IEC 61850 TO THE SERVICE OF POWER SYSTEM FLEXIBILITY

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ABSTRACT

Integration of Distributed Energy Resources (DER) on the MV and LV networks is increasing significantly. The shares of variable renewable energy sources become gradually important.

The irregular production of DER that are mainly connected to the distribution grid, along with fast variations in supply and demand, challenges the Distribution System Operator (DSO)'s missions to maintain a continuous service. This situation leads the DSO to seek for more flexibility to ensure a reliable operation enabling a very high penetration of renewable energy sources. Besides, flexibility is one of the ways to answer to Grid Code prescriptions.

The eDER solution is a communication interface between the DER producer and the DSO control center. Its communication protocol and data model follow the IEC 61850 standard which allows a fast and effective communication level between the DER producer and the DSO.
By implementing the eDER, the DSO can get real-time information about DER production such as active / reactive power and voltage value.

This eDER can integrate advanced functions such as forecasting, active / reactive power and voltage regulation. Having these functions makes the eDER ready to be integrated into microgrid systems and not only be managed by the DSO.

Considering the growing number of energy actors such as DSO, TSO, aggregators, markets… the eDER runs under "IEC 61850 standardized framework" which makes it interoperable and suited to main manufacturers.
The information exchanges inside the DER and between the DER and TSO/ DSO are protected by a cyber-secured framework.

The eDER interface can lead to significant cost savings for the power system since DER operations can be optimized and operated in a smart way.
The provided flexibility allows more participation in the demand-response markets too.

This paper will concentrate on the power network flexibility services allowed by IEC 61850 technology ***improving interface between DSO and DER.***

INTRODUCTION

Need for flexibility in the power system

Flexibility is the ability of a power system to maintain continuous service in the face of rapid and large swings in supply or demand. Traditionally, flexibility was provided in power systems almost entirely by controlling the supply side. **In systems with increasing shares of renewable energy sources, additional flexibility is needed to maintain system reliability as the variations in supply and demand grow to levels far beyond what is seen today** [1].

The DSO are seeking for this flexibility to follow their commitment of maintaining a safe and a reliable power grid. Moreover, for the near future, DSO will need to follow the Grid Code and so, follow the TSO instructions by adapting regularly its system.
Beyond that, grid operators as the French DSO, witness a notable increase of the renewable energy installed capacity with more than 80% since 2015 [2] (only from PV (photovoltaic) and wind energy).

Need for real-time grid information

Traditional power generations base their supply program on forecast data. This affects their production when the real-time demand does not match with the forecast.

Moreover, the renewable energy investments are fully encouraged by many organisations and the government, which leads to a notable penetration of these sources in the grid.
These renewables resources can be supported by storage system to increase their capacity to absorb the grid load fluctuation.
Unfortunately, the two most abundant energy sources – wind and solar – incurs significant stability and reliability issues due to the intermittency of those sources.

The DSO need to perform a fast response toward these load fluctuation and the inherent stochastic nature of the renewable energy.

The grid operations must be based on **the real time system status.** [3]

IEC 61850 TO IMPROVE THE POWER SYSTEM FLEXIBILITY

To meet the DSO needs for getting the real time system status, our researches were conducted in order to improve the observability of the grid system. This observability provides more control on the load fluctuation to the DSO.

IEC 61850 to improve the observability

EDF's strategy based on standardization uses the IEC 61850 to ensure the interoperability of its systems and therefore fit most of the manufacturers.
That is why EDF developed an interface to connect the producer and the DSO using the standard IEC 61850. [4] provides more information about this solution.
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 microgrid experimentation with the IEC 61850 interface

The microgrid operates in grid-connected mode, but, when a fault occurs in the upstream grid, it should disconnect and shift into islanded operation mode.
To achieve these management goals appropriately, the coordinated control strategy between Genset, PV, BESS *(Battery Energy Storage System)* and loads is needed.

The experiment of a microgrid infrastructure runs under the Concept Grid[1] platform and aims to test how the IEC 61850 interface successfully enables these management goals and improves the demand-response management of the grid.

