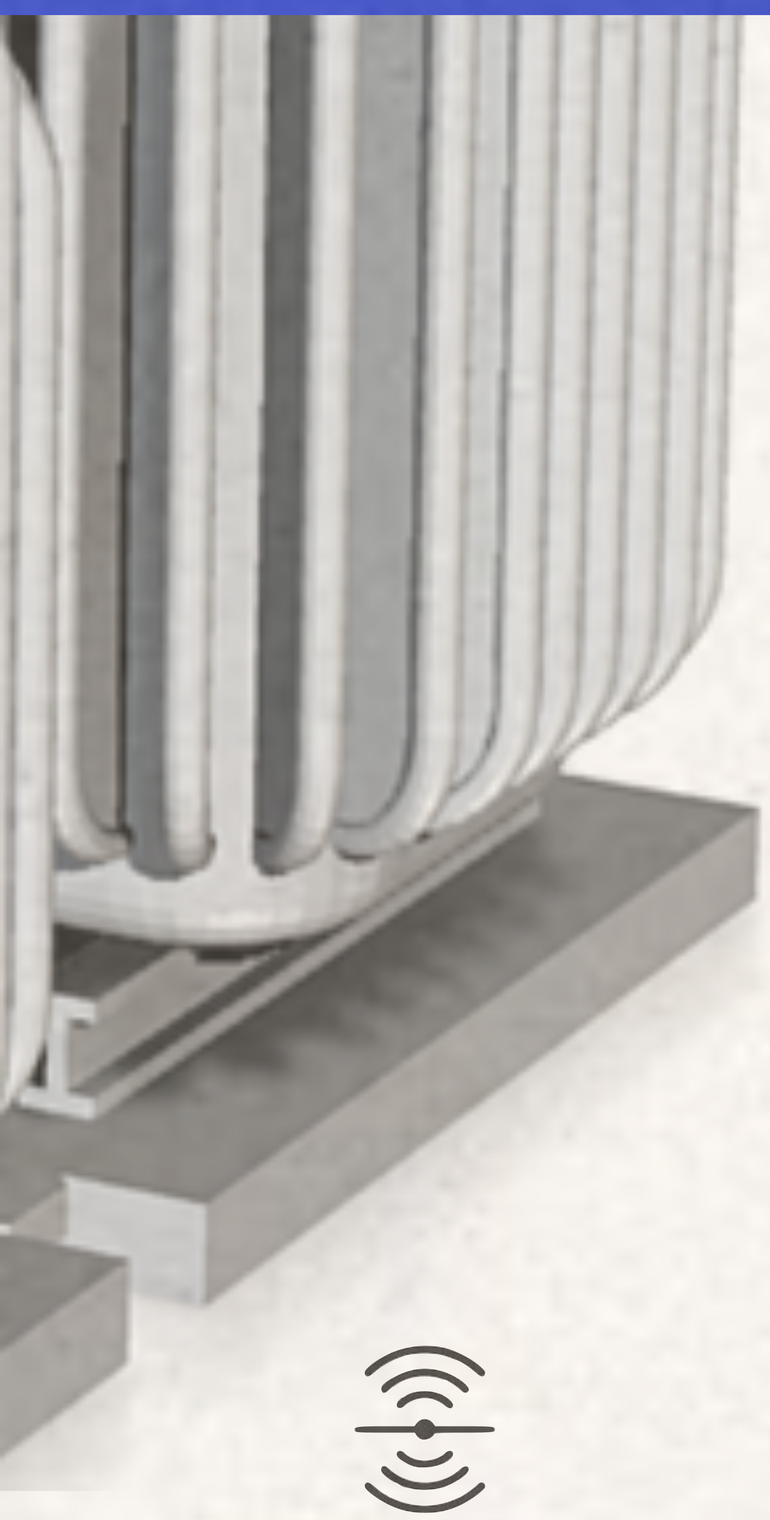
ALTERIA
AUTOMATION

SMART GRIDS

SUBSTATION TRANSFORMER MONITORING

A TURN KEY SOLUTION

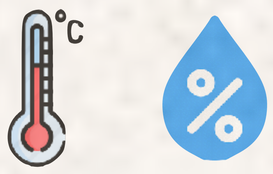


- ENHANCED SUSTAINABILITY
- MINIMIZES ENVIRONMENTAL IMPACT
- EDGE AUTOMATED ACTIONS
- DIGITAL TWIN
- PREDICTIVE MAINTENANCE
- USE OF ARTIFICIAL INTELLIGENCE

