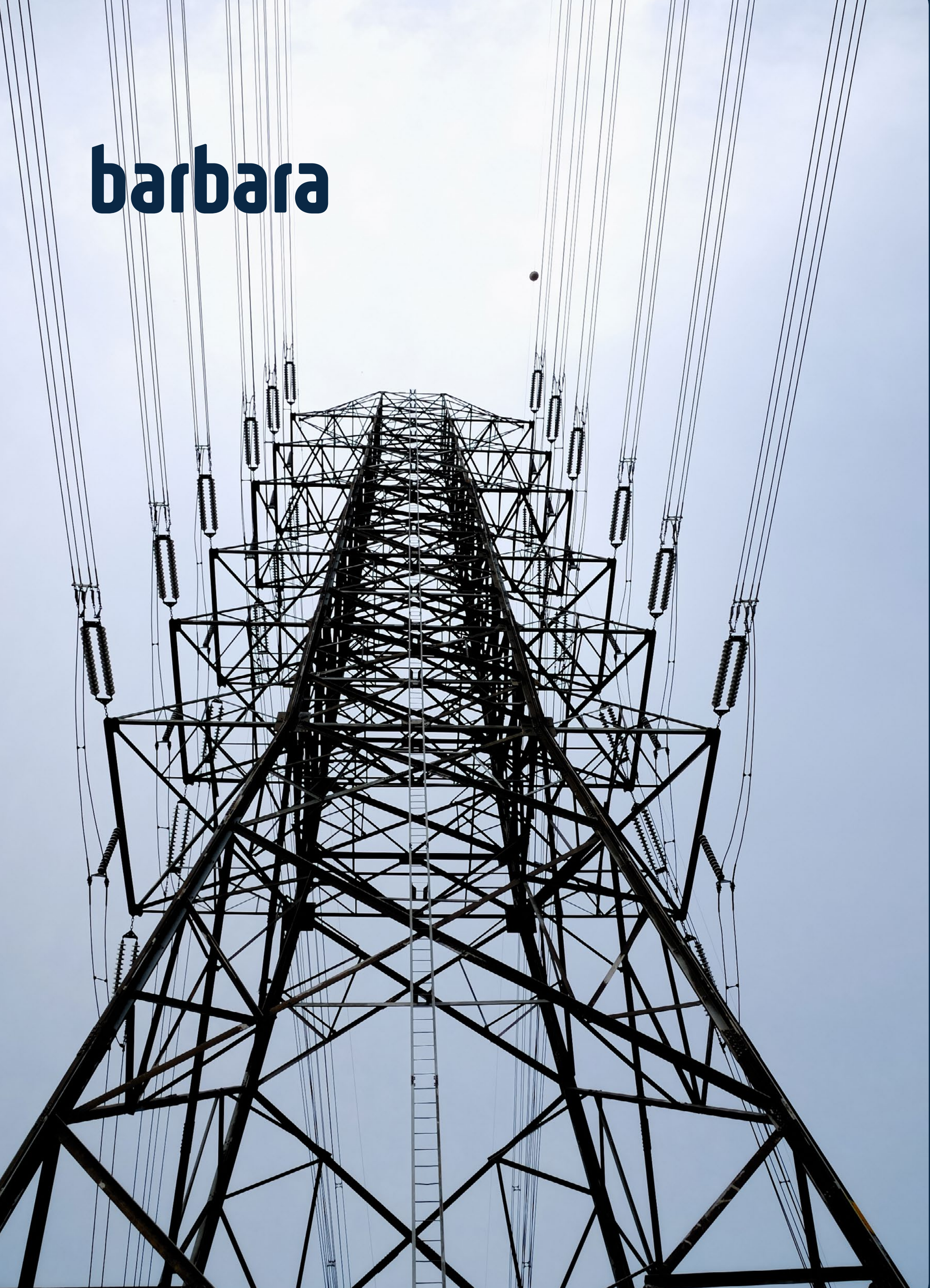


USE CASE

Enabling an early prediction model for underground high-voltage lines with Edge Computing

Barbara´s Industrial Edge platform enables the efficient operation and predictive maintenance of high-voltage transmission lines through the application of distributed artificial intelligence and machine learning.

2023, Barbara

www.barbaraiot.com

INTRODUCTION

In the realm of digitalizing the electricity industry, transmission, and distribution operators (known as TSO and DSO respectively) are actively working towards integrating solutions that enhance the monitoring, detection, and prediction of faults while improving the transmission capacity of their network assets.