Short presentation of the microgrid infrastructure

The microgrid infrastructure was represented using the following equipment:

- Genset, PV farm as the two energy resources
- Battery for the storage system
- Loads
- Amplifier

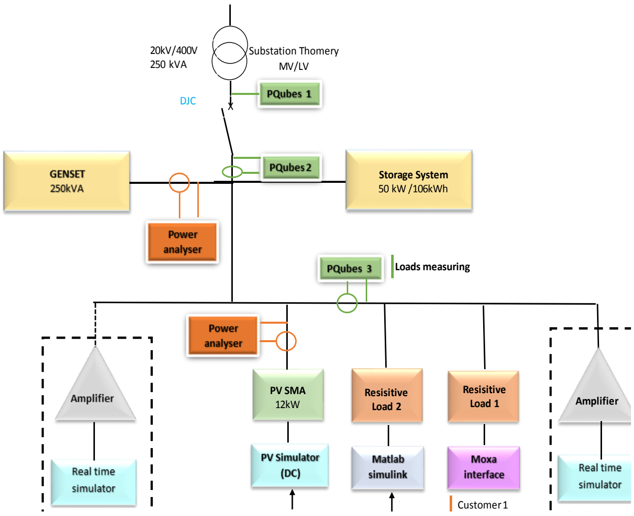

Illustration 1: microgrid infrastructure

Testing the IEC 61850 interface for microgrid under the islanding mode

To switch to the islanding mode, the experimentation fakes an HV fault. To power back the grid, Genset and/ or the BESS were used.

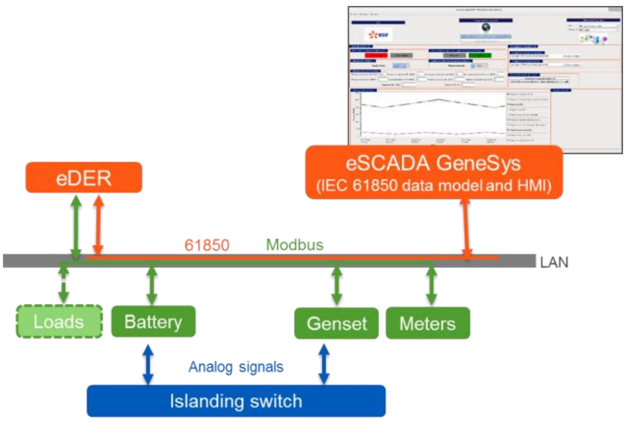

*Illustration 2: Microgrid infrastructure for **the islanding Mode***

Three use cases were run under this mode. The first one uses only the existing Genset, the second one uses the couple Genset-BESS and the third one uses only the BESS.

1 Concept Grid is an EDF laboratory including notably LV / HV distribution assets and various pieces of equipment undergoing tests in normal or abusive conditions.

Here's a summary of the results:

Power Back	**Constraints identified**	**Key facts**
Using Genset only	Synchro-coupling function in Genset for resynchronization after islanding	
Using Genset and the BESS	-V/f regulation on BESS system - **Necessary protection and stability studies**	Reduction of the time needed to bring power back to loads thanks to BESS
Using the BESS only	**-Necessity to study the network protection plan** - V/f regulation on BESS system - Necessary protection and stability studies	**-No power cut,** offers the possibility to power the Microgrid without the Genset

The eSCADA provides an HMI through its connexion with the eDER based on the IEC 61850.

This eDER converts successfully the IEC 61850 protocol into the ModBus to communicate with the energy resources (Genset / BESS).

Using the BESS, the eSCADA allows a great management performance when powering-back the grid with no outage time and no need to use Genset: fuel saving, emissions reduction and optimization of the generator life time.

