DISTRIBUTION SURGE ARRESTER MONITORING

Michel CORDONNIER
Enedis – France
michel.cordonnier@enedis.fr

Christian GAZZOLA
DERVASIL - France
christian.gazzola@dervasil.com

Damien JEANNEAU
SICAME - France
djeanneau@sicamegroup.com

Iulia IVAN
Enedis – France
iulia.ivan@enedis.fr

Denis SPORTIELLO
Enedis – France
denis.sportiello@enedis.fr

Alban-Marie LIMONET
Enedis – France
alban-marie.limonet@enedis.fr

ABSTRACT

Low-Power Wide Area Networks (LPWAN) offer new perspectives in deploying Internet of Things (IoT) solutions for DSOs to ensure continuity and quality of supply in a cost-efficient way. This paper describes one of the first IoT industrial solution installed on the electrical distribution network operated by Enedis: a wireless surge arrester monitoring device (WSAM). This paper presents the end-to-end solution, from the measurement capture to the SCADA (Supervisory Control And Data Acquisition).

INTRODUCTION

Enedis, main distribution network operator in France [1], operates 350 000 km of MV overhead lines. Around 2 million surge arresters are installed on the MV network to protect particularly MV/LV transformers, connections of OverHead and UnderGround lines (OH/UG connections) and other remote-controlled switches.
The specificity of surge arresters used by Enedis is to remain short-circuited when they are out of service in order to give priority to the safety of the installations. The current surge arresters are fitted with a mechanical fault indicator which forces the network operator to inspect a part of the network in order to find the faulty surge arrester. Each year, 400 surge arresters are out of order. Each fault results in an average of 61 minutes of power interruption for the last section of faulty grid not re-energized by SCADA automation.
Enedis and DERVASIL (a SICAME group company) [2] decided two years ago to develop and to test a wireless surge arrester monitoring device (WSAM) based on LPWAN technology.

Figure 1: Typical Pole-top MV/LV transformer protected by three horizontal surge arresters.

ENEDIS SPECIFICATION OF REQUIREMENTS

The first goal of Enedis is to enhance SAIDI (System Average Interruption Duration Index) by:

- Increasing responsiveness by making it easier to locate faulty surge arresters
- Decreasing equipment wear out during searches
- Improving perceived customer quality (average cut-off time and number of recloses)

The second goal is to deploy a cost-effective end-to-end solution that includes the purchase, the installation, the operation, the maintenance costs as well as its lifetime.
In order to reduce the purchase and installation costs, the design choice was focused on a dedicated device, entirely independent of the surge arresters. This solution makes it possible to keep existing surge arresters and to dissociate the lifetime of the IoT device from power equipment. This solution can be easily installed on the earth grounding wire. Moreover, it can be replaced independently of the surge arresters in case of equipment failure or in case of technological evolutions in the telecommunication network.
The reduction of operation and maintenance costs implies a judicious choice of the telecommunication system. Public LPWAN provide good communications performance without any infrastructure investment. Low battery consumption of the wireless protocols employed by the LPWAN allow 15 years lifetime of the device without any battery replacement. In order to respect the lifetime objective and to optimize power consumption, the information volume sent by the device was minimized.
The installation process on the network was also optimized. The monitoring fault indicator can be installed without requiring any particular telecommunications or IT skill.
The third goal is to manage the devices via Enedis' Information System and to transmit the alarms to the SCADA.

DERVASIL MONITORING SOLUTION DESCRIPTION

Based on Enedis specification of requirements, Dervasil developed the WSAM device, solution adapted to the behaviour of the surge arrestors deployed on Enedis network.

Behaviour of Zinc-Oxide Based Surge Arresters Analysis

In order for DERVASIL to precisely define the monitoring scheme of surge arresters, Enedis has analysed over a longer time frame (2011-2015) the root causes of surge arrester failures.

The vast majority of surge arresters currently commissioned on the system are ZnO based technology (Zinc Oxide). In the case of ZnO surge arresters, such events can certainly be detected and even anticipated thanks to precise monitoring of the surge arrester current conduction (aka leakage current).

