OPENNODE. OPEN ARCHITECTURE FOR SECONDARY NODES OF THE ELECTRICITY SMARTGRID

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ABSTRACT

The operation of power distribution networks becomes more and more challenging in the presence of distributed energy resources, as well as new demand side management requirements. Utilities need new tools to monitor and operate the power distribution network, maintaining or increasing the reliability and the quality of service in these new conditions. Today's power distribution grids have to be transformed into "smart distribution grids" that feature on-line monitoring data and enable efficient, fast and secure grid operation. This issue is tackled in the OpenNode project [1]. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement Number 248119.

*OpenNode focuses on the research and development of an open **Secondary Substation Node** (SSN), which is seen as an essential control component of the future smart distribution grid, a **middleware** to couple the SSN operation with the utility systems for grid and utility operation and a modular **communication architecture** based on standardised communication protocols to grant the flexibility required by the stakeholder diversification and to cope with massively distributed embedded systems in the distribution grid.*

To address the challenge, a consortium of nine organisations from six European countries is working in the OpenNode project. The project started on January 2010 and has a duration of 30 months.

INTRODUCTION

The European energy industry is facing three major challenges:

a) The increased integration of fluctuating power resources to achieve the climate goals.
b) The increased "smartness" especially in the electrical distribution grid to renew the infrastructure to cope with increasing capacity requirements.
c) The stakeholder diversification separating the grid operation, the power provisioning, the metering services, auxiliary services and others.

These challenges can't be seen independently but have to be considered jointly when developing components for the upcoming smart grid.

Electrical Infrastructures are facing important challenges on the last years. Market liberalisation, new regulatory framework, new generation technologies, customer centric networks, demand rising, distributed generation, environmental issues, security of supply or infrastructure ageing are the driving factors that require an action.

The new electricity supply network will be based on incremental changes over traditional grid. Electrical system is too complex to face a revolutionary change, so the introduction of new technologies must interface with old ones. Also assets management and return of investments stress the problem.

In addition, the European energy industry is changing due to the liberalisation of the EU energy markets and the new model where prices are determined by supply and demand rather than through regulations.

At the same time there are serious concerns over the long-term sustainability of the energy sector as a whole and its environmental impacts, most governments wish to increase the share of renewable energy, for it many new regulations in European countries demands smart metering, energy efficiency, quality of service, reduce CO2 emissions and telemanagement of electrical infrastructure.

It should be taken into account that all these targets lead high risks associated with a complete or partial collapse of an already fragile energy infrastructure. In recent years many severe outages has taken place due to poorly or inadequate maintained distribution networks [2]. It is obvious that a massive investment in the distribution network infrastructure by the Utilities is required.

In this context the use of smart metering to obtain remotely the customer consumption data is the main application, but the most interesting point is that AMM can contribute to meet several of these targets, as well as this solutions can also be used to support the participation of the customer in the demand response (DR) and in the demand-side management (DSM), as well as enable various value added services. Utilities are thus challenged to connect a variety of disparate systems, including AMI/AMM, Billing, CRM, SCADA, GIS, and supervisory measurement and control systems in order to target these challenges.

OPENNODE OBJECTIVES

OpenNode project focuses on the electrical distribution grid operation and explore answers on the three challenges introduced:

a) How we can improve the distribution grid monitoring to cope with volatile states in the grid.
b) How we can integrate the "smart" substation automation devices (e.g. IEDs and attached sensors and actors) to increase the efficiency of the distribution grid.
c) How we can interoperate with the different roles e.g. operation of the smart meters, power and grid operation.

OpenNode project focuses on research and development of smart distribution grids comprising the following components:

- An open **secondary substation node** (SSN) collocated within the secondary substation that will realise a massively distributed embedded system.
- A **Middleware** to couple the SSN operation with third systems.
- Modular **communication architecture** based on open communication standards to enable the various configurations taking the regional differences of the stakeholder diversifications into account.

We understand the SSN as the key for the distribution networks of the future, providing the Smart Grid architecture with distributed computation capacity rather than depending exclusively of the centralized systems in the utility.

This advanced computational capacity of SSNs will enable the exchange of information and the integration with utilities systems like distribution management systems (DMS), monitoring and supervisory control systems, customer care systems, etc. The SSNs will allow more types of digital information sensors and controls that will help to improve reliability, security, and efficiency of the electric power grid.

Built over the basis of a secure network, utilities will take advantage of a common architecture for the distribution system automation, and will have an **open, interoperable, extensible and modular platform** for the development of new advanced services.