During the islanding Mode, the eDER took the control of the system by performing not only the supply management but also the load management powered by its connexion with the eSCADA (*eSCADA sends some set points for the load generation to reduce instantly their consumption (load shedding)).*

- ⇨ This experimentation opens the possibility for the IEC 61850 to perform not only the supply management but also the demand management.
- ⇨ The eDER becomes a demand-response tool

Testing the IEC 61850 interface for Microgrid under the grid-connected mode

This experimentation tests flexibility use cases such as:

- Optimizing the activation of energy resources according to energy prices (*the production cost should fit the current market price)*
- Optimizing the energy production and load to prevent the peak periods of times
- Test the participation in demand-response and the frequency regulation

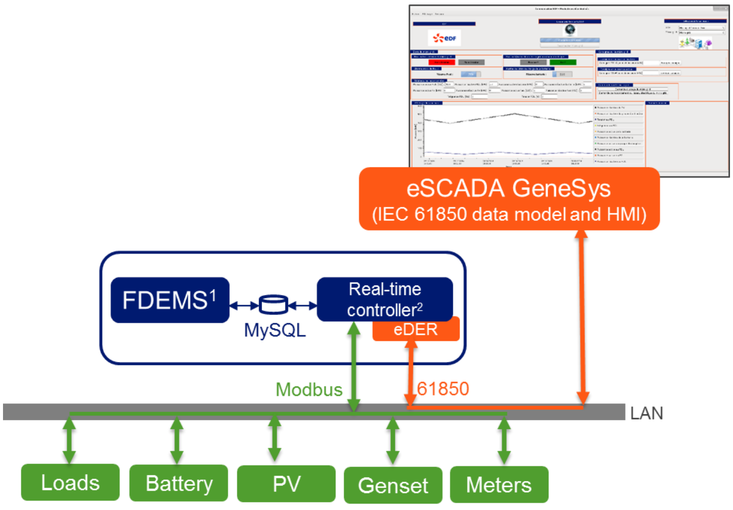

*Illustration 3: Microgrid infrastructure for **the grid-connected Mode***

[1] FDEMS (Facilities DER energy management systems) is the PILOT system developed by EDF.

[2] The real-time controller is the PEGASE system developed by Store & Forecast *(EDF's spin-off company).*

To perform the flexibility use cases above, the following smart solutions were used:

The couple eDER-PMS

The IEC 61850 interface, eDER, was connected to the eSCADA and integrated into the PEGASE.

The eDER and PEGASE show a strong complementarity facing the smart grid and flexibility challenges: optimization, forecast and storage management algorithms from Store & Forecast **meets perfectly** the communication standards, cybersecurity elements and electro-technical algorithms from the eDER.

The couple eDER-PEGASE represents **the real time controller** by managing the data exchange with DER.

The eDER-PMS operations:

- Track the power
- Track the frequency-voltage values
- Run the storage management and electro-technical algorithms before deciding the optimal set points of energy resource's activation.

PILOT tool

The PILOT tool supports the "scheduler" for 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 PILOT tool delivers the amount of electricity to be sold, the optimum state of load and defines set points for the subsystems.

EMS

The EMS, the Energy Management System compiles data from the eDER-PMS, the PILOT tool and the market.

The eSCADA allowed us to supervise the results of our flexibility use cases (Illustration 4):

- active and reactive power curves,
- frequency / voltage curves
- Battery power generation curve
- Grid status (connected, islanded….)

CONCLUSION

The experimentations proved that IEC 61850 is an adequate solution to provide real time information to the DSO, allowing him to perform a fast supply and demand management.

The conclusion of **the grid-connected test** is that the IEC 61850 interface allows the DSO to:

- Optimize the power production of its DER according to the market signals and prices.
- Improve its reaction to the DER unpredictable load.

The conclusion of **the islanding test** is 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 manufactures to start using the IEC 61850 for the following reasons:

- Standardized IED configuration language
- Standardized set of services for exchanges between IED
- Standardized data model built for electrical grids

REFERENCES

[1] Project number: POWDE14426, By Dr. Georgios Papaefthymiou, Katharina Grave, Ken Dragoon Date: 10 March 2014

[2]Data from RTE (French TSO) (http://clients.rte-france.com/lang/fr/clients_producteurs/vie/prod/parc_reference.jsp)

2016 Wind and Solar power capacity installed: 396,6 MW + 1426 MW
2015 Wind and Solar power capacity installed: 39 MW + 357 MW

[3] CIGRE 2016 – paper C6-302

[4] T. Coste, O. Carré, Li Peng, 2016, "DSO interacting with heterogeneous DER in distribution grid" C*IRED 2016*, Helsinki, Paper 0325

