MV/LV TRANSFORMER SUBSTATIONS MONITORING GIVES RAPID RESPONSE TO FAULTS (CASE STUDIES-NEW TECHNOLOGIES)

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ABSTRACT

The case described is a project deployed by Viesgo Distribución in collaboration with Ingeteam Power Technology that pretends to provide remote access and management tools for the over 8,000 MV/LV package stations existing currently in the Viesgo grid.

The MV/LV Transformer Substations Monitoring pilot project handles the supply and installation of hardware devices (RTUs) and centralized software to monitor the behaviour of 200 MV/LV Secondary Substations (with 6,000 residential homes) with some specific requirements:

- RTUs should be low cost devices contained in an small cabinet ready to be installed by Viesgo’s own personnel
- The solution must be easily configurable and adaptable to improve its functionality: add more parameters to monitor, include new remote commands, implement new protocols...
- The system must be capable of integrating and using the existing devices and communications infrastructure based in well-known technologies; 3G/4G, Web Services, Java, https...

INTRODUCTION

Service suppliers want to provide value-added services enabled by new technological innovations reducing, at the same time, their Operation and Maintenance (O&M) costs. Considering the large number of secondary substations, it would be expected that the performed interventions could produce relevant results on technical and economical savings, improving the quality of service.

Innovation pilot in the field of MV/LV substations monitoring, whose target is to develop a scalable and flexible solution to monitor different kind of parameters that could influence the operation of MV/LV transformers:

- Make secondary substation status visible for the control room, allowing a faster resolution of detected problems;
  - Manage voltage limits
  - Optimize assets and reduce field site visits
- Use load profiles and related parameter evolution to know the real state of key distribution transformers;
  - Better balance of LV feeder load
- The communication technology can be used for more than one purpose without affecting its main functionality and with low cost increase.
  - Possibility of changing settings remotely.
  - Ability to implement automatisms, which make easier system operation.

The status of more than two hundred substations has been made visible in the grid control room through the MV/LV monitoring pilot project in Spain, enabling the prevention or faster resolution of power failures.

Monitoring units can monitor a range of magnitudes which could affect assets or supply to customers, including voltage/power/harmonic levels and external incidents such as flood, fire, humidity or break-in.
Monitoring units are wired or communicated with different kind of sensors, from presence, flood, fire or humidity sensors up to several brands of Power Analyzers or circuit breaker status. They enable alarms, events, faults, circuit breaker status and various magnitudes to be sent to the SCADA system or DMS.

The monitoring unit is able to operate the LV cubicle circuit-breaker whenever needed (overload, fire and other reasons).

**PRE-ENGINEERED SOLUTION**

The project targets to develop a scalable and flexible solution to monitor different kind of parameters that could influence the operation of MV/LV transformers. It aims for a low–cost and easily configurable device ready to be installed by utility’s own personnel.

A pre-engineered solution can be well adapted to a distribution network with a large number of similar installations. A solution that has been standardized, industrialized, and fully factory-tested saves commissioning time and is flexible enough to accommodate future network development.

Substation profiling work was done to cover the maximum number of substation topologies with one pre-engineered solution. This solution covers installations with up to four MV/LV transformers with 1 or 2 low voltage cubicles each. The configuration for the number and order of the inputs/outputs, communications addresses and other parameters were fixed to achieve a closed configuration to cover all possible topologies. With a minimum parameter setting, it is possible to cover any type of installations deployed on Viesgo’s network.

**Scheme of the installation**

The Low Voltage control Box is placed in the MV/LV Transformer Substation. The Low Voltage control Device (LVD) is installed in the cabinet beside the rest of required devices for communication and enable power supply in the event of Vac failures (batteries and charger/rectifier).

Different sensors that can be installed in the substation, some sensors will be installed in every substation, such as the intruder detection, fire alarm, or the state of the 230Vac protection switch whilst other sensors such as flood detection or other as temperature/humidity/condensation/noise could be only installed in specific cases.

In some substations there is more than one Supply Network Analyser installed. These Network Analysers are connected to the “LVD” through a RS485 communication bus using Modbus RTU protocol. Temperature, humidity, condensation and noise sensors also are integrated through the RS485 bus.

Analogue measures of current and voltage can also be measured directly by the LVD through currents sensors placed in the secondary part of the transformer (in the input of the Low Voltage Box).

**SYSTEM ARCHITECTURE AND FIRST INSTALLATIONS**

The monitoring unit and the monitoring platform is prepared to be scalable, allowing future modifications or
extensions and minimizing the future investment. The architecture is Multi-manufacturer, multi-platform and multi-protocol, favouring web based technology. It allows sending configured alarms via mail or sms from the different devices, sensors or SW. It can also be deployed on existing substations, retrofitting them to open a new field of smart applications.

Communication architecture integrates seamlessly with third-party hardware/software using standardized open protocol as Web Services or telecontrol protocols like IEC 61850 or IEC61870-5-104.

Many utilities use multiple software systems for grid management, and Web Services are very flexible for data processing (settings, advanced configuration, alarms, checks, events, measurements, etc.) as well as for the expansion of the data. Web Services have been deemed to be the more convenient communication and therefore been included as the initial option to manage the information from different applications. A cloud based solution was not initially available, and although at a later stage this possibility was considered, it was finally dismissed for the pilot project.

