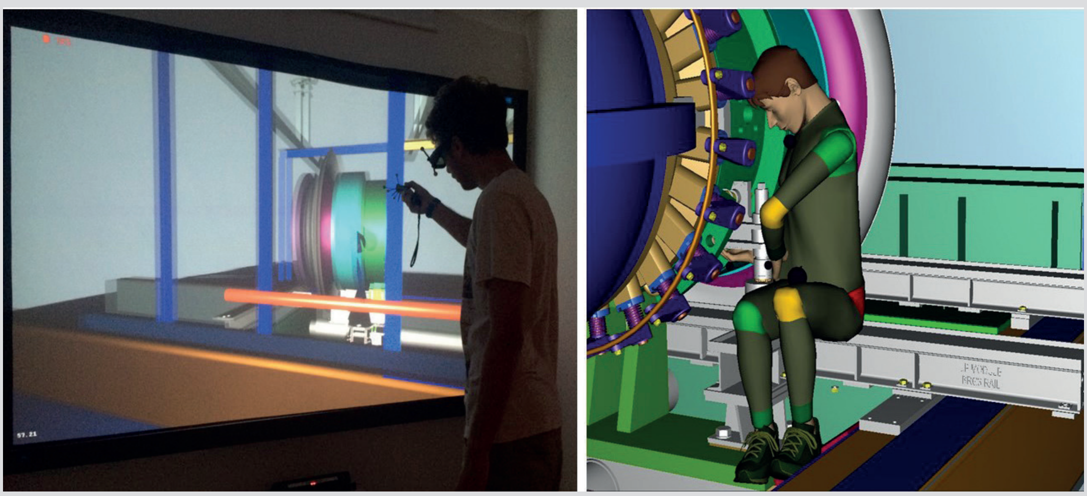


Figure 2: on the left – immersive environment simulation; on the right – ergonomics evaluation