Surge arresters constantly face a phase-earth potential difference between their terminals. As a consequence, a conduction current flows continuously in the conductor connecting the arresters, usually 3 in parallel, the MV/LV transformer or the OV/UG connection to the earth grounding wire.

This leakage current, provides a faithful projection of the arrester status and behaviour.

Without overvoltage, surge arresters act as insulators with very high resistance and therefore a very low conduction current, in the order of magnitude hundreds of micro-amperes.

When a temporary surge flows through, brought for instance by a phase-ground fault or transient overvoltage effects, the conduction current can then reach several dozens of milliamps.

When facing indirect lighting strike, the surge wave causes in the surge arresters some current impulses of several kiloamps. Such impulse leads to a swift temperature increase of the Zinc Oxide varistors and therefore a sensible increase of conduction current up to values in the vicinity of an ampere.

The leakage current then reduces over time as the ZnO varistors cool down and cool back to ambient temperature.

If the surge arrester is not able to cool down after a surge, for instance after repeated significant over-voltages, a thermal breakdown occurs. This results in a non-reversible increase of leakage current leading to the arrester destruction.

Once these patterns are analysed and understood, with precise measurements of leakage current from a few microamps to several amperes, it becomes possible to record and monitor the status and behaviour of surge arresters installed on the network and send an alarm to the SCADA when the surge arrester is faulty.

Wireless surge arrester monitoring device (WSAM) architecture

Driven by the Enedis specification, Dervasil has developed a wireless surge arrester monitoring device (WSAM).

This device measures and analyses conduction current flowing through the earth cable, downstream from the arresters.

The following Synoptic provides a general overview of the device structure:

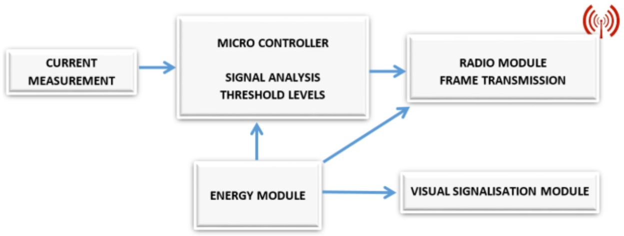

Figure 2: Monitoring Fault Indicator Diagram.

Conduction current is measured via a ferromagnetic core positioned around the earth cable.

Current thresholds are set in the microcontroller in order to transmit through a radio module relevant monitoring information.

The first challenge has been to design a device able to measure microamps and *also* withstand impulse currents of tens of kiloamps due to indirect strikes or even network short circuits following possible failure of a surge arrester. To address this challenge, an extensive investigation and testing protocol was jointly driven in order to reach the expected level of reliability.

The second challenge has been to design an electronic structure (software and hardware) very frugal in energy consumption to provide an autonomy beyond 15 years.

Among the different LPWAN systems, Dervasil chose LoRa technology for the surge arrester monitoring system since it matched the most the imposed requirements (i.e. low energy consumption, wide area coverage, cyber-security constraints).

FIELD TESTS

Enedis initiated in the summer 2016 a real-life field test for a two-year period. The context and objectives of the experiment were as follows:

- Evaluate the installation protocol vs. normal working practice in various network configurations (transformer, OH/UG connection…)
- Assess the influence of topography on radio propagation
- Record, with a leakage current monitoring device the various events such as strike surge or transient surge over the period.

11 WSAM prototype devices were installed across over two areas nearby Nîmes and Montelimar cities in France. These two locations have been chosen due to their high keraunic activity.

In Nîmes area, 5 devices were installed on arresters protecting various configurations of MV/LV transformers and one was positioned on an OH/UG connection.

Figure 3 represent the local MV network configuration for Nîmes area and highlights the location of devices while Figure 4 and Figure 5 illustrate an example of typical installation on a pole top transformer.

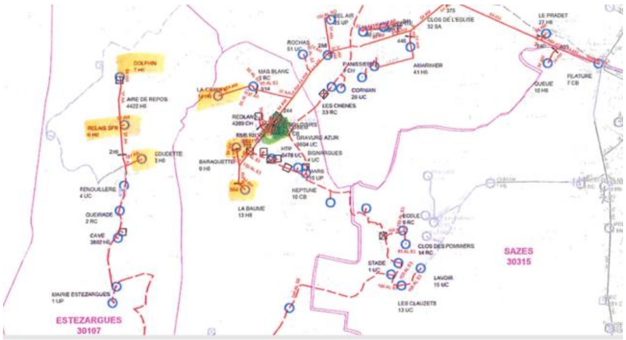

Figure 3: Devices installed the area of Nîmes

Figure 4: One of the targeted pole-top MV/LV transformer protected by three horizontal surge arresters.