Power transmission grids are extensive networks that span various locations, including overhead, underground, and submerged installations.

Accessing these networks becomes challenging in the case of underground and submerged systems, leading to considerable uncertainties in pinpointing faults (measured in terms of distance, often in kilometres), which subsequently result in substantial costs for companies.

To mitigate future failures and minimize system costs, the maintenance of underground lines holds significant importance, especially through the implementation of comprehensive maintenance solutions encompassing predictive, preventive, and corrective measures.

This is where the role of optical sensors comes into play, as they provide real-time measurements of line properties, facilitating the efficient identification of faults.

ABOUT OPTICAL SENSORS

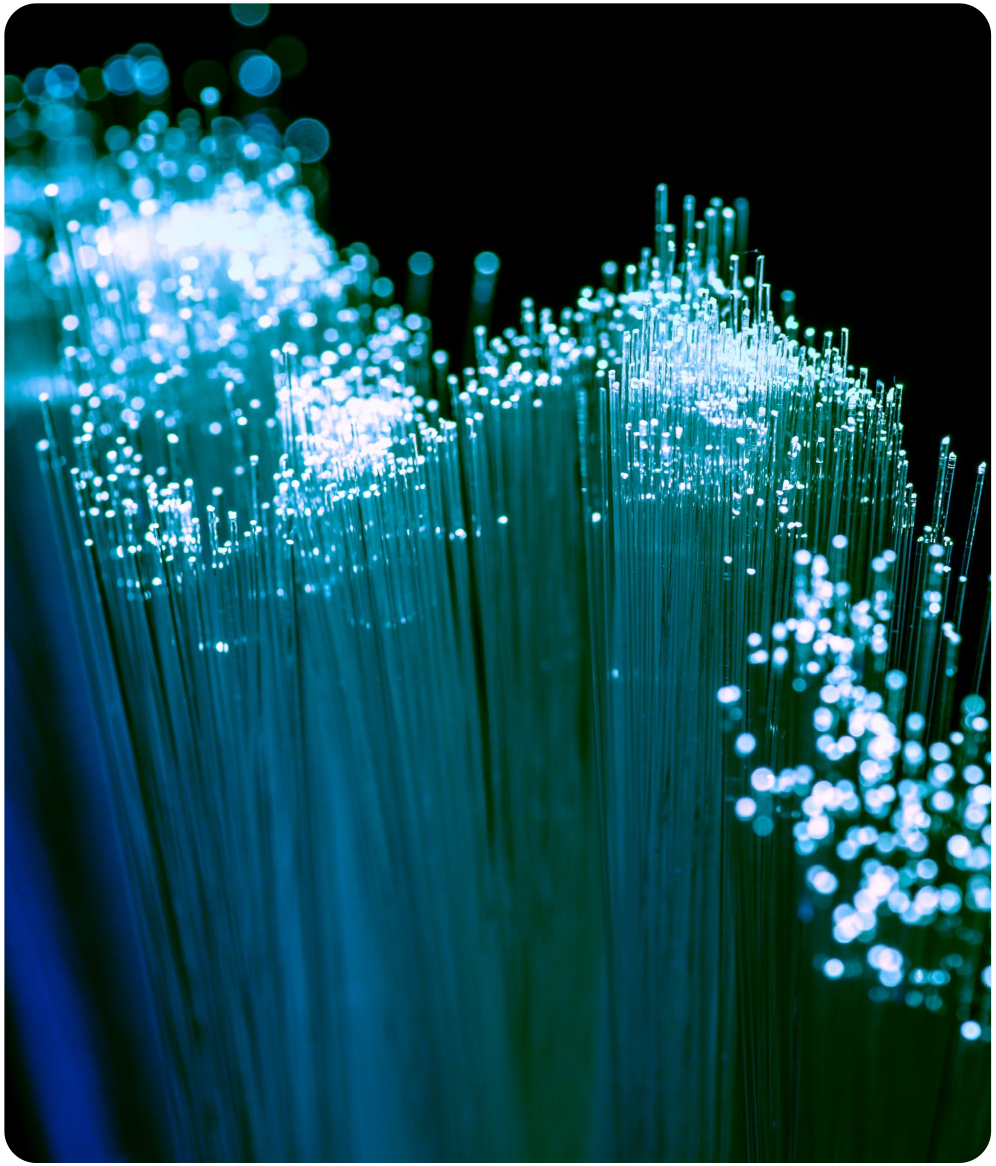
Presently, the most widely utilized sensors are those equipped with auxiliary power supply, necessitating their connection to the network itself, which can introduce potential interferences due to their electrical systems.

