USING AMI FOR NETWORK MONITORING AND CONTROL: NEW EQUIPMENT AS A STEP TOWARDS A SMART GRID IMPLEMENTATION

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ABSTRACT

ERDF (EDF Group's Distribution Subsidiary) has launched two significant projects to pave the way for a Smart Grid implementation on the French distribution grid. The first one is the "Linky" project with the goal to design and test an AMM system in a pilot field of 300 000 meters before a wider rollout. The second one is the so-called "Linky-Network" project, with the following goals:

- *Combine the use of the AMI (Advanced Metering Infrastructure) for the grid operation and the needs of metering in order to improve the distribution network monitoring and control;*
- *Take advantage of the collected AMM data to optimise network development and operating costs (optimise losses), power quality (by reducing outage time, optimise voltage drops) and asset management.*

To address these goals, the Linky-Network project includes on-field demonstrations in order to assess the opportunities of using AMI to improve fault location and supply restoration, but also enhance network and substation observability (monitoring and sensing functionalities).

The key issue addressed here is to design the technical architecture that will be used on the field, during the pilot phase, to demonstrate the functionalities described above. The paper will also detail what kind of technical solutions would be valuable and efficient in order to deploy these functionalities, after the pilot experience feedback in a rollout perspective. Keeping in mind that the development of new AMI solutions could impact them but also offer new perspectives.

INTRODUCTION

EDF's Distribution Subsidiary (ERDF) has installed nearly 300000 meters and 5000 data concentrators in order to evaluate the latest AMM technologies. Right after this AMM pilot deployment, a national rollout should start in 2011, that will end with the replacement of the 35million meters at the customers' premises.

Alongside this project, ERDF has initiated a project aiming at capitalizing on the AMM solutions in order to improve network operation, control, maintenance and development [2]. The two main objectives are to develop a set of the most valuable functionalities to be tested in conjunction with the AMM pilot deployment in Lyon and Tours in 2010 and to launch an analysis on some innovative functionalities that could be implemented in a longer-term rollout perspective.

THE LINKY-NETWORK PROJECT

A full Smartgrid project

As presented in SmartGrids Europe 2009 in Barcelona [1], the Linky-Network project breaks down in seven work packages:

- WP1: Geographical Information System data exchanges
- WP2: MV Network control and SCADA
- WP3: LV supervision and Outage Management
- WP4: Network Development
- WP5: Quality of Power Supply
- WP6: Replacement of the 175Hz PLC used to send tariff signals
- WP7: Smart Secondary Substation

All these work packages illustrate how to combine the use of the AMI for the grid operation and the needs of metering in order to improve the distribution network monitoring and control and also take advantage of the collected AMM data to optimise network development and operating costs (optimise losses), power quality (by reducing outage time, optimise voltage drops) and asset management.

In this paper we will focus on the studies achieved especially in the scope of WP2 and WP7.

New functionalities for MV network control and SCADA

The WP2 targets three objectives, and their related functionalities, considered as strategic for the grid operator :

1. Enhance the effectiveness of MV network operation and remote control. The functionalities involved are:
   a. Sending signalisations coming from Fault Passage Indicators (FPIs) installed in MV to the control centre in almost real time
   b. Alarming and locating MV overhead phase breaks and categories of resistant faults by measuring LV phase triangle
2. Improve the observability of the MV/LV network, especially for the use of the next generation of DMS tools based on state estimation algorithms, by measuring currents and voltages in both voltage levels and calculating the active and reactive powers
3. Increase pro-activity for maintenance of MV/LV networks by monitoring the distribution substation with various sensors (transformers and local temperature, water level, …)

Definition of a technical architecture for the pilot

The implementation of these features for the pilot, using the AMI, implies the deployment of new equipment on the network connected to the metering data concentrator: the Intelligent Network Interface for Supervision or "INIS"[1]. As outlined in Fig. 1, the sensors are connected to the INIS by point-to-point binaries connections for the digitals or analog links for measurements. Also the INIS integrates dedicated grid functionalities using incorporated measurements for the fault detection on MV networks in order to avoid the installation of multiple devices.