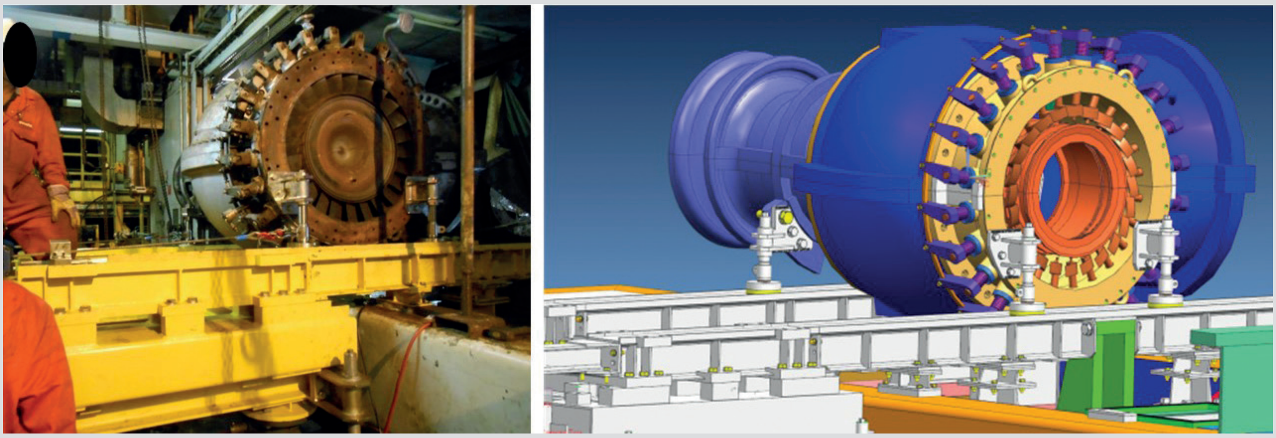


Figure 3: comparison between job execution and simulation

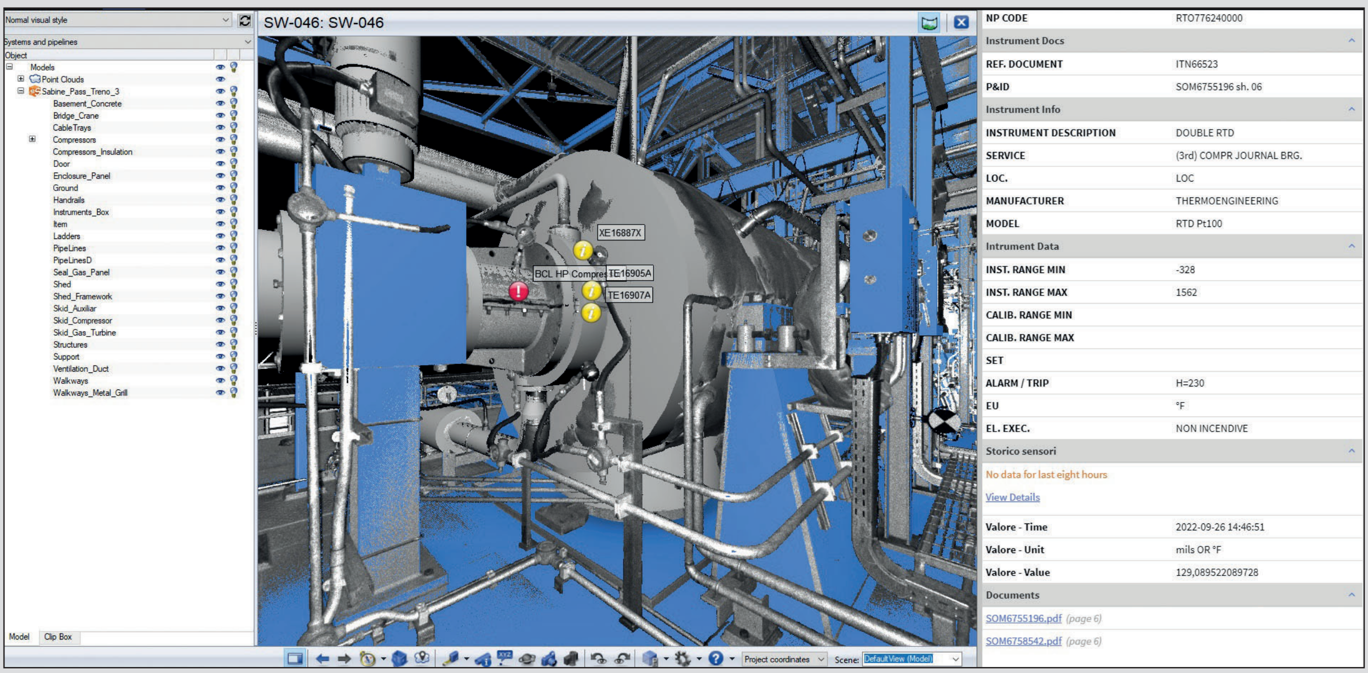
ometry allows first to be able to study it in depth, and gives us the opportunity to use software applications to simulate the various modification, disassembly and handling activities that must be carried out. This last simulation aspect is of fundamental importance, it allows to catch any non-conformities, accessibility, ergonomics and safety problems and project mistakes in advance and to correct them promptly and then have the work carried out without unexpected events.

Let's take for example a real project: the replacement of a PGT5/2 turbine module (7MW, 11 Ton approx.) Installed in an offshore platform in service since 1987. 5 days of work of a single operator supported by the customer's staff, were needed to acquire the points cloud relating to the machines deck; an additional month of work was needed for the following 3D modeling. The 3D model depicting the Geometrical Digital twin of the plant weighs about 600MB.

All the disassembly and handling phases were simulated using 3D CAD software; some particularly complex phases have been recreated in an immersive virtual environment and ergonomics assessment for operators has also been made. After each simulation iteration, the design of the Smart Tools under development was updated *(Fig. 2)*.

Having the ability to simulate all activities and validate special equipment in a virtual environment has allowed us to provide the

Figure 4: Vibration sensor readings visualization in the geometrical digital twin



customer with a Field Modification Instruction and a set of Smart Outage Tools specifically made for his system. In support of the documentation, a video simulation was also produced which faithfully represents the particularly critical passages.
Thanks to all these studies, the customer, with the supervision of a Nuovo Pignone technician on site, completed module replacement in 30 days, without any unexpected events. Previously, routine maintenance of the same module had taken up to 180 days *(Fig. 3)*.
Having a geometric Digital Twin of a system available, also opens the doors to other applications. Through dedicated software it is possible to link specific documentation of any part of the plant to the 3D geometry: P&ID, video-procedures, instruction manuals, project documents ... For example, having to explain to a colleague how to carry out routine maintenance, like changing a seal on a compressor, we could open the Geometrical Digital Twin of the system to show how and where the seal is positioned; what the operator must do to access it and, once the seal seat is visible, view in the same virtual environment the procedure that explains how to disassemble, reassemble and align the seal. This procedure could be a simple .pdf file or an interactive video *(Fig. 4)*.
The Geometrical Digital Twin is not only useful for simulation purposes and for intuitively connect maintenance procedures to involved components. The model can also be associated with the readings of the sensors installed on the machines: to know the reading of an instrument, just "move" in the 3D model until it is identified and displayed. These are just a few examples. In fact, any type of data and digital information can be associated and geo-referenced to the Geometrical Digital Twin.
In conclusion, being able to translate a real system into a digitized geometrical copy opens the door to various opportunities and allows us to take advantage of the virtual world possibilities. It can be used as a design and simulation tool to create customized "tailored" solutions based on the specific needs of the customer, as an information tool for a faster and more friendly use of the functional details of the system, as a training tool or for any other application that draws the advantage of having a faithful and digital representation of the system available. □