In contrast, fibre optic sensors are passive and immune to magnetic field interferences arising from electrical devices.

Optical monitoring systems enable the placement of highly accurate sensors in critical points of electrical networks (connectors, directly on the conductor, in buried or gallery sections...), and in adverse operating environments, where there are no power supply points nearby, or where other sensors can not obtain accurate data due to the impact of waves or electromagnetic fields.

Besides, these sensors can be located anywhere in the network, as they are sensors that do not require an auxiliary power supply.

With all, new possibilities open up for the management of unaccesable electrical network assets.It should be noted that this type of assets is becoming increasingly important in national and/or European electricity transmission.



THE CHALLENGE

Conventional preventive maintenance of high-voltage underground networks involves periodic field tests that necessitate live work, scheduled outages, and on-site visits by operators.

Similarly, the difficulty in implementing predictive maintenance and the lack of continuous monitoring for cable conditions, in many cases, intensify the need for corrective maintenance. Unfortunately, this often leads to prolonged interruptions and is driven by the challenges associated with general fault pre-location and specific fault localization.

In this context, the technological challenge lies in developing **a novel optical monitoring system based on artificial intelligence and machine learning.** Such a system aims to enhance the operation and predictive maintenance of electricity grids.

Moreover, **the goal is for this system to operate on a decentralized infrastructure, enabling secure execution of algorithms at the grid´s edge thereby reducing latency and addressing connectivity issues.**

Furthermore, the system will be deployed on a decentralized infrastructure, allowing the execution of algorithms at the network´s edge, minimizing latency and eliminating unnecessary data traffic.

“

The project has focused on developing a predictive analytics module integrated into an existing optical monitoring system. The system incorporates sensors for collecting data on known variables related to the performance of critical assets within a transportation network”

— BARBARA

SCOPE OF THE PROJECT

A novel BRAGG optical monitoring system is designed and developed for measuring current and temperature in critical electrical grids with predictive analysis capacity based on Artificial Intelligence and machine learning.

To this end, a decentralised infrastructure is proposed, in which to execute the algorithms on the grid´s edge, guaranteeing security and reducing latency and the dependence on connectivity.

To carry out this project, the state of an underground 220KV power transmission cable with XLPE dry insulation, located between two substations in the province of Barcelona, was monitored.

This installation has monitoring systems complemented with predictive analysis systems that focus on the thermal inertia of the conductors in both indoor and outdoor environments. These systems collect data that is collected by the CAMOS200 system, developed by (*) Lumiker.

The project aims to design and develop a cutting-edge BRAGG optical monitoring system capable of measuring current and temperature in critical electrical grids. The system incorporates predictive analysis capabilities based on Artificial Intelligence and machine learning.

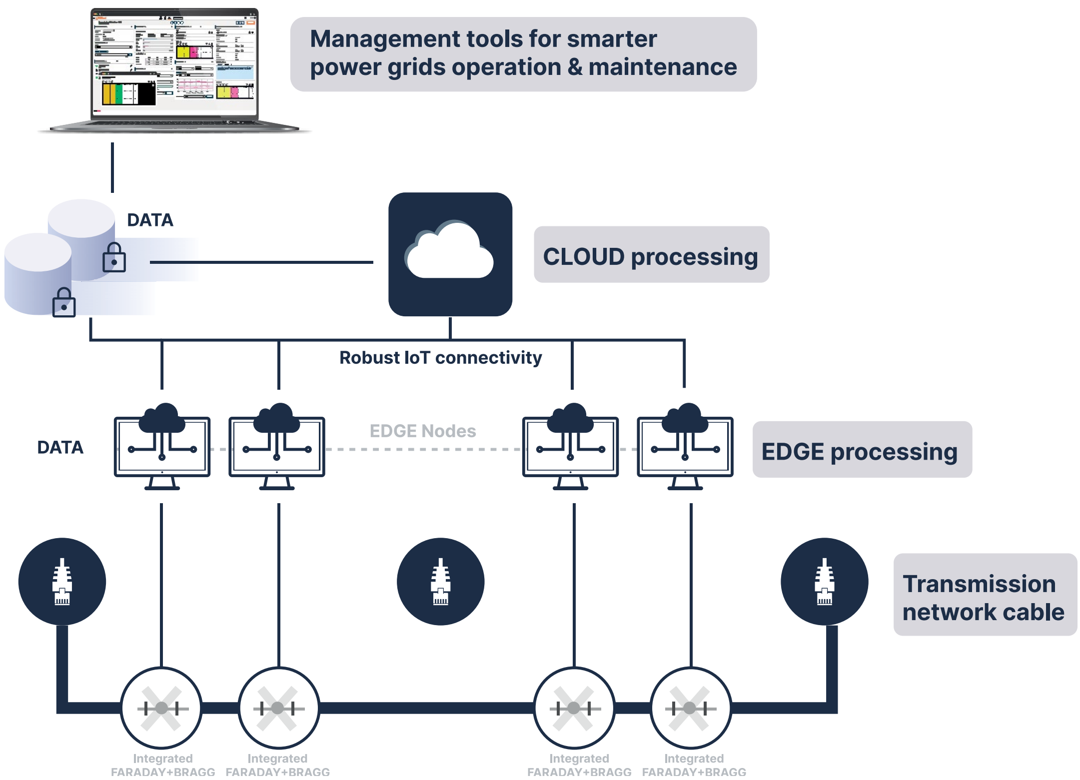
To achieve this goal, **a decentralized infrastructure is proposed to execute the algorithms at the edge of the network, ensuring security, minimizing latency and avoiding dependence on permanent connectivity.**