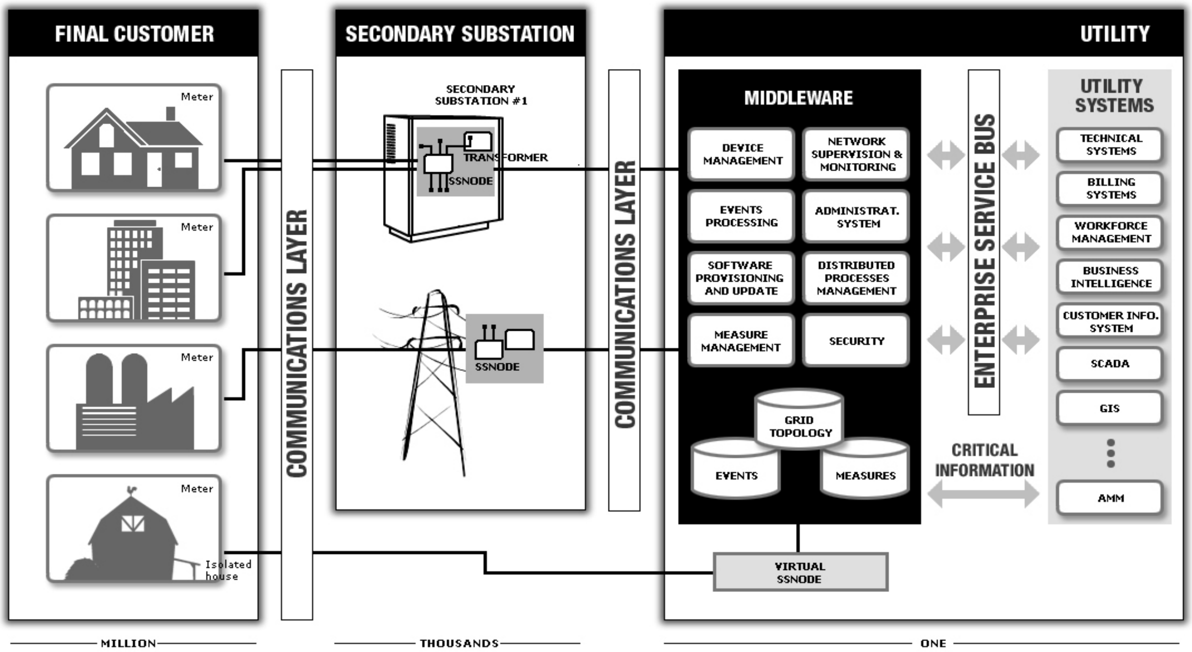

Figure 1: Overall OpenNode architecture

OPENNODE APPROACH

To accomplish the objectives presented in the previous section a consortium has been established composed by 9 partners from 6 different European Countries, including European ICT leaders, European Consulting standard leaders and some of the greatest Utilities in Europe.

OpenNode is firmly based on the results of two other projects from the European Community 7th Frame Program. These two projects are OPEN meter and ADDRESS:

- **OPEN meter** [3], which main objective is to specify a comprehensive set of open and public standards for AMI.
- **ADDRESS** [4], whose target is to enable active demand as the active participation of small and commercial consumers in power system markets and provision of

services to the different power system participants.

OpenNode will link those two projects in such a way that will let together with OPEN meter the technological architectures needed to achieve the results of ADDRESS. OPEN meter will provide the metering architecture and OpenNode the Smart Grid control and management subsystems through the SSN and the MW that will allow the distribution network to perform the ADDRESS vision.

The main components of the OpenNode architecture, the network of **Secondary Substation Nodes**, the **Middleware** and the modular **Communication Architecture** are introduced in the following sections.

Secondary Substation Node

The Secondary Substation Node (**SSN**) is the essential control component of the future smart distribution grid and is the key delivery mechanism to provide the integration of the new metering infrastructure with many other activities at the Utility and third parties. This **SSN** is the main focus of the OpenNode project.

Figure 2 shows a general outline of the system architecture, highlighting the **SSN**.

The SSN will be allocated within the secondary substation and realise a massively distributed embedded system. The aim of this system is to serve as aggregation system for status monitoring and metering and as distributed system for control purposes able to take decisions autonomously as well as remotely controlled.

The SSN is a distributed control system in the medium to low voltage distribution network whose objective is to aggregate data from local and remote sources as well as aggregate information from the connected smart meters and local devices at the customer side.