The INIS is connected to the AMI (metering data concentrator) with an Ethernet interface and a standard application protocol (IEC 60870-5-104).

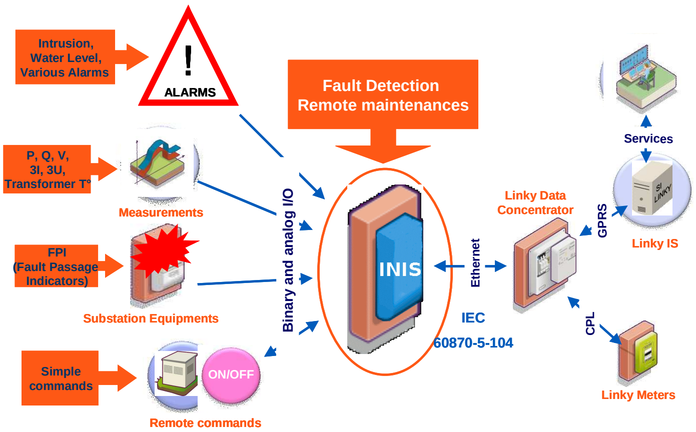


Figure 1: INIS Integration

At the WAN and Information System level, the solution will allow the establishment of an IP route on the GPRS media. This route is self-initiated if the INIS needs to send alarms that require short terms analysis. The information is directly sent to the SCADA in an IEC 60870-5-104 format.

On the opposite side, sets of web-oriented services have been defined to cover the needs of data exchanges for the work packages of the Linky-Network project (fig. 2). For the WP2 related to MV network remote control, a dedicated service allows to initiate the IP route to the final grid IS. When the route is established, the SCADA is able to communicate with the INIS using the IEC 60870-5-104 protocol in order to retrieve needed information coming from the grid (measurements, sensors, …).

One of the goal was also to use on the shelf products in order to focus the pilot only on functionalities validation and not devices experimentation. A call for tender dealing with 125 INIS for the Linky-Network pilot was launched in 2010.

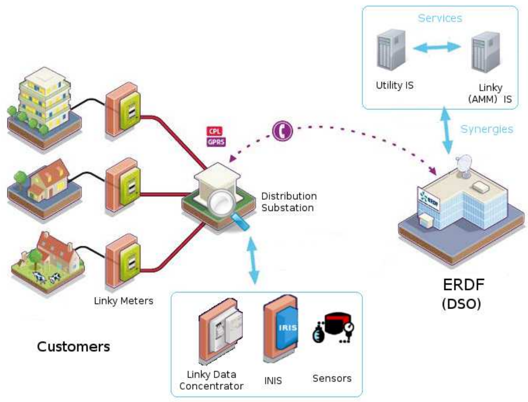


Figure 2: Overall architecture

Towards a new generations of more integrated equipments

Beyond the technical solution presented above for the pilot, the perspective of the rollout pushes to search for optimal solutions that could cover the valuable functionalities in a cost efficient way. : That's the goal of the WP7 entitled "Smart Secondary Substation".

Furthermore the arrival of new generations of Power line Communication (like PLC G3[2]), and alternative communication architectures that will result, may impact today choices for the pilot and generalization but also offer new perspectives. Further studies have been carried out in order to assess the impacts on the trajectories and synergies between AMM and grid needs.

NEW GENERATION OF EQUIPMENT

The main objective of the first six WP of the project Linky-Network is to implement and test on the field new features and to demonstrate at short term the interest/capability of taking advantage of an AMM system to optimise distribution operation, control and development.

These synergies are based on the provision of a set of services from a national information system and the deployment of an AMI. These services and infrastructure offer the opportunity to improve the instrumentation of MV and LV networks by pooling the installation equipments covering metering and grid needs in the distribution substation. The pilot Linky-Network will assess the functional contributions of such a strategy. With the target of a generalization of these functions, we have defined the general specifications of a new generation of equipment in order to optimise the architecture.