REAL TIME MONITORING

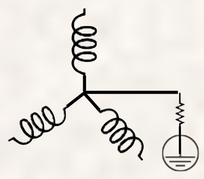
PARTIAL DISCHARGE

SF6 GAS LEAK



ENVIRONMENTAL

FLOOD

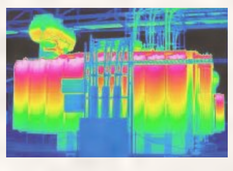


EARTH FAULT

EMF

FIRE

OIL LEAK



THERMAL

PRESENTATION

Smart grids are advanced electrical networks that use digital technology to monitor, control, and optimize the production, distribution, and consumption of electricity.

These systems leverage sensors, automation, and communication technologies to gather and analyze real-time data, allowing for faster decision-making and more efficient energy distribution.

New technologies enable efficient energy management, integrating renewable energy sources like solar and wind, while *improving grid reliability, resilience, and sustainability.*

By optimizing asset lifespan and reducing unplanned downtime, DSOs can decrease operational costs and environmental impacts.

This supports long-term sustainability through better resource management, greener energy distribution, reduced carbon emissions, and enhanced energy security, all while enabling greater customer participation in energy-saving data-backed programs.

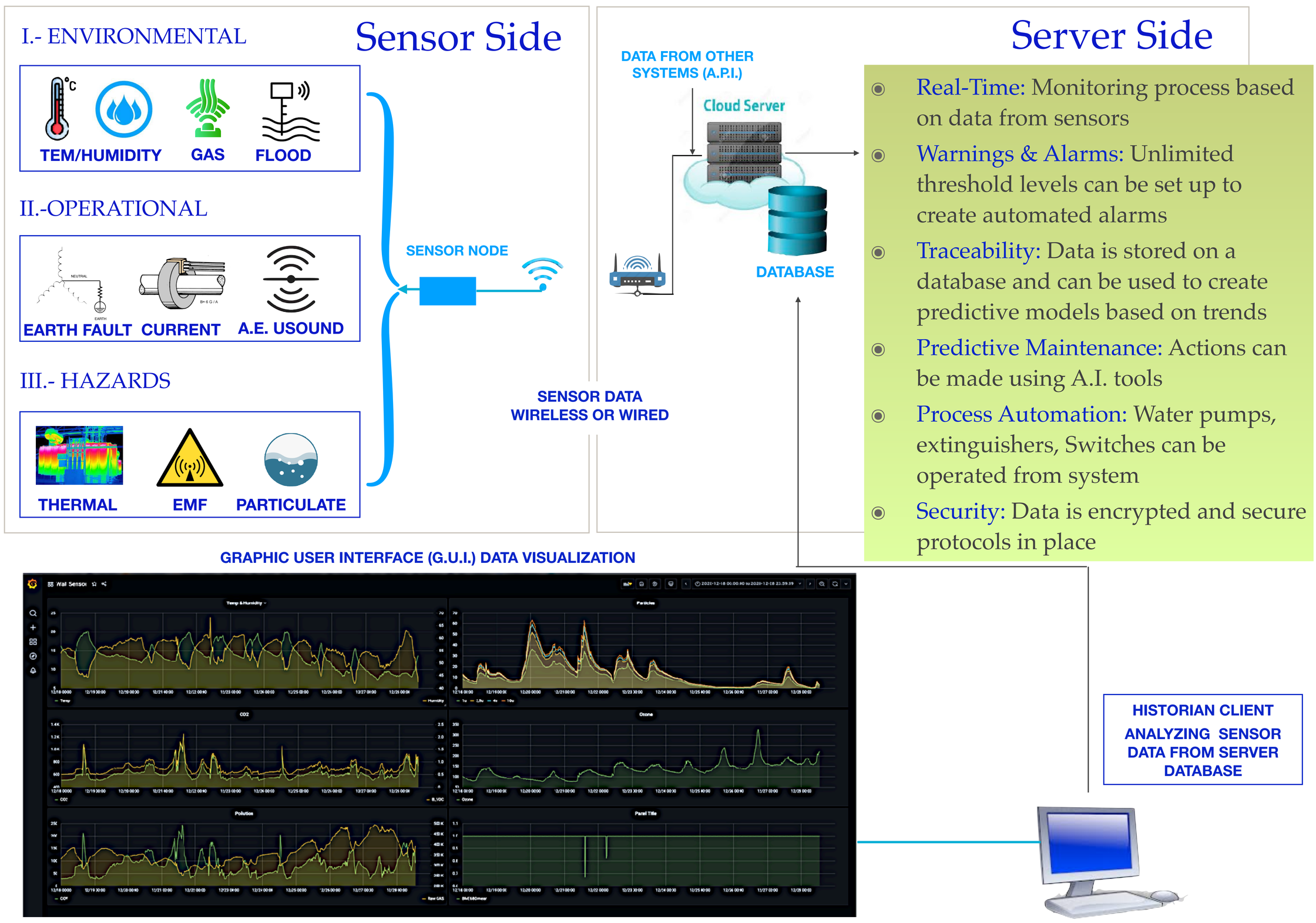
Distribution System Operators (DSOs) are looking to improve the sustainability of their operations and *ALTERIA has developed a turn key solution to monitor the heart of the Smart Grid system*: The Substation Transformer Center.