For the project implementation, the focus was on monitoring the condition of an underground 220KV power transmission cable with XLPE dry insulation. The cable is situated between two substations in the province of Barcelona.

The installation is equipped with monitoring systems that are complemented by predictive analysis systems, specifically targeting the thermal inertia of the conductors in both indoor and outdoor environments. These systems gather data, which is then collected by the CAMOS200 system developed by Lumiker.

NB: LUMIKER, has extensive experience in different sensor technologies based on fibre optics, processing, and developing innovative passive monitoring systems for the measurement of temperature, current, strain, etc.

PROPOSED SOLUTION: BARBARA EDGE PLATFORM



Barbara´s Edge platform offers Edge Computing-based solutions tailored for critical installations. **It addresses the deployment and execution of algorithms directly within transmission substations.** Additionally, it provides notification services and manages connectivity between the Edge and Cloud.

The proposed solution adopts a Cloud-Edge architecture with the objective of optimizing cable load levels, considering environmental conditions, and anticipated operating temperatures. Moreover, the system incorporates various functionalities such as detecting abnormal temperatures, analysing harmonics, and evaluating capacitive currents.

The predictive analysis system is seamlessly integrated with the existing CAMOS Interrogator installed in the pilot installation. This integration is achieved through the utilization of an Edge Node, developed by Barbara, which incorporates models and analysis capabilities from (*)Alerion, the University of Cantabria (UC), and Lumiker.

These entities collaborate to provide functionalities such as conductor load optimization using machine learning techniques, anomaly detection, and early fault detection.

