SIEMENS FAULT COLLECTOR GATEWAY TEST ON LE "SANDBOX" – THE FIRST OPEN NATIONAL ENERGY SANDBOX IN EUROPE

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ABSTRACT

The energy industry is rapidly changing from centralised and conventional power system to decentralised and renewable power system. These changes requires the integration of innovative technological and operational solutions which could ensure the network and energy supply stability, energy security, and public interest. However, under current regulation and internal industry companies' procedures it is difficult to test new technologies in real world conditions.

In this paper we present the first Lithuanian open energy sandbox, called LE Sandbox, which provides the innovative technology developers an easy and open access to the gas and electricity production, distribution and supply infrastructure and data. In addition, the paper include the results of the first proof-of-concept "SIEMENS" SICAM Fault Collector Getaway pilot project developed under the LE Sandbox framework. The paper presents the benefits and findings of real environment testing as well as the growing market need for the open access to the energy infrastructure and data.

INTRODUCTION

During the last decade energy industry is facing the challenges of rapid change from centralised and conventional power system to decentralised and renewable power system [1]. The new operational models are not only limited with new demands for reduction of emissions, but additionally must increase the energy efficiency, security of supply, market transparency and access for consumers and third parties to the energy market and data.

The rapid changes of the energy industry all around the globe requires innovative technological and operational solutions and their application in the energy field in order to satisfy the demands listed above. However, the energy industry at the same time is highly regulated and many of the licences, procedures and legislative instruments have not kept pace.

Due to this reason, the innovators are facing barriers to accessing the energy industry infrastructure as well as testing new products and business models which could change the way energy markets works. To overcome these barriers the National Regulatory Authorities in Singapore and United Kingdom have initiated the Regulatory sandboxes in 2017 [2, 3] while the Haystax Technology, following the success of its Digital Sandbox KC in cooperation with GXP Investments have started their private energy sandbox initiative in USA from 2016 [4].

As the rule, the sandbox refers to an isolated non-live IT system artificial environment which can be used to test new code or inputs and observe the effects without impacting the live environment. The concept there later well adapted in baking and financial sector [5].

However, the energy industry has limited possibilities and use cases for testing innovations in artificial and closed IT environment, hence the energy sector sandboxes are different and allows testing with actual customers and infrastructure in a live environment under the limited set of conditions. In this paper we want to present the opening and one of the first use of the newly initiated "Lietuvos Energija" (further – LE) sandbox in Lithuania where "SIEMENS" SICAM Fault Collector Getaway (FCG) was applied and tested on the first open national distribution network in Europe together with cloud based application "Fault Localization in the Cloud" for fault visualization not only on desktop computers or laptops but also on mobile devices.

LE ENERGY SANDBOX

The energy sandbox project was initiated in February of 2018 by the Lithuanian electricity and gas distribution network operator "Energijos Skirstymo Operatorius", which rapidly grew up to LE Sandbox [6]. In the LE Sandbox, the group of energy companies provides free access to the infrastructure and data it manages. This enables programme participants to test new technology solutions in real-life conditions.

As we know it is the world's first and largest open energy infrastructure and data sandbox at the moment as it opens a possible to have free access to the entire Lithuanian electric and gas distribution network, electricity production units and supply companies for technology testing and development. Indeed, the LE Sandbox opens the possibility to access LE energy companies, which provides energy to almost 2 million consumers and are covering the all energy value chain, ranging from power generation from thermal, hydro and renewable power plants, trade and supply in wholesale and retail markets, to the management of electricity and gas distribution systems in the area of about 65.3 thousand. km² and other activities.

The LE Sandbox project is open to any company, technology startup, university or science centre which is involved in the design and development of innovative solutions for the energy sector.

Collaboration within the scope of the LE Sandbox is purely non-commercial – in other words, participating technology companies will not be financially rewarded for their role as well as charged for the usage of the infrastructure, LE experts' consultations or data. Where a connection to infrastructure is required, LE's specialists in cooperation with the applicant will determine an optimal testing location in Lithuania.