Substation transformer sensor-based real-time monitoring significantly contributes to sustainability, as *sensors monitor critical parameters* like temperature, load, fire, oil & gas leaks, and Partial Discharge (broken insulation) in real time, enabling early fault detection, predictive maintenance and paving the way to use sensor's data to the ground breaking use of A.I.

By addressing issues before they lead to failures, DSOs minimize the need for emergency repairs, reducing the consumption of materials, energy, and transport resources typically required in preventive and/or reactive maintenance.

Additionally Real-time data also ensures transformers operate at peak efficiency, reducing energy losses and *lowering the carbon footprint of the electrical grid*.

GENERAL LAYOUT

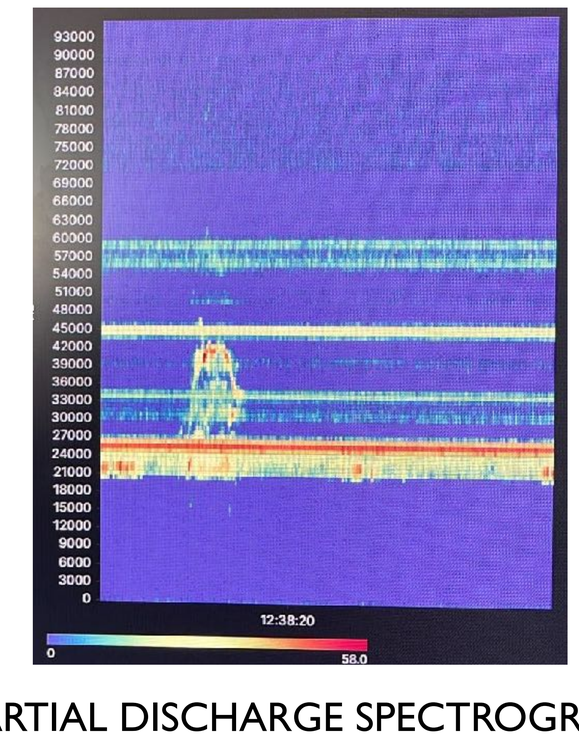


APPLICATIONS

LOSS OF INSULATION: PARTIAL DISCHARGE & CORONA EFFECT

Among the four available methods for monitoring partial discharge, the Acoustic Energy method utilizing ultrasound spectrum analysis with fast Fourier transform (FFT) has been selected for its effectiveness.

This approach allows for continuous real-time analysis in the form of a spectrogram. Given the vast amount of information generated, interpreting the sensor outputs requires advanced data processing techniques known as "Feature Extraction," which can be simplified to the concept of "dimensional reduction."



PARTIAL DISCHARGE SPECTROGRAM

ACOUSTIC ENERGY SENSOR FOR PD DETECTION

The Acoustic Energy sensor not only detects partial discharges from the transformer but is also sensitive to the corona effect and various types of discharges within the switching equipment at the transformation center, offering excellent signal-to-noise ratios.

As a result, these sensors can be deployed extensively throughout the transformation center.

Using multiple units, provides the identification and localization of various insulation loss problems within the environment.

WHY OTHER APPROACHES DON'T WORK

THE FRANKENSTEIN APPROACH:

Heterogeneous integration of commercial sensors

Distribution operators have conducted various proof-of-concept tests using commercial sensors and instrumentation equipment to acquire the data.

For example, infrared cameras have been used to generate heat maps of substation transformation centers. These cameras output data through a port in video format.