Figure 5: WSAM device installed on the earth cable.

Leakage current data feedback is presented as a bar graph showing maximum values of leakage current measured for any given day (Figure 6). Whilst values are transmitted weekly, alarms are communicated in real time.

Directly after installation, leakage currents are measured. Values up to 100 µA were observed on MV/LV transformers setups. Such low values are coherent with ZnO arresters expected behavior.

On OH/UG connections, we observed currents however were in the hundreds of milliamps. In this type of situation, induced currents in the metallic screen of the UG cable is added to the leakage current of the arresters.

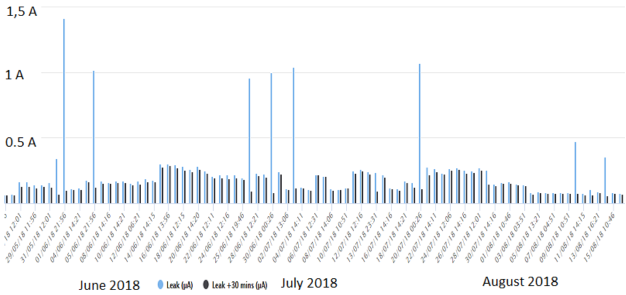

Figure 6: Sample of currant measures over 3 summer months in 2018 for one device showing peaks for leakage current

While monitoring is still possible, the OH/UG configuration have been excluded from the refined data analysis for this reason.

After two years, return on experience allows us to draw the following conclusions:

- The majority of leakage current pictures are very well correlated with high level of lightning activity in the area on that day. This phenomenon is illustrated with a detailed example in the next chapter.
- Induced surge impulse leakage current can be simultaneously observed over several arresters in the area close to the strike.
- Despite several heavy lightning activity periods, we have not observed a tangible leakage current measurement pattern evolution over the two years

Correlation between lightning activity and measurements

Figure 7 illustrates conduction current measurements over period from 01/03/2018 to 17/03/2018 for two devices in the Nîmes area.

Figure 7: Conduction current measurements over period from 01/03/2018 to 17/03/2018 for 2 devices in the Nîmes area.

Out of 4 peaks for each device, 3 have occurred on the same dates: on the 1st, 8th and 12th march 2018. For each peak, a correlation with lighting activity in the area has been positively verified.

As an illustration, the following map shows lighting activity corresponding to the peaks on Marth 12th.

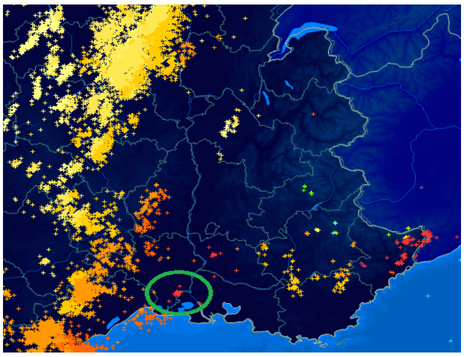

Figure 8: Lightning activity in South East of France on 12/03/2018.

END-TO-END SOLUTION DESCRIPTION

The Enedis end-to-end solution diagram is illustrated in Figure 9.

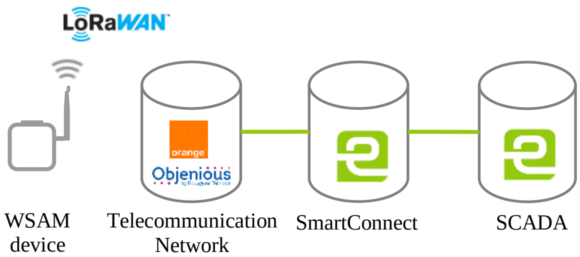

Figure 9: End-to-end solution diagram.