These specifications have been written by a working group including people both from metering and grid division of ERDF as well as from EDF R&D in order to clearly identify actual and future needs. EDF contributions to European projects like OpenNode[3] allowed us to share

1 The French acronym is "IRIS" : Interface Réseau Intelligente de Supervision

2 New generation of multi carriers PLC specified by ERDF

3 www.opennode.eu

the expression of needs with several major utilities.
Requirements have been classified according to their value regarding actual and long term needs (increase controllability and network automation, enhance observability in MV and LV, improve DER insertion in LV, …). As a result, the general specifications have been established to prepare implementation of prototypes.

Different needs to cover

The generic acronym used to define this equipment is "SGTU"[4] for SmartGrid Terminal Unit. The SGTU is intended to integrate functions traditionally found in two separate devices (data concentrator from AMI located in distribution substation and RTU located in some points of the network). Functionally, the data concentrator is the interface between meters and the metering information system. But in many cases, the location of this equipment is also interesting for the grid electricity operator. It is in this context that the concept of SGTU makes sense. However, the metering and grid functionalities to deploy are highly dependent on the type of distribution substation to be equipped. In certain cases (pole mounted substation) some substation won't have any equipment:

1. Distribution substation without metering data concentrator: these substations correspond to cases where there are not enough customers connected downstream to economically justify the installation of a data concentrator. For these substations the installation of a SGTU is neither justified. The meters will communicate with a common data concentrator for several substations (via PLC G3 which can allow the communication signal to pass through distribution transformers) or directly via radio or GPRS.
2. Standard distribution substation with metering data concentrator: these substations require the installation of a data concentrator integrating a few grid functionalities. These have the capability to:
   a. Connect external FPIs and basic binary substation sensors thanks to integrated input interfaces
   b. Measure the three phase voltage on LV
   c. Calculate and analyse the LV voltage phase triangle to detect overhead lines break that are not always detected by MV feeder protections.

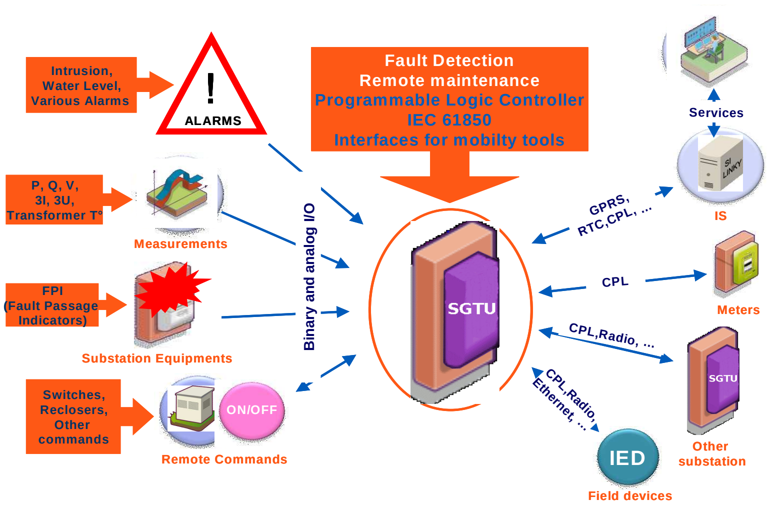
   For this need, ERDF modified the requirements of the Linky data concentrator in order to incorporate binary input interfaces, LV voltage measurement capabilities and the implementation of an algorithm to detect some resistive faults (line breaks). The data concentrator always includes an Ethernet port to connect external devices (like RTU or INIS) in the same scheme of the Linky-Network pilot.
3. Distribution substation with extended capabilities including metering data concentrator: In the MV network of ERDF, some substations are already remotely controlled (an average of three by MV feeder). These points are used by centralized automation functions to isolate the faulty network (remote fault location) and restore the safe parts. Between these points, high priority points have been assigned to substations in order to efficiently drive the field crews during the "on the field" fault location process. For these substation, metering and grid functions are pooled in same equipment, the CRTU, also allowing the complete supervision of the substation (monitoring or controllability) as described afterwards. ERDF has evaluated around 100.000 the substations to be equipped.

4 The French acronym is "KPA" : Concentrateur Poste Asservi

Different functionalities to incorporate

For these strategic substations, the CRTU should incorporate metering and grid functionalities in order to:

- Provide communication and control with meters or any other PLC entity (PLC repeaters, others SGTU, PLC sensors, ...),
- Manage the sensors and the actuators for remote supervision of equipments inside the substation (measurements, switches, …),
- Collect data and events from both metering and grid processes,
- Perform grid operational functions located inside the substation (fault detection, automatisms, …)



- Exchange with the information systems.