However, this approach presents several challenges:

- *Complex data pre-processing required:* The raw data from the camera requires external pre-processing to avoid transmitting live infrared video directly to servers.
- *Integration is cumbersome:* Combining this video-based time series or streaming data with datafrom other sensors is problematic.
- *Costs are unfeasible:* The final solution becomes expensive due to the need to purchase a commercial camera system along with an external pre-processing system that demands significant computing power.

Ultimately, this kind of "Frankenstein" integration results in low reliability and high implementation and maintenance costs.

The high acquisition and operational costs, have proven such heterogeneous integration solutions to be unsustainable for this application.

FLOODING DETECTION

Flooding is one of the main issues that DSOs are facing today. Climate change has made the occurrence of strong storms even in extratropical settings more often, causing flash flooding due to torrential rains.

A specialized sensor has been developed to predict flooding by continuouslymonitoring water levels. Water detection has historically posed reliabilitychallenges, with many sensors relying on basic mechanical systems such as floats connected to rheostats or potentiometers to measure water height.

Recently, ultrasonic sensors that gauge water height based on time of flight have been introduced.
However, several operators emphasize the need for prompt detection of water presence to identify the onset of Substation flooding and track its progression.

This requirement led to the design of a custom sensor. The chosen measurement methodology utilizes a multiple capacitive sensor, which offers several advantages.

This sensor is encapsulated along with all its electronic components in epoxy resin, preventing any contact with environmental humidity.

This design allows for early detection of water presence and enables monitoring of flood progression with a resolution of 25mm.

Additionally the system is resistant to EMI (Electro Magnetic Interference) and vibrations typically present in transformation centers.

FLOODING SENSOR

SMOKE & FIRE DETECTION

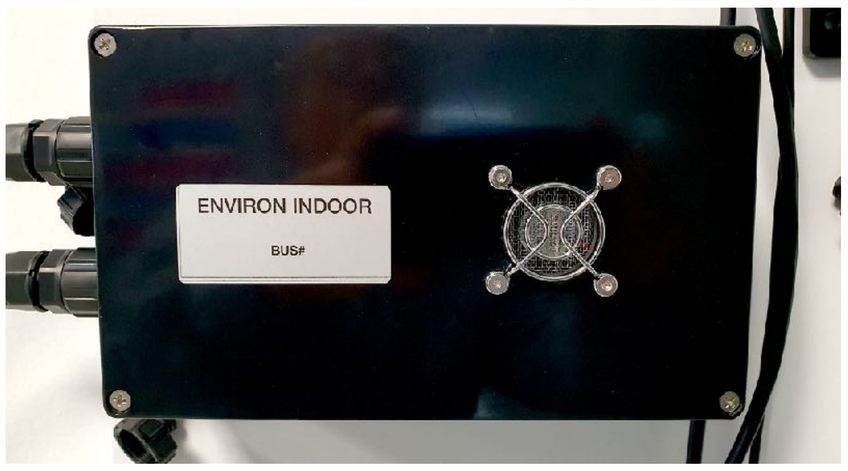
The insights gained from consulting with various distribution operators proved invaluable in developing an effective fire detection system.

Some operators had previously installed ionization fire sensors similar to those commonly used in homes and public places, but encountered numerous false positives, leading to their removal from facilities.

To address this challenge, we utilize Sensor Fusion technology, which enhances event detection by combining readings from multiple diverse sensors. In this system, fires are detected early through the integration of several types of sensors:

- A particulate matter sensor continuously monitors airborne combustion particles in real time.
- Thermal cameras and indoor ambient temperature sensors track temperature fluctuations.
- A volatile organic compound (VOC) sensor detects the presence of odorous compounds produced during combustion.

“By implementing Sensor Fusion technology, we achieve early fire detection while minimizing false positives”