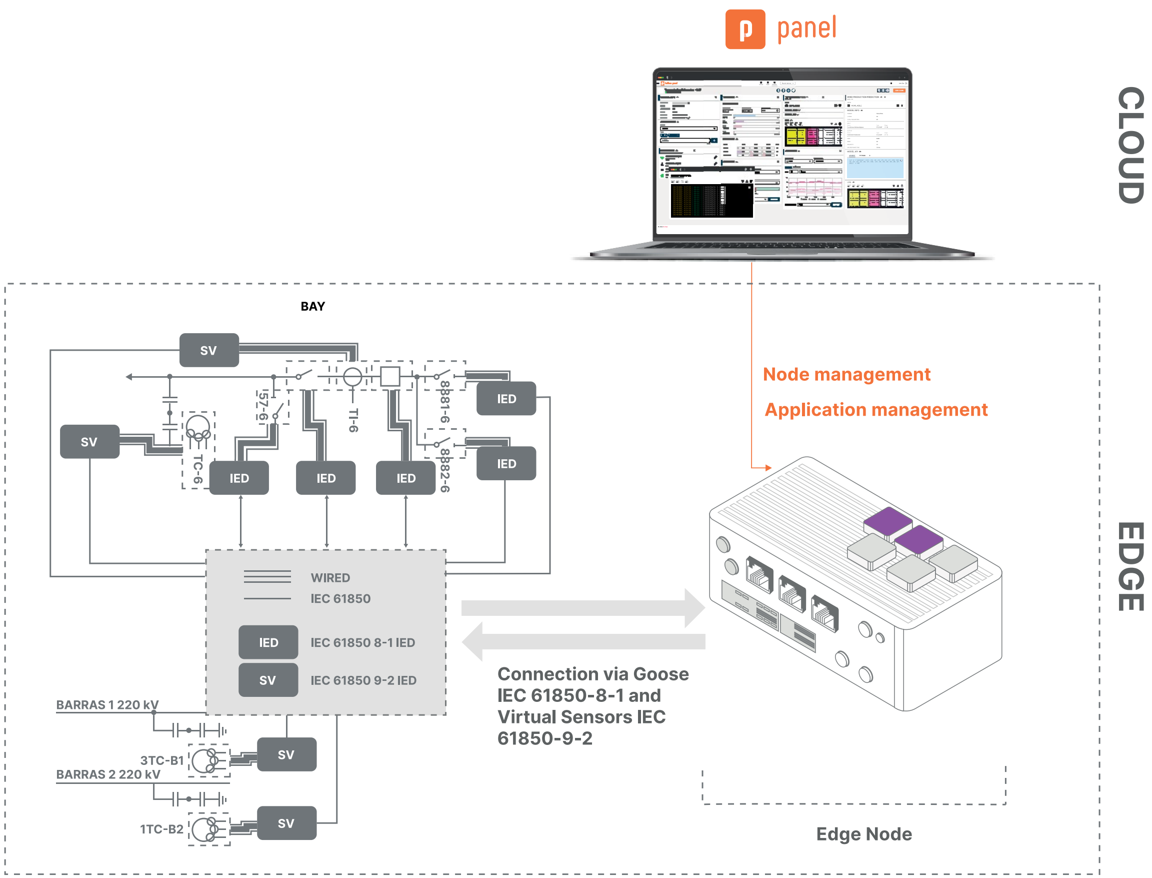
The CAMOS200, an optoelectronic system utilizing optical transformers and BRAGG fibres for current and temperature measurements, processes the signals within the interrogator equipment. Subsequently, the measurements are transmitted to the Edge Node. The Edge Node comprises processing algorithms and a thermal model. It operates on the Barbara-developed Operating System, a Linux Kernel that is regularly updated and patched.

NB: (*) Alerion is a startup with specialized expertise in high-performance embedded software development, computer vision, and artificial intelligence applications.

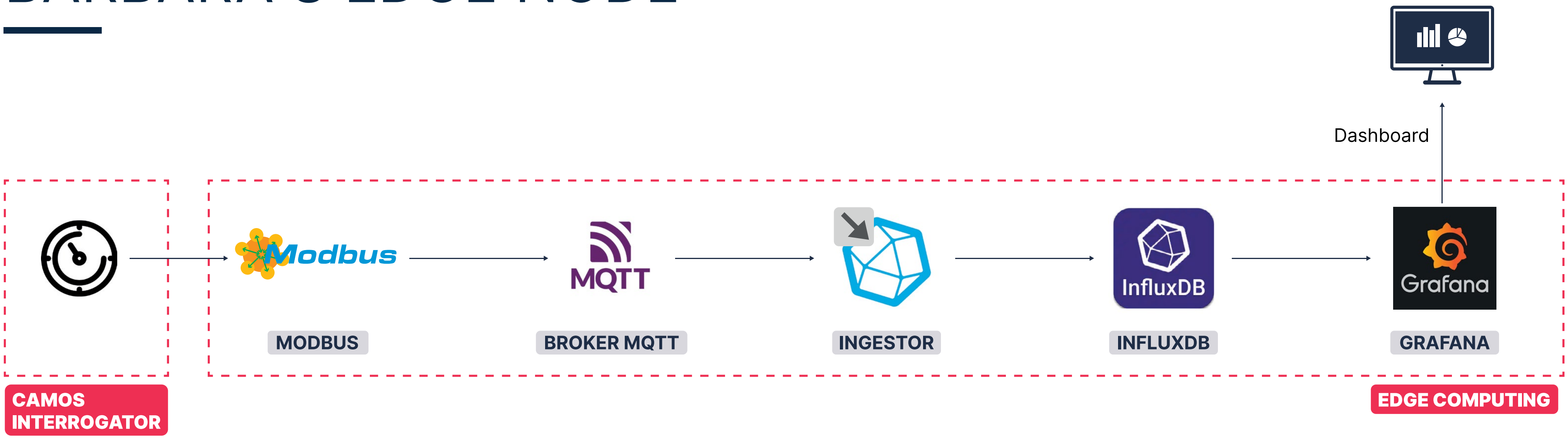
Barbara OS has been designed with “Security by Design” philosophy and incorporates various security features, including data encryption, secure boot, and certificate management, among others. This makes it an ideal choice for edge devices deployed in environments with critical privacy and resilience requirements.

