EXPERIMENTAL MICROGRID WITH IEC 61850 STANDARD

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ABSTRACT

EDF R&D has undertaken various activities in the field of microgrids. Most recently, EDF R&D carried out new tests on its experimental lab "Concept Grid" with the purpose of testing internally developed solutions of ***DERMS (Distributed Energy Resource Management System) relying on IEC 61850 standard for piloting a microgrid****.*

INTRODUCTION

Local energy systems including microgrids are becoming a key component of the distribution network of the 21st century. In this way, microgrids or local grids are not seen any more simply as a set of load and generation with the capability to island during outages, but they are now considered as an integral part of the power grid, interacting with the distribution system operations through advanced control and distribution management systems.

In this context, EDF R&D has been working for many years now to develop methods and tools for the Smart Grid industrial digital transition. A specific field of research has focused on the standardisation of exchanges, data models, pivot format and interoperability of smart grid equipment.
More recently, EDF R&D conducted some experiment to demonstrate the application of the **IEC 61850 communication standard to retrieve data from microgrid assets and feed various algorithms**, in order to efficiently manage the microgrid and improve the system flexibility to help the DSO in maintaining a safe and reliable power grid.

The experiment made use of an **IEC 61850 interface** called "eDER" to transmit control signals to the different DERs onsite and provide the grid operators with relevant data through its SCADA system ("eSCADA"), which was also based on IEC 61850.

The testing configuration comprised a diesel genset, a battery energy storage system, controllable and non-controllable loads, PV generators and power amplifiers connected to a subpart of EDF experimental grid (fig. 1).

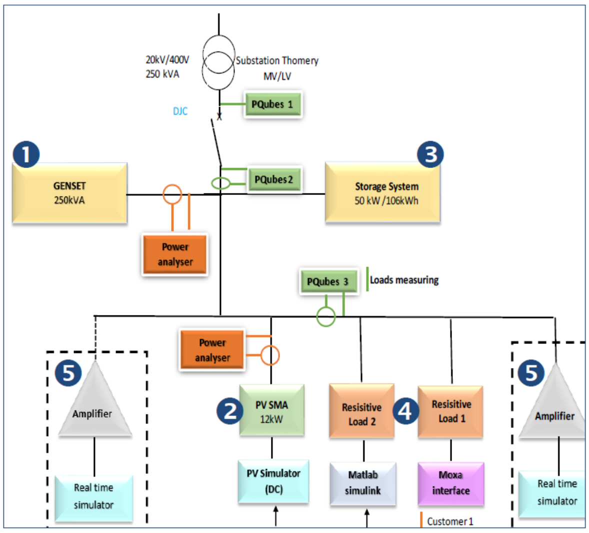

Figure 1 – Overview of the microgrid used infrastructure

IEC 61850 TO OPERATE MICROGRID

EDF's strategy based on standardization uses the IEC 61850 to ensure the interoperability of its systems and therefore fit most of the manufacturers.

EDF challenged its eDER solution by experimenting it in a microgrid infrastructure.
Microgrid represents smaller geographically systems.
Being small means that:

- Demand is less predictable,
- Supply from renewable energy sources is more variable, as the large percentage of the renewable energy generators are likely to be affected by the same weather events.

Due to their reduced demand predictability and increased variability of renewable energy supply, generation scheduling in microgrids is more challenging.

The experiment was carried out on a **testing facility** located in the EDF R&D research center based in Les Renardières (France). Named "Concept Grid", this platform is a is a full-scale smart grid test facility designed to anticipate and facilitate the transition from electricity distribution systems to smart grids.
Built as a closed circuit, but representing real power distribution grids, Concept Grid makes it possible to conduct a full range of grid optimisation scenarios in complete safety.

USE CASES & TEST RESULTS

During the study, tests on the eDER interface were carried out using different microgrid configurations and control strategies with the following objectives:

- Optimize energy spending and operating expenses based on optimal power curve calculation at PCC and taking into account electricity price curve forecast for the next day, and on-site load & generation forecast; goal is to derive the maximum possible benefit from local microgrid flexibilities based on changing price of electricity depending on the time of day and to reduce demand charges of electricity bill by controlling the power at PCC;
- Participate in Demand Response programs to maximize revenues by piloting microgrid resources to reduce or shift the electricity usage during peak periods in response to time-based rates or other forms of economic incentives;
- Frequency regulation: provide fast Frequency Regulation as an ancillary service;
- Islanding: provide islanding/re-sync capability to ensure backup power supply in case of main grid failure; two islanding modes were tested: programmed islanding and unforeseen islanding.
- Demonstrate a Virtual Power Plant between the site of Concept Grid and a PV plant in Narbonne, Southern France.