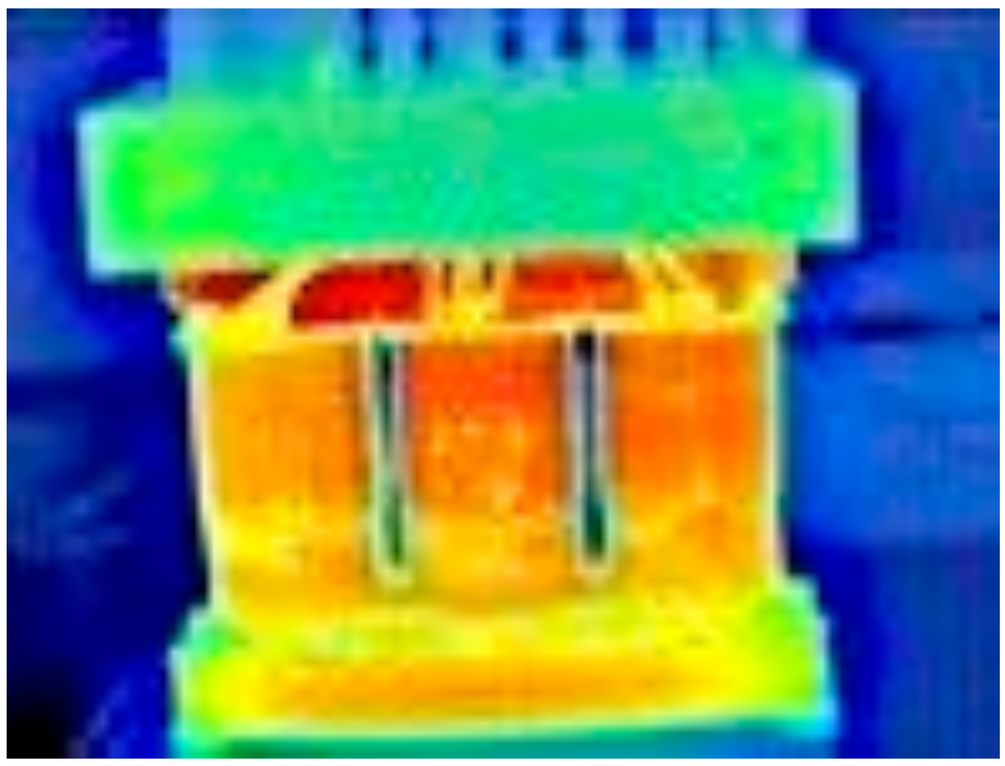
SMOKE & FIRE SENSOR

ABNORMAL HEATING

Monitoring abnormal heat sources is a critical factor in ensuring the substation equipment safety.

Components such as transformers, switchgear, and wiring terminals are susceptible to overheating, making early detection essential for preventing potential failures.

To enhance anomaly detection capabilities, this sensor features pre-processing functions at the source.



THERMAL IMAGING SENSOR

These functions include measuring hot spots on the transformer in relation to other reference points within the center and the external environment.

This output format is well-suited for the application, eliminating the need to process cumbersome video formats typically associated with commercial infrared vision systems.

This advanced pre-processing capability allows for the detection of anomalies before they escalate, offering significantly improved functionality.

HUMAN PRESENCE DETECTION

Detecting human presence has become a critical concern for DSOs, particularly in Europe, where substation intrusions have surged due to a sharp rise in copper theft.

Substation intrusions are a significant concern for DSO legal departments, as the rise in accidents and fatal incidents involving unauthorized human presence has led to increased litigation.

To enhance intrusion detection, an operator suggested utilizing video cameras operating in the visible spectrum. However, as previously mentioned, managing video formats can be problematic due to the large volume of data they generate.

Additionally, the effectiveness of visible spectrum cameras is limited by lighting conditions. Essentially, a camera is only as good as its lighting system.

In contrast, we propose using one or more millimeter-wave radar sensors for intrusion detection. These low-cost sensors are commonly employed in autonomous driving systems (ADAS).

Unlike passive infrared (PIR) sensors typically used in residential and industrial alarms, which struggle to detect stationary individuals, our millimeter-wave system can identify the number of people present and their positions within the transformation center—up to five individuals—and does so even if they remain still.

This radar sensor system can also trigger a camera along with its associated lighting, producing a series of high-resolution images for evidentiary purposes in cases of copper theft or vandalism at the Substation.

SF6 GAS LEAK

SF6 (sulfur hexafluoride) gas leak sensors are vital for safety and environmental protection in electrical power systems.

SF6 is used in high-voltage circuit breakers and other electrical equipment due to its excellent insulating properties.

However, SF6 is a potent greenhouse gas with a global warming potential thousands of times greater than CO2, making even small leaks harmful to the environment.

Detecting leaks early prevents the release of this gas into the atmosphere, reducing its environmental impact.

SF6 GAS CONCENTRATION SENSOR

Additionally, SF6 is toxic at high concentrations and can pose health risks to maintenance workers in confined spaces.

SF6 sensors provide early warnings, ensuring a safer environment.