The applicant of LE Sandbox will also remain the owner of the objects of intellectual property rights created on the grounds of LE Sandbox, including those that were developed, discovered or created by fully or partially using the infrastructure, resources, information and / or data provided by the LE. The relationship is driven, rather, by common interests and valuable knowledge exchange, including possibilities to:

- explore opportunities for the adoption of technology in the energy and utility sectors;
- obtain a reference from the energy vertical;
- work and exchange expertise with highly experienced energy professionals;
- analyse the applicability of a technology in a real-world production environment and business setting;
- provide a working proof-of-concept for further business development and collaboration opportunities;
- present technology testing and development results.

Successful innovations can pursue further collaboration with LE through our Open Funding and other initiatives supporting further development and market entrance of the innovative technologies.

From the opening of the LE Sandbox and till the end of 2018, more than 20 applications were received from technology companies, start-ups, universities and research groups, most of which have already initiated or are on the way to start their pilot projects in LE Sandbox. The rapid growth of the applicants shows the feasibility and necessity of open infrastructure projects which allows freely apply and test the innovative solutions in the energy field. The companies not only from Lithuania, but also UK, Germany, Norway, Finland, Poland, USA, South Korea and other countries have showed their interest and applied for testing their new technologies in the LE Sandbox.

The further development of the LE Sandbox with high initiative is continued by the Ministry of Energy of Lithuania. In December of 2018, the Government of the Lithuania has approved the plans to develop the Regulator sandbox, which will create an environment where existing regulations can be relaxed to promote innovation development and adoption in Lithuania energy sector, before 2020.

THE FIRST LE SANDBOX APPLICATION

SIEMENS was the first company which applied and tested their pilot earth faults and short circuits indication technology on LE Sandbox. Figure 1 (left) shows the communication diagram and generalized usage scheme of the SIEMENS SICAM Fault Sensor Indicator (further – FSI) and SICAM Fault Collector Gateway (further – FCG). We can see that in addition to local LED display on the fault sensors, the earth faults and short circuit indications from SICAM FSI sensors are transferred to a SICAM FCG via a secured short-range radio connection. In turn the SICAM FCG establishes the connection to a higher-level control center via GPRS using the standardized communications protocol IEC 60870-5-104. In addition, the SICAM FCG can also send SMS directly to a field service engineer's mobile phone to attend the situation faster locally. Alternatively, the SICAM FCG can also communicate to the SIEMENS "Fault Localization in the Cloud" application using the Extensible Messaging and Presence Protocol (XMPP) and the faults can be visualized in the Fault Localization in the Cloud application, for example on a smartphone, see Figure 1 (right).

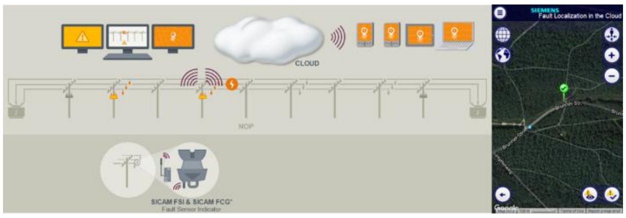


Figure 1. Simplified SIEMENS SICAM FCG and SICAM FSI usage scheme (left) and the Fault Localization in the Cloud user interface mobile device view (right)

SICAM FCG testing aims and pilot set-up

For the application and test of the SICAM FCG on the LE Sandbox environment three different sites for installation were selected in Lithuania medium voltage distribution network. During the test, the SICAM FCG was connected to SENTINEL-D-AÉRIEN French-made fault detection sensor. SICAM FCG collects fault information from the SENTINEL sensor and sends it to the Fault Localization in the Cloud (see Figure 2).

Figure 2. Test installation with third-party fault detection sensor Sentinel-D-Aérien

Moreover, the SENTINEL-D-AÉRIEN sensor is designed for operation on 15 to 25 kV power lines. For this pilot, the sensor was reconfigured to work with 10 kV power lines.

The fault sensor SENTINEL-D-AÉRIEN permanently measures the electromagnetic field generated by the overhead line (further – OHL). The parameters, such as type, height and geometry of the pole and also the voltage level of the line have to be configured. Power supply is enabled by the buffer battery of the system. Although the sensor's consumption is only 2 mA in idle mode and 60 mA in signalization mode, this is a constant drain of the battery. It has to be considered for the total power consumption of the system and also later on for alternative power supplies, e.g. using the sensor version with built-in buffer battery. The sensor recognizes following types of faults: earth faults (mono-phase) and phase-to-phase-faults (poly-phase). It signalizes faults by flashing LEDs (red/green) and simultaneously switching dry-contacted binary outputs.

