DEVELOPMENT, APPLICATIONS AND BENEFITS OF THE NETWORK DIGITAL TWIN

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ABSTRACT

The network digital twin is the must-have technology of any advanced DSO[1].

One of the main challenges for DSOs is deploying the most efficient and effective solutions for operation and maintenance of electricity network and infrastructures. New technologies that are flourishing in the market show high potential for the electricity industry, too. Examples are cloud and edge-computing, artificial intelligence (AI) with machine learning, IoT[2] sensors, wearables, augmented and virtual reality, 3D modelling, LIDAR[3], drones and robotics, advanced simulation and modelling software. Their adoption by DSOs and integration with existing systems (such as GIS[4], AMI[5], ADMS[6]) offer new innovative approaches to distribution systems operation, epitomized by the network digital twin.

This paper describes how existing and new technologies combine to realize the network digital twin, its relevant applications and benefits. Several practical examples and lessons learned from proof of concepts, pilots and innovation projects carried out with start-ups, technology providers and data scientists are illustrated.

KEYWORKDS: *Network Digital Twin, artificial intelligence, 3D-modelling, IoT sensors, augmented reality.*

1. INTRODUCTION

The network digital twin[7] is an up-to-date and accurate virtual replica of the physical network, its components and their dynamics. It relies on pervasive digitalization of DSO processes, as well as on new technologies that digitize physical assets and make their digital twins accessible and useful. Transformation brought by the network digital twin will affect network assets, network data lake, processes, people, customers and other stakeholders.

The applications of the network digital twin go well beyond operation and maintenance, spanning to network design and development, work force management and training, cooperation with suppliers and technology partners, and interaction with customers and other stakeholders.

For example, 3D modelling, with AI-enabled processing and classification, enhances preventive maintenance planning and asset management; it also allows precise measurements of distances and angles, and site virtual inspections. IoT sensors dynamic data, together with those of smart metering and remote control systems, enable predictive maintenance and anomaly detection, once integrated into an edge computing architecture supported by artificial intelligence. Augmented and virtual reality, and wearables (like smart glasses), integrated with work force management systems and others (such as remote control, smart metering, GIS, asset management) allow new approaches to training, remote assistance, and to implement the control rooms of the future.

Simulation and modelling software accelerate design and development of new DSO technologies: on one side, facilitating collaboration among network experts, start-ups, technology providers, and suppliers; on the other side allowing agile modular approaches to solutions development, as shown by experiences in other industries, such as construction and aerospace.

To realize this great potential, new technologies require significant adaption to fit the typical DSO operating environment, safety and service requirements. For example, smart glasses that perform well in external operating conditions, and fit with the helmets used by technicians exposed to electrical risk, are not available off the shelf; AI models that fit to DSO use cases are at early stages.

2. THE NETWORK DIGITAL TWIN IN ENEL

Digitalization is a fundamental tool for operation and management of power network and infrastructures. It helps providing a timely and effective response to multiple external forces and make reasoned decisions at every level, guaranteeing operational excellence and efficiency. Enel has been working for the last decades in the digitalisation, by developing critical network technologies for remote control and automation, smart metering, GIS, work force management.

The Network Digital Twin will enhance this level of digitalisation with a transformational impact on all

1 Distribution System Operator
2 Internet of Things
3 Light Detection And Ranging
4 Geographical Information Systems
5 Advanced Meter Infrastructure
6 Advanced Distribution Management System
7 NETWORK DIGITAL TWIN is European mark of Enel property registered with No. 017929296.

dimensions of network operation.

Starting with network assets and infrastructure digitisation: Using new innovative technologies for 3D modelling and digital acquisition it is possible to create digital twins of existing network equipment, power lines, substations facades and interiors.

Several technologies can be used, depending on the relevant use cases: Lidar, fixed or mobile scanners, 360° cameras. Mounted on drones, helicopters, or cars these tools can be used to model network overhead power lines, while getting the accurate positioning of the network infrastructure. Operative squads can use fixed or portable scanners whenever they visit plants to collect 3D point clouds of substations interiors and exteriors. Points clouds so acquired can be elaborated to do measures (e.g. check the height of lines, poles etc.), make analyses of interference with vegetation or other infrastructures, and virtual inspections to plan interventions or train workers.