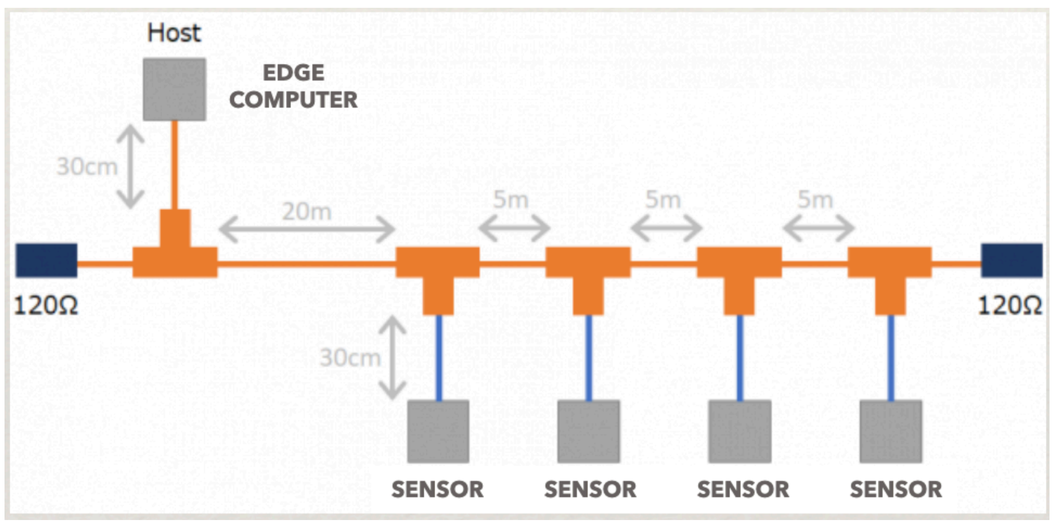
Timely detection of leaks also helps avoid equipment damage, preventing costly repairs and system failures.

In summary, SF6 leak sensors are essential for maintaining operational efficiency, safety, and environmental sustainability in electrical infrastructure.

To detect leaks, the SF6 sensors use non-dispersive infrared (NDIR) technology. NDIR sensors work by measuring the absorption of infrared light at a specific wavelength that SF6 molecules absorb.

This highly sensitive and reliable method enables the detection of even the smallest leaks, long before they become dangerous to personnel or result in significant environmental harm. NDIR detection technology is widely preferred due to its accuracy, fast response time, and ability to operate in harsh conditions, making it ideal for monitoring electrical systems in real-time.

THE EDGE COMPUTER



Sensor data acquisition requires pre-processing at the source, along with other essential tasks. To meet these needs, the sensor system has been designed to connect to a custom-built, low-power, high-performance EDGE computer.

Unlike other edge computing solutions on the market, This EDGE computer is built from the ground up and comes with pre-configured sensor inputs, ready for immediate use. The sensor power supply is integrated into the same connector and bus wiring, operating efficiently at 24 volts.

For data transmission, we use RJ45 waterproof connectors with an IP67 rating. The differential pair transmission method used ensures high resistance to noise and interference from strong electric fields.

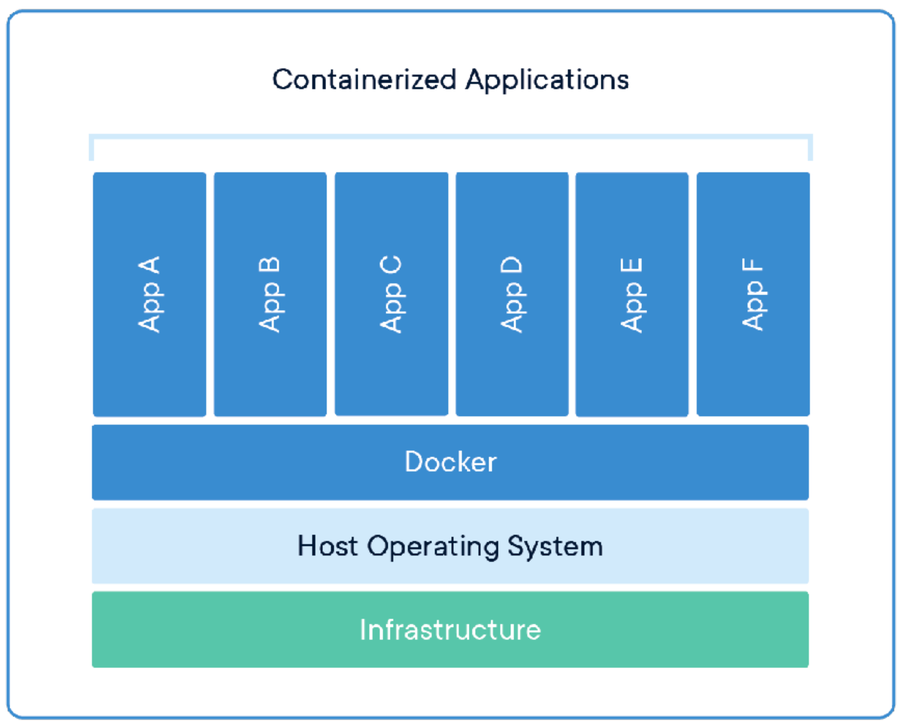
The computer has up to four sensor inputs (for different sensor zones) that can be used simultaneously. The bus topology allows more than one hundred sensors to be connected to a single computer, using hundreds of meters of cable.