The integration architecture of the SGTU and the links with its environment are presented in Figure 3:

Figure 3 : SGTU integration

Different equipments to connect

In this architecture, the SGTU acts like a communication gateway operator. Thanks to its connectivity, it uses the available media to communicate with:

- Downstream equipments: they can be meters or grid equipments monitoring the network.
- Transverse equipments: they may be other SGTU, usual RTU, FDI or sensors (IED[5]) with communication capabilities to monitor the distribution network.
- Upstream equipments: these can be directly an information system or intermediate equipment that manage the interface with the IS.

For all these needs, the SGTU should be scalable regarding its telecommunication interfaces to be able to use any media (PLC “G3”, LTE[6], …) all along the rollout procedure.

Standard data models and protocols to implement

The major key to implement an open and inter operable architecture is of course the massive use of IP protocol. IP offers necessary services to manage the AMI but also the overall telecommunication network. The capacity of addressing hosts and routing messages enables to build an architecture where the connection to devices located in different areas is easier. IP allows as well to manage QoS in order to answer different needs in terms (rate, delay,…). Also multicast is natively supported by IP and can be useful to send messages to various group of devices.

Finally IP is “future proof” and IPv6 will confirm this status and will implemented in new generations of media (like PLC “G3”). In addition the use of standardized data models and application protocols (traditionally DLMS/COSEM for metering and IEC 61850 for the grid) is mandatory to develop solutions that will support easily new architecture and future needs. But the question of the choice of the data model is not closed because even if the choice of IEC 61850 for grid needs is obvious, the one of keeping two data models in an integrated equipments is always in minds [3]. Furthermore, the functional modularity is also a key point to ensure long-term usage of the SGTU. It will depend on its own capability to change the functions of the equipment by updating one or more software components (firmware, libraries, …). At this stage, two ways emerge to solve this issue: using public API provided by the provider or standard Programmable Logic Controller (IEC 61131). This may allow the utilities to implement new functionalities.

Evolution of AMI

As presented before, the concept of SGTU is an intelligent communication gateway allowing gathering a lot of information transmitted using various kinds of media. Today in most European utilities GPRS and PLC are associated in three layer architectures to build the AMI. But the next generation of PLC (like PLC G3) and also wireless solution (like LTE) may offer new opportunities. The PLC G3 proposed as standard by ERDF (and actually tested in a pilot of 2000 meters) allows in particular to

- Provide robust communication by allowing a dynamic trade-off between throughput and robustness
- Provide higher data rate (minimum of 20kbps effective data rate in the normal mode of operation)
- Able to cross the transformer
- Support natively IP protocol

Such characteristics may offer opportunities of improving the business model of AMM systems by minimizing the number of distribution substations equipped with data concentration points and by deploying cost efficient communication infrastructure to support Smartgrid functionalities such as :

- Deploying communications sensors and devices at any point of the network (not necessary in the substation)
- Establishing peer-to-peer for grid automation (self healing) or regulation (DER, losses, …)
- Having access to a private communication network for the field crews and deploy mobility services.

Nevertheless if more and more processes are relying on the AMI, some majors points have to be faced to ensure a successful implementation for utilities: we may mention by example security accesses, continuity of service and priority management.

5 Intelligent Electric Device

6 Long Term Evolution, is the latest standard in the mobile network technology

CONCLUSION

The approach presented there and the specifications help rollout Smartgrid implementation by demonstrating how :

- The **AMI** can be used as **communication infrastructure to handle Smartgrid functionalities**. The integration of new IT technologies can help Utilities to face upcoming challenges.
- The specifications of **this new generation of equipment can address both needs of metering and grid**. The synergies between the different businesses have been developed to be profitable for the utilities.

Nevertheless there are still challenges ahead, by instance :

- Security issues become more and more critical with the use of standard and/or open solutions.
- IT technologies improvements have shorter life cycles than grid rollouts which are long term investments.

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