Enel has been using mobile laser scanners for 3D modelling in different countries (Italy, Peru, Colombia, etc.). In Peru, Enel has modelled in 2018 more than 15.000 km of MV, LV and street lighting lines, and in Colombia, Enel is 3D modelling 9.000 km of distribution lines (25% of total grid length of Enel in Colombia) in 2019.

A 3D models repository with a web application for elaboration of grid assets and power lines information captured through different technologies is currently available with all Italian models and is going to be expanded with global data.

For new infrastructures or equipment, digital twins will be available since the beginning, created during the design phase and used for the entire life cycle, and in all processes of procurement, installation, operation, maintenance and dismissal, by all the relevant players.

A network data lake will eventually pool all these digital twins with a continuous flow of data from both network devices (e.g. for smart metering and network remote control), IOT and smart sensors in the network and in substations.

Within an edge computing architecture, artificial intelligence allows to elaborate this huge amount of data quickly and efficiently, fostering human and manual analysis capabilities and automating processes.

Relevant use cases include: predictive maintenance and anomaly detection, for OPEX reduction and quality of service improvement; detection of technical and non-technical losses; safety, such us on-line detection of anomalies inside primary and secondary substations to alert from unsafe internal conditions; virtual inspections of plants, infrastructure, useful to efficiently plan on-site inspections, or train workers; network development activities (network planning, work assignments, work execution, quality control, asset maintenance and investment and network analysis); automatic classification of point clouds, and anomaly recognition on images; and simulations to detect grid losses, reactive flow, unbalances, including MV-LV state estimations.

Workers will have also have new tools and technologies to access and process information, take decisions, collaborate with each other's, with the use of x-reality (e.g. augmented, mixed and virtual reality) and wearables. Some of the use cases that show highest potential entails augmented and mixed reality for orienteering, remote assistance to workers in field, virtual inspections and training; virtual reality to train workers on safety; wearables, such as smart glasses and smart watches, for hands-free operations through augmented reality and safety purposes.

Enel has developed an application for WFM smart phones to support manoeuvres in field through augmented reality. Using this technology, a field worker can download technical specifications, videos, schemes and manoeuvres guides from a certain asset with just pointing the asset with the smart phone camera, as shown in Figure 3. This application may be also reside on smart glasses to provide hand-free operations, improving field worker safety and efficiency.

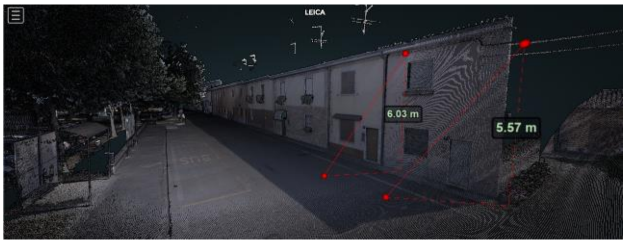

Figure 1. Example of point cloud collected through mobile mapping

Figure 2. Augmented reality for remote orienteering

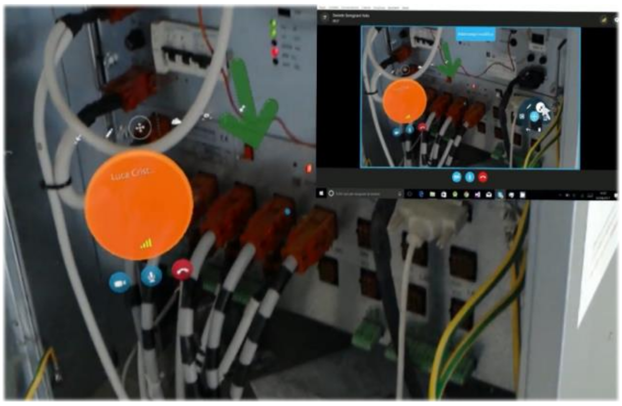

Figure 3. Augmented reality for remote assistance

Figure 4. GPS centimetric measurement

3. CONCLUSIONS

Digitalization is a key factor for Enel to achieve its objectives regarding operational excellence, service quality and sustainable development goals fulfilment.

Smart meters, remote control and automation devices, GIS and work force management constituted a first step in grid digitalization, which brought tangible huge benefits in terms of quality of service and operational excellence.

The network digital twin will shape the future of grid operation and its transformational impact will affect all relevant processes, workers, work organisation, as well as relations and engagement of customers, partners, suppliers and stakeholders.