SHARED USE OF THE EDGE COMPUTER WITH OTHER APPLICATIONS

The edge computer can be configured as a versatile, multipurpose tool through the use of containerization technology. Containerization allows each application to operate in its own isolated environment, ensuring that they do not interfere with one another, while still sharing the same hardware resources.

Many DSOs are actively seeking ways to optimize the deployment of edge computing capabilities within their substations, particularly those related to the Smart Grid transformation.

Edge computing reduces latency, improves real-time decision-making, and enhances system resilience, while still maintaining strict cybersecurity protocols through the isolated environments provided by containerization.

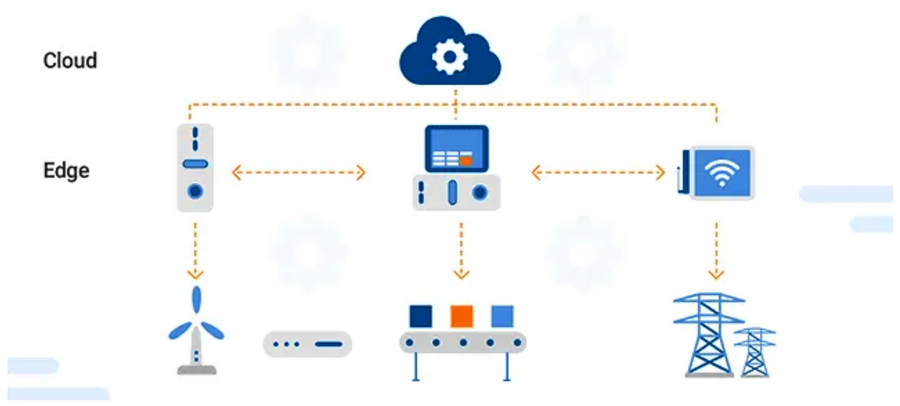


TELEMETRY & CONTROL TO THE SUBSTATION FROM THE DATA PLATFORM

A pivotal feature of our new substation monitoring system is the seamless integration of a sophisticated Telemetry, Tracking, and Command System (TTCS).

This system is designed to provide operators with enhanced control and visibility over substation operations, enabling both real-time monitoring and remote interventions.

The TTCS enables a wide range of remote actions, making it an invaluable tool for grid management and emergency response.



For instance, in the event of a fire, the system can automatically trigger fire suppression mechanisms, such as activating fire extinguishers, to prevent further damage to critical infrastructure.

One of the most compelling examples is its ability to activate bilge pumps in the event of a flash flood. Flooding is a growing concern for substations in low-lying areas, and the TTCS allows for immediate response, thus mitigating the risk of equipment damage or power outages.

TRACEABILITY OF ACTIONS AND CYBERSECURITY ISSUES WHILE ENABLING TTCS

This level of remote intervention using TTCS significantly enhances operational resilience, as it allows for rapid responses to evolving conditions without requiring personnel to be physically present at the substation.