For our use case, we connected the sensor's binary outputs to our SICAM FCG gateways binary inputs. Since the sensor can indicate the direction of the fault in respect to the direction of the substation and the mounting direction on the pole, we use the binary output related to the optical signal (red/green) to simulate also the fault direction on the cloud-service web user interface (further – WebUI). Therefore we place the geographical map indicator of the sensors in the corresponding direction: red for veering away from the substation, green for approaching the substation.

Under such set-up, the pilot has for different testing aims:

- Aim 1 – is to make a proof-of-concept that the SICAM FCG can work with third-party fault detection sensors.
- Aim 2 – is to check if it is enough to reconfigure the SENTINEL-D-AÉRIEN sensors in order to work with lower voltages than initially designed.
- Aim 3 – is to prove that SICAM FCG can operate in other countries with the SIM card of German mobile operator, under the usage of the new EU mobile roaming directives.
- Aim 4 – is to test the cabinet solution of the SICAM FCG enclosure and solar power supply in the environmental, seasonal and lighting conditions of northeastern Europe.

The investigation and results

Aim 1 - 3rd party Sensors on SICAM FCG

We have simulated fault messages by executing the self-test procedure of the fault sensors. These fault messages as well as status messages of the gateways/sensors were clearly displayed in the cloud-service WebUI. This proves, that we generally can connect third party fault collection sensors with binary output to our SICAM FCG and display occurring events in the WebUI. By using auxiliary relays and DC/DC converters, we also can connect fault sensors, whose output voltage do not fit to the input voltage of the SICAM FCG binary inputs.

Aim 2 – Sensor configuration / setup

With the currently chosen configuration and setup of the fault sensor and the mounting position on the pole, we did not detect faults on the 10 kV OHL during the functional period of the gateways/sensors, because no faults occurred on the particular line during this period. We have observed in other environments, that faults on OHL generally occur more often in fall/winter time.

Thus, one of the next steps in the pilot project will be to have intentionally issued faults on the OHL and observe the behavior of the respective fault sensor. In that term, we will also adjust to mounting position of the sensor on the pole, to consider the ratio of expected voltage level to actual voltage level.

Aim 3 - Fault Localization in the Cloud (cloud-service)

The cloud-service WebUI is a browser-based application capable of running on several device types: smart phones, tablets, laptops and desktop computers. Thus making it available for service teams in the field or operators in the substations or control centers.

The SICAM FCG gateway communicates the connection status into the cloud-service. If the gateway is offline for any reason, e.g. power supply failure, communication failure, or even theft, then an indication will be issued, that the connected sensors have not sent the "alive" signal. Our indication for the functional period of the battery is the last time, where the gateways have forwarded the alive signal to the cloud-service on the one hand. On the other hand, also the evaluation of the connection status of the respective SIM card in the carrier's maintenance portal can give an indication of the functional period of the gateways.

Mobile network Coverage in rural areas

The SICAM FCG has a built-in GPRS (2G) modem for communication to either a SCADA system (IEC 60870-5-104) or the cloud-based service "Fault Localization in the Cloud". We wanted to test, how reliable the GPRS coverage in rural areas still is, taking the fact into account that many carriers already start reforming their GPRS networks in advantage of the UMTS/LTE (3G/4G) technology. In the US, for example, only T-Mobile US is still offering GPRS connectivity for M2M/IoT use cases on a long-term basis.

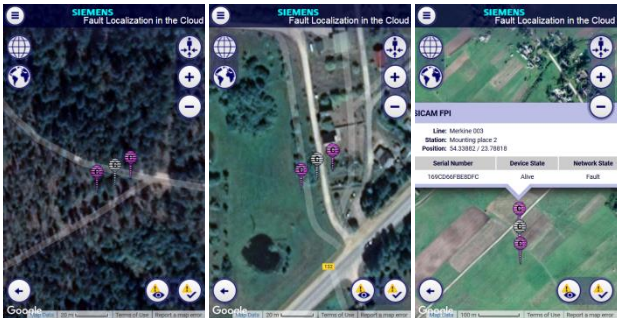
Some operators are reforming the freed frequencies for other (new) types of radio networks, such as Narrowband-IoT.