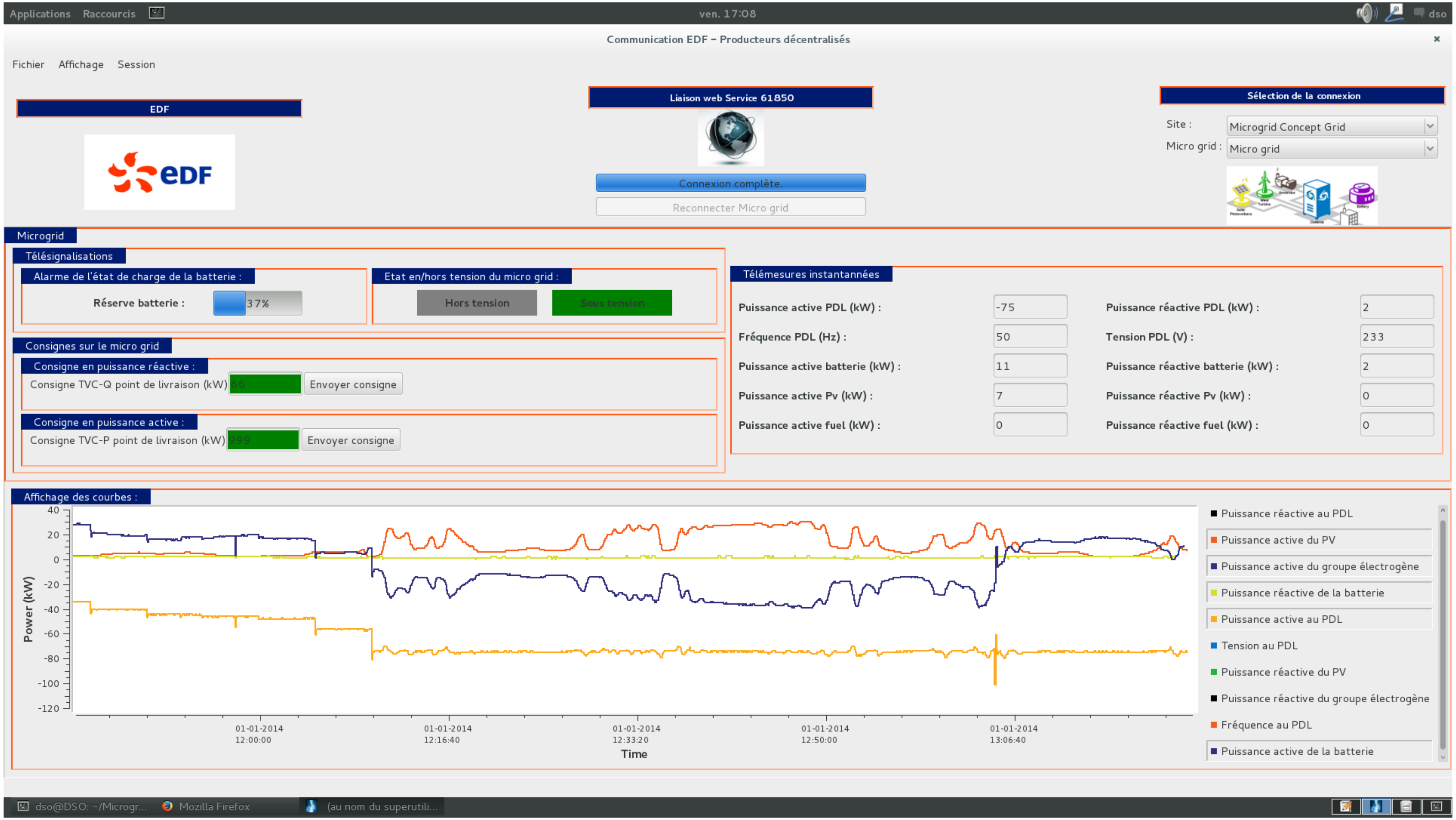

Figure 4: eSCADA HMI of the microgrid system under the grid-connected mode