Telecommunication network

LoRaWAN operate in unlicensed radio spectrum and can be either public or private. In France, two LoRaWAN public network operators provide national coverage, Objenious (subsidiary of the Mobile Network Operator Bouygues Telecom) and Orange.

Since surge arresters are mostly located in remote areas, LoRaWAN public networks are the most suited for this particular use case. Enedis have contracts with both French LoRaWAN operators. The possibility to enrol the sensor in either network allows to maximize coverage and to ensure good communications performance and flexibility for the installed equipment. The WSAM device can also be attached to a private LoRaWAN gateway for particular use cases.

The WSAM are programmed to send alarms when the surge arrester breaks down. Besides the alarms, the devices send a weekly 'heartbeat' message to the network. This message is used by the supervision system to monitor the good functioning of the device.

Enedis SmartConnect Platform for Connected Objects

Enedis develops SmartConnect, its dedicated connected object software platform to follow the implementation of connected objects, from Proof of Concept to industrialisation.

SmartConnect aggregates the bulk of data from connected objects used by Enedis. The system consists of three technical components:

- The web interface
- The mobile app
- The server-side data treatment and service provider.

SmartConnect offers software-based management of the connected objects lifecycle to its users.

Figure 10 illustrates SmartConnect process which will be described hereafter.

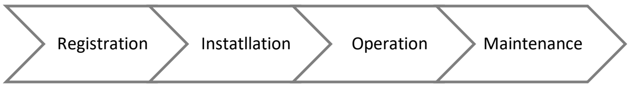

Figure 10: SmartConnect process.

Registration

The registration phase consists in recording the object with the telecom operator (provisioning) and the SmartConnect platform through its web interface.

Installation

Connected object installation is performed through the mobile app, enabling a technician on the ground to link a connected object to the relevant electricity network infrastructure. This phase do not require any particular telecommunications or IT skill for the technician.

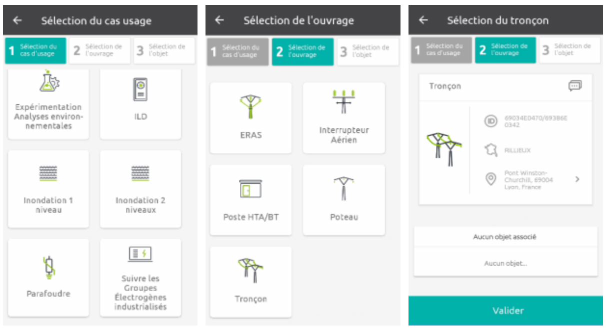

Figure 11: SmartConnect mobile app.

Operation

Object data is generated as follows:

- Connection to operator to extract object data
- Convert object data to business information
- Business rules treatment
- Rendering of information through the web application and transfer of data to the SCADA system"

Maintenance

SmartConnect implements monitoring of the communication chain to detect any object, network or system malfunction.

Figure 12: WSAM device prototype.

INDUSTRIAL IMPLEMENTATION

Besides the field tests described in the previous paragraphs, the Dervasil WSAM device was summited to various qualification tests in Enedis laboratories such as high power tests and functioning tests in EDF Smart Grids platform, Concept Grid [3].
The WSAM device functioning was validated and can be installed on Enedis network.

CONCLUSION

More than 2 million of surge arresters are installed on the French MV network operated by Enedis.
The IoT solution presented in this paper, the WSAM device, brings cost benefits for utilities to improve SAIDI. By employing this solution, we estimate a time reduction of 30% in the process to localize a faulty location, to sectionalize it off the MV feeder and to re-energize the healthy part of the feeder.
This IoT solution offers new perspectives of evolution especially for Enedis to introduce surge arresters with disconnectors thanks to the automatic localization of a failure, removing the need for the network to be inspected after each storm.
The company DERVASIL proposes a solution which could be implemented on all MV networks. The WSAM device could monitor surge arresters but also other types of MV components like transformers or composite insulators. Enedis is currently analyses this different use cases.

REFERENCES

[1] https://www.enedis.fr/english
[2] https://www.sicame.com/en/
[3] B. Puluhen et al., 2015, "Concept Grid : A new test platform for Smart Grid Systems. General presentation and experiments", Proceedings *CIRED 2015*.