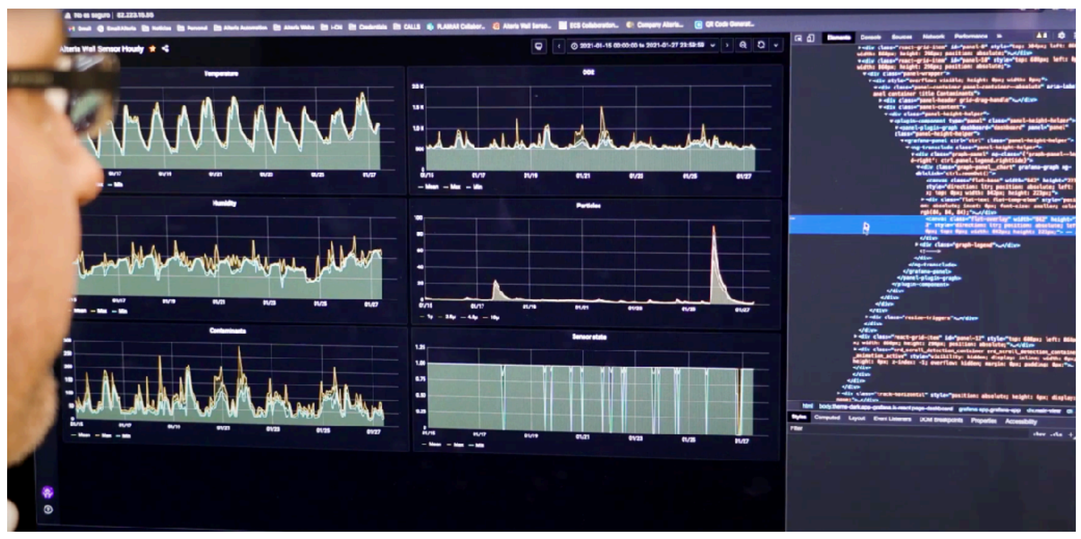
The inclusion of telemetry capabilities ensures that all actions performed via the TTCS are tracked and logged in real time, providing a comprehensive audit trail (traceability) for operators and regulatory bodies alike.

Detailed tracking not only improves accountability but also enables predictive maintenance and system optimization.In addition to real-time monitoring and control, the TLS & mutual TLS system is designed with robust cybersecurity features to ensure that all commands and the data exchange are secure.

The system employs TLS with a fine graded access control providing the right amount of privileges to each user and device to prevent unauthorized access and safeguards against potential cyber threats.

DATA PLATFORM & ARTIFICIAL INTELLIGENCE

Our data platform solution leverages **InfluxDB** as the time-series database and **Grafana** as the visualization tool, both operating within **Docker containers**.



Use of artificial Intelligence:

Predictive Analytics: AI models analyze historical time-series data stored in InfluxDB to predict future trends, such as system failures, and consumption analysis

Anomaly Detection: AI algorithms continuously monitor real-time data in InfluxDB via Grafana, automatically detecting unusual patterns and alerting users to potential issues before they escalate.

Automated Insights: Machine learning models process large datasets to identify hidden correlations, offering automated insights and optimizing decision-making processes.

Dynamic Thresholding: AI can establish adaptive thresholds based on historical data trends, making alerts more accurate by accounting for seasonal or operational variations.

Advanced Visualization: By integrating AI with Grafana, users can interact with intelligent dashboards that highlight key trends, provide recommendations, and display AI-driven metrics for better data-driven decisions.

Benefits of the technology Stack:

- **Horizontal Scalability**: Easily scale both InfluxDB and Grafana by adding more instances as needed.
- **Flexibility**: The Docker containers can be run on any machine that supports Docker, making deployment flexible and straightforward.
- **Cost-Effective**: Open-source technologies reduce software licensing costs while providing robust functionality.
- **Performance**: InfluxDB is optimized for high write and query loads, suitable for applications that generate large volumes of time-series data.
- **Visualization**: Grafana provides powerful visualization tools to make sense of complex data.

SUBSTATION TRANSFORMER ISSUES

ENVIRONMENTAL

6.-Flooding
5.-Roof Water Leaks
2.-Gases (SF_6, O_3)

OPERATIONAL

1.-Partial Discharge
1.-Corona
1.-Terminal Tightness
3.-Abnormal heating
8.- Earth Fault (NEV)

HAZARDS

4.-Smoke detection
3.-Fire detection
9.-Substation Intrusion

SENSOR SOLUTIONS

2.- Gas Sensor

1.- Acoustic energy Sensor

4.- Particulate Matter Sensor

6.- Water Flood sensor

8.- Neutral Earth Voltage Sensor

7.- Spike Current Sensor

3.- Infrared Imaging Sensor

5.- Humidity Sensor

9.- Presence Sensor

Certifications Provided by

SGS

ENAC
Entidad Nacional de Acreditación

Designed and manufactured in Europe

CE conformity Mark

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