Testing under the grid-connected mode

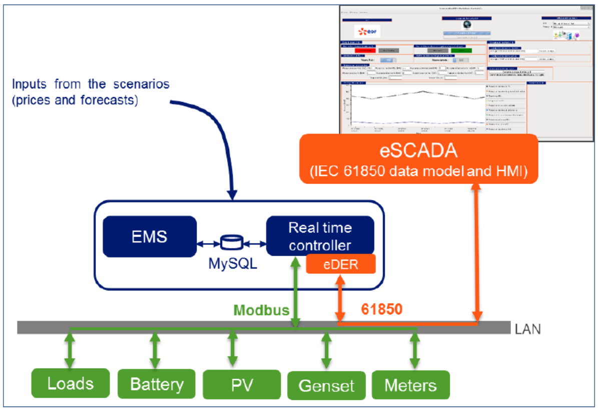

Figure 2 - Microgrid infrastructure for the grid-connected mode

Under this mode, experimentations aimed to test flexibility Use Cases such as:

Use Case 1	Use Case 2	Use Case 3
Optimizing the activation of energy resources according to energy prices	Optimizing the energy production and load to prevent the peak periods of times	Test the participation in demand-response and the frequency regulation…

To do so, the following smart solutions were used:

The couple eDER / real time controller

- The IEC 61850 interface "eDER" was connected to the eSCADA and integrated into a real time controller solution (not based on IEC 61850).
- **The couple eDER / real time controller manages the data exchange with DERs** such as: track the power; track the frequency-voltage values; or run the storage management and electro-technical algorithms before deciding the optimal set points of energy resource's activation.

EMS (Energy Management System)

- The EMS supports the "scheduler", which manages **multi-energy systems**: it gets inputs such as electricity production, access to the PV and Genset systems and considers constraints such as costs, maximum number of Genset activation, etc.
- The EMS delivers the amount of electricity to be sold, the optimum load to maintain and defines set points for the subsystems.
- The eSCADA allowed us to supervise and control the flexibility use cases: Active and reactive power curves; Frequency / voltage curves ; Battery power generation curve ; Grid status (connected, islanded….).

Testing under the islanding mode

To switch to the islanding mode, the experimentation provokes an MV (medium voltage) default. To power back the grid, a Genset and/ or the BESS were used (fig. 2).

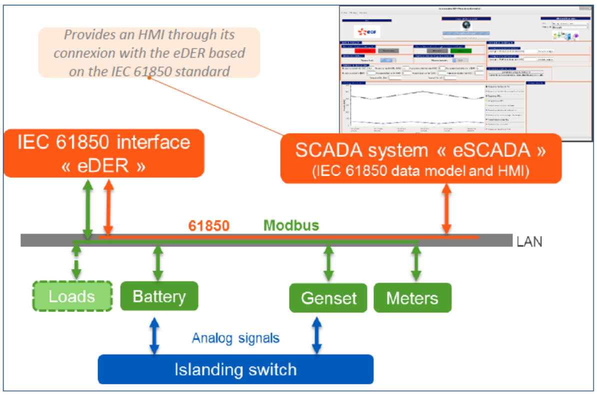

Figure 3 – Microgrid infrastructure for the islanding mode

Overview of the results per Use Case under this mode:

Use cases	Constraints identified	Key facts
Use case 1 **Genset only**	Synchro-coupling function in Genset for resynchronization after islanding	
Use case 2 **Genset + BESS**	V/f regulation on BESS system Need for protection and stability studies	Reduction of time needed to bring power back to the loads thanks to BESS
Use case 3 **BESS only**	Need for a protection plan study V/f regulation on BESS system	No power cut, offers the possibility to power the microgrid without using the genset

During the experimentation, the eDER converted successfully the IEC 61850 protocol into the ModBus to communicate with the energy resources (Genset/ BESS). The eDER took the control of the system by performing not only the supply management but also the load management powered by its connection with the eSCADA (load shedding) and the immediate execution of the control signals.

Testing Virtual Power Plant with remote DERs

A last use case aimed at testing the feasibility of coordinating distant DERs within a Virtual Power Plant (VPP).
For this scenario, the local Concept Grid microgrid was associated with remote PV panels in Narbonne, Southern France.
The purpose of this use case was to demonstrate the capability of the VPP to maximize the PV generation in Narbonne site relying on the battery storage installed at Concept Grid which is 1 hour south of Paris.

Figure 4: Microgrid & VPP demonstrator

DISCUSSION

Scheduling in microgrids was challenging due to the low demand predictability and high variability of renewable energy supply in small power systems.

- Using the BESS, the eSCADA allows a great management performance when powering-back the grid with **no outage time** and without using the Genset, which leads to fuel saving, CO2 emissions reduction and optimization of the generator's life time.
- The couple **eDER / real time controller showed a strong complementarity** facing the smart grid and flexibility challenges: optimization, forecast and storage management. Algorithm of the real time controller met perfectly the communication standards, cybersecurity elements and electro-technical algorithms of the eDER.
- IEC 61850 makes it possible to implement cybersecured communications between equipment as it was designed in full compliance with the ad hoc standard for cybersecurity IEC 62351. Cybersecurity is one of the top priorities for microgrids as it aims at guaranteeing the data integrity of the microgrid system safe operation.

CONCLUSION

The experimentation proved that IEC 61850 interface is an **adequate solution to provide real-time information** to the DSO, providing him the opportunity to react quickly to the supply and demand management (more flexibility).

- The grid-connected test showed that the IEC 61850 interface allows the DSO to optimize the power production of its DER according to the market signals and prices, as well as improve its time-reaction to the DER unpredictable load.
- The islanding test showed that the eDER could successfully communicate with ModBus to address real time set point to the grid.

We recommend next generation of the Genset and BESS manufacturers to start using the IEC 61850 for the following advantages:

- **Using standardized data model built for electrical grids**
- **Using standards for the IED configuration language**
- **Using standardized set of services for exchanges between IED**

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