The implementation of Barbara Panel allows for remote management of Edge nodes. Additionally, the proposal includes the design and development of a central console to manage edge nodes and their applications. **This console enables control over the life cycle of the Edge nodes, including firmware updates either in full or partial capacities.**

Remote management of Edge Nodes is a vital functionality for effectively managing a fully distributed infrastructure with many elements. Without this remote and centralized management capability, the deployment, operation, and maintenance costs of the system could render the project implementation unfeasible.



MICROSERVICES IN BARBARA´S EDGE NODE



Barbara´s Edge node takes the measurement values from the CAMOS Interrogator system via Modbus TCP communication. This is done by means of a dockerised connector implemented by Barbara that is able to act as a master in the Modbus TCP connection and to read the different registers of the CAMOS Interrogator.

This connector generates reports with the data obtained in JSON format, which are published by MQTT, to an internal MQTT broker.

The internal MQTT broker is subscribed to the ingestor, which receives the JSON messages with the data, parses them and injects them into a database. As the data obtained are time series of current and temperature, an InfluxDB database is chosen.

The algorithms implemented in the Edge can obtain the time series data by making a request to the InfluxDB database and in turn subscribe to the MQTT broker to directly read the messages generated with the reports by the Modbus connector, and thus, make inferences in real-time.

The communication of processing module results at the Edge to the CAMOS interrogator takes place through the Modbus TCP/IP connection. The results are written into specific registers that are configured for this purpose.

These results are displayed on the local Human-Machine Interface (HMI) located in the CAMOS system´s rack cabinet. In the event of alarms, they are redirected to the system´s output relays.

BENEFITS OF THE PROJECT

The project offers several benefits:

1. **Optimization of Electricity Network:**
By gaining knowledge about the state of cables, the project enables the optimization of electricity network operations. This includes balancing the demand and supply of the network and minimizing the risk of overexploitation. Consequently, the quality and safety of services the network manager provides are improved.

2. **New Business Opportunities:**
The commercialization of data analysis and time prediction solutions utilizing machine learning and artificial intelligence techniques creates new avenues of business for operators. This allows them to leverage valuable insights and offer innovative services based on advanced analytics, enhancing their revenue streams and market competitiveness.

3. **Digitization and Flexibility of Smart Grids:**
Deploying artificial intelligence at the edge contributes to the digitization and flexibility of Smart Grids.

   The integration of intelligent algorithms and predictive capabilities enhances the grid´s efficiency, resilience, and adaptability. It enables real-time decision-making, improved fault detection, and effective load management, resulting in a more agile and sustainable energy infrastructure.

   Overall, the project brings significant advantages, including optimized network operations, new business opportunities for operators, and the advancement of Smart Grid digitization and flexibility.

WHY THIN EDGE COMPUTING

At Barbara, we think that the Smart Grid cannot be solely managed from centralised platforms. Connectivity, data volume, the need for real-time responses and the security and privacy of data and equipment are all challenges that only a highly distributed and independent IT infrastructure can handle.

Barbara has developed the Cybersecure-by-design Edge platform to enable and manage distributed intelligence.

It is a technological solution that:

- Is robust and tested in the energy sector
- Allows scalability to hundreds or thousands of installations of facilities
- Has a short time to-market period
- Provides cybersecurity by design that meets standard IEC-62443-4-2 security level 1

Barbara´s platform brings intelligence into machines by deploying and orchestrating Edge Apps at scale .

Barbara Edge Platform is cybersecure by design and is used in highly critical sites, establishing peer-to-peer interoperability between sites, running automated AI processes in situ, and sharing sovereign data between stakeholders.

Barbara´s interoperable Edge technology stack incorporates all widespread industrial protocols southbound, freely runs any dockerised process or micro-service concurrently on the same device and includes all connectivity options northbound.

Edge Nodes and their AI algorithm lifecycles are maintained by our cloud-based tool, Barbara Panel, also available as API.

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