Roaming behaviour results

The SIM cards used in our case, are generally enabled for worldwide roaming by our supplying carrier Vodafone. For connecting to the local mobile network in the installation area of the sensors and gateway, a roamed

connection would be established primarily to the preferred roaming partner of Vodafone in the respective country/area. In the EU, to our knowledge, permanent roaming of M2M and IoT devices is not explicitly prohibited. We make use of this directive, by supplying SIM cards issued in Germany. In Brazil and Singapore for example, a permanent roaming is prohibited by the respective regulatory authority [7].
We have observed that the SIM cards were accepted by the Lithuanian mobile network operators and the roaming connection was established automatically without connection rejects. It was not necessary, to manually set a certain network provider in the SICAM FCG.

Aim 4 – Mounting places of the Sensors and Gateways
The equipment was installed in Southern part of Lithuania in winter time (February 2018) to simulate harsh environmental conditions. From our experience, OHL often suffer outages in winter time, due to ice on the conductors, damages by vegetation, e.g. fallen trees or branches. We have chosen different types of areas for the mounting places (see Figure 3).



54.118484 24.193798 | 54.333073 23.944674 | 54.338300 23.788411

Figure 3. The equipment installations with GPS coordinates at forest (left), mixed buildings/trees (middle) and free field (right) type areas in Lithuania.

Power Supply of the Gateway Enclosure
The Photovoltaic Panel has been chosen as power supply for the SICAM FCG gateway and the Fault Sensors. The main reason for this choice is that the installation can be done on a live-wire, the OHL does not necessarily have to be shut down. Whereas Voltage Transformers (further – VT) would normally have to be installed on a non-conducting line. Also, in terms of hardware cost, the photovoltaics (further – PV) panel is considered to have a lower price than a VT or an energy harvesting appliance.

Power Supply by PV panel results
PV panels do not fit for every mounting area. In northern parts of Europe, where in winter the sun hangs very low also during daytime, shadows of trees or buildings influence the recharging of the buffer battery significantly. We were aware of this fact before installation; however wanted to test the effectiveness of the PV panel power supply.
Equipment mounted in rural areas with free line of sight might still be equipped with PV panels. The specs might have to be adjusted (size / rated power) according to the expected light conditions. We have seen, that the buffer battery of the installation in mounting of free field (see Figure 3) has survived until mid of November 2018. This indicates, that the lighting conditions in free field areas might be suitable for PV panel power supply.
Equipment, which was installed in forest areas, where the tree shadows fall on the PV panel in wintertime also during the day should be rather equipped with VTs or energy harvesting appliances. The buffer battery of the installation in the forest area mounting place 1 has not survived the previous winter time (end of March 2018).
In mixed buildings/trees areas (see Figure 3) the choice of power supply should be decided upon the actual lighting conditions of the respective mounting place. We have seen, that the buffer battery of our installation in the mixed area must have been charged from time to time by the PV panel until mid-October 2018, where lighting conditions were unsuitable for charging by PV panel.

Tasks for further development

Following up our pilot project, the next steps would be, to intentionally issue “real” faults (e.g. short-circuits) on a OHL by the operator, to check the behavior of the sensors in environments where the voltage level does not fit to the configurable levels.
We will also test alternative power supply sources by adding VTs instead of PV panels, considering also an additional power supply unit, or adding energy harvesting appliances (on live wires) considering power caps as backup for completing the fault indication procedure by the SICAM FCG.
A new approach would be to use sensors which monitor also the conductor condition, e.g. the temperature relation of environment and conductor and indication of ice on the OHL.

CONCLUSIONS

The rapid growth of the applicants submitted to LE Sandbox from all around the globe shows the lack of available open access to energy infrastructure for the innovative solutions developers. Since not all applications can be performed under current regulation, the infrastructure sandbox should be connected with regulatory sandbox.
During the first application of LE Sandbox, we have proven that the overall concept of “Fault Localization in the Cloud” with the used hardware and gateway is working as expected. From the hardware installation and configuration up to the status message display in the cloud-service. However, the “one-size-fits-all” approach for the gateway enclosure hardware does not fulfil. For different areas, different hardware configurations should be used. We will refine our hardware portfolio

considering even more the geographical and communication-related environments of interested customers.

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