DATA HANDLING
In the Central Server a GPRS/3G/4G router with an APN service provided by a telecommunications operator that allows IP access to the LVD was installed. The electric utility had clearly defined its priorities: general security, technical service, operation and maintenance.

Using a vendor-independent open protocol, the data provided for LVDs and sensors will lead to improve DMS/OMS/O&M application programs in the datacentre. IP-based technologies and service oriented approaches made Web Services the best candidate for data exchange and management.

Alarming & Notification system was considered as a great advantage and has been successfully implemented to notify workforces and managers by e-mail or sms in real time.

Web Services
Information between Low Voltage Device (LVD) and Central Server is exchanged via Web Services, although the LVD have also other communication protocols available. A Web Services based system feeds real-time information to the control room and sends alerts to maintenance crews – who can prevent incidents based on pre-alarm signals – or to the emergency services, if needed.

The communication protocol for Web Services is by means of SOAP over HTTPS (SOAP 1.2 and WSDL 1.1). The Central Server and the LVD can work as clients or servers publishing some services that the LVD will invoke and vice versa.

The main services that have been defined to monitor the power transformer centres are:

- **Alarms**: request, spontaneous sending, signal status refresh (getAlarms…)
- **Measuring**: measures request (getMeasures…)
- **Commands**: command code sending (setAlarma, setON…)
**Firmware** updating: version number information, update… (getFirmware, setFirmware…)

**Configuration**: settings request, setting sending (getSettings, setSettings…)

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**Sequence Diagram - setFirmware**

![Sequence Diagram - setFirmware](image)

**Security Issues**

One of the goals of the architecture is to build a security framework, which is relevant for multiple involved areas; trusted hardware and firmware platform, access technologies (TLS, IPsec…). To determine what security measures should be taken, the first step was to define which should be implemented in the roll-out:

- Security Architecture Recommendations. Configuration of the Firewalls & APN/VPN telecom provider selection and specific requirements.
- Vulnerability & Penetration Test. How the devices react on attacks or known vulnerabilities.
- Robustness Test. Ensure the device is not vulnerable to network anomalies, can lead to denial of service etc.

After the evaluation has been assessed, operational and design recommendation in several areas were considered; general, datacentre, communications and substation:

**General**:
- Establish a *patch management* process
- Establish a process to review *firewall rules* and configurations
- Establish a *password policy*
- Install network *intrusion detection systems* (IDS) or intrusion protection systems in the datacenter
- Turn on *logging* of security events whenever possible

**Central Server**:
- Strong *Web Portal Authentication*
- Split *Functionality on the Central Server*
- *Network Segmentation*

**Communications**:
- Encryption and Authentication in Application *Protocols*
- Review Access Control Mechanisms on *LVD*
- VPN from Substation to Viesgo Datacenter
- Review Security at the Telecom Provider
- Separate Smart Metering from Substation Automation

**Substation**:
- Substation LAN Access Control
- Limit reusing passwords between substations

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**CENTRAL SERVER**

There is a Central Server, based on a standard data model, embedded in a Data Center and managed by Viesgo to monitor the MV/LV Transformer Substations behaviour (Monitoring Tool). The central server is a centralized system, with the frontend and its connectivity with the backend developed with Java/Oracle11. The networks used to transfer information and data from one node to another (e.g. from the LVD to the Central Server, or from the LVD to the authorization server) can be accessed from a public network (Internet).

LVD sends to the Central Server the information of the substations. Load profile files are available to be consulted by the Monitoring Tool. Load profiles associated with the power delivered by each transformer allows calculating energy balances at transformer level, losses estimation (technical and non-technical), or other possibilities offered
by suppliers.

Central Server/Monitoring Tool main characteristics:

- Web Server: to work as an interface for the different users.
- Database: Alarms, Status of the sensors, load profiles, Substation voltage /current /power /harmonics measures, user activity register for one year at least.
- Authentication and authorization: the user authentication and authorization is done through a server and using database
- LVD communication state: check every 15 minutes the connection with the RTU.
- Users Activity register: register all the actions than could modify the system.

**CASE STUDY RESULTS AND EVALUATION**

This pilot project has contributed to optimize crew assets, improve asset reliability and employee productivity, has improved decision making and specifically has enhanced:

- Transformer load study. The data provided by all deployed LVDs and its automatic information retrieval has enabled the evaluation of power consumption per transformer to determine whether they are adjusted to the real demand.

**Transformer Load graphic**

- Quality analysis of the LV network. The magnitudes monitored by the LVD have allowed to detect high neutral currents, unbalance between phases, high harmonic distortion rates etc.

**Detected defects analysis**

- Critical alarms. Although fortunately very few Fire or Flood alarms have been registered (about 6/year), they have helped to draw conclusions as well, such as high temperature alarms the MV/LV transformer substations due to an incorrect performance of the ventilation system.
- The economic advantages of the energy balance have not been evaluated in depth yet. Although all the data needed for an economical analysis is available, this study will be conducted in the next stage of the project.

**TECHNICAL CONCLUSIONS**

- Timeline for the deployment reduction due to the use of standards.
- The HW and SW architecture has been successfully tested in the pilot Project
- Open platform that has allowed the update of the different HW elements
- The system is based on a scalable platform enabling the implementation of new functionalities throughout the project.