The main functions of the SSN are:

- Acquisition of customer energy consumption
- Receiving reports on QoS
- Polling smart meter information to determine loss of power or disconnected meters
- Real time monitoring of power quality at the secondary substation
- Status monitoring of local devices in the secondary substation
- Collect information about Outages and their duration
- Perform load shedding
- Automatic device operation and remote controlled operation (e.g. switch on-off) via smart meters
- Remote contract management (change of tariffs, change of contracted power, administrative cuts, etc…)
- Demand Side Management through the power control function

The SSN is able to interact with the local devices, sensors and electrical equipment at the substation in order to:

- Acquires real time periodic electrical measurement: consumption at the transformer, voltage, power etc…
- Acquires digital signals from the electrical equipment and is able to interact with them

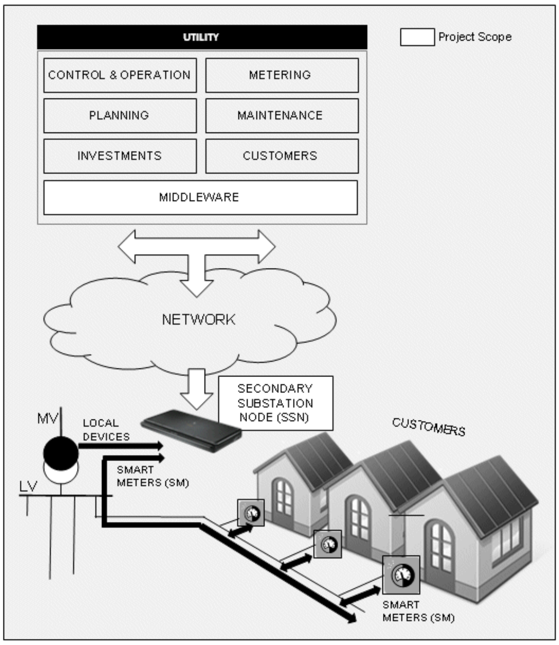

Figure 2: Architecture overview

Middleware

Basic aims of the Middleware are:

- Couple the SSN operation.
- Receive the information from all the existing SSNs, storing it, and providing it to the Utilities systems that may require them.
- Monitoring and supervision of the whole MV / LV power grid status: reporting possible failures and, if required, perhaps take a corrective action.

Therefore, the **integration capability** with the myriad of Utilities systems is one of the most challenging issues. These systems may request information (measurements, status, configuration, etc) from any of the OpenNode devices (SSNs, SMs, sensors, actuators, bays, etc) and many standards and protocols may be involved on the road, but nowadays Utility systems themselves are not using a common protocol. To achieve the integration with these heterogeneous systems it is necessary the use of standards.

Two approaches are implemented at the Middleware:

- Future oriented: Use a common information model based on an agreed vocabulary known by all the systems which includes all the concepts needed to deal with a power network. This common information model is the Common Information Model, CIM [5]. The Middleware facilitates harmonization approaches to the CIM model from metering and automation data.
- Present and easy to implement with current systems technologies: Use Web Services Resource Transfer, WS-RT, that promotes the use of Web Services in combination with an XML Schema, allowing that the services can manage any type of data with a generic mechanism.

Another challenge faced is to provide a proper **measurement repository** that can cope with a huge storage load: dozens of millions of measurements per day are expected. This repository should support a flexible storage schema, scale easily horizontally and provide a good performance in reading and writing operations. The new technology trend selected to achieve this goal is the NoSQL distributed databases that don't follow the traditional ACID characteristics because they are designed to be scalable and partitioning tolerance (available) according to the CAP theorem [6]. This kind of NoSQL engines are used on system with very high volume and speed data processing as in Facebook, which managed 120TB at 2008 [7].
Finally, other highlights are the **supervision algorithms** that can be added dynamically to the Middleware. They can take advantage of the near real-time information available from events, metering data and grid automation commands and measurements that arrive at the Middleware. The Middleware includes an event processor engine that allows filter, aggregate, group, and analyze this information in different ways: as event stream processing, complex event processing or event pattern matching. These analyses help detecting the rules defined at the supervision algorithms which should improve maintenance and corrective tasks at the power network.

Communication architecture

Here the focus is on open communication standards to enable the various configurations taking the regional differences of the stakeholder diversifications into account. On the **application layer** data models are being designed to fulfil the stakeholder diversification challenge and for the interconnection of actors like grid operator, metering service providers or other value-added services.
On the network and physical layers the architecture provides a uniform view of the connectivity of the nodes to ease installation, maintenance and to allow dynamic addition and removal of nodes; all this supporting a wide variety of exchangeable technologies.
Our communication technology solution is based on:

- For the interface between the smart meters and the SSN we will use DLMS/COSEM standard over PLC. GPRS and 3G will be used on remote meters and in areas with low density of electrical deployment.
- For the interface between the Middleware and the SSNs currently two options are considered. The first is to use IEC 61850 data models only, that would mean to convert metering data into (potentially new types of) IEC 61850 containers. The second option is to transport DLMS/COSEM for metering and IEC 61850 for automation in parallel on the same channel (see Fig. 3).
- For the communication between the Middleware and the stakeholders a mix of communication standards and models will be created based on IEC-61850, CIM, IEC-60870 (for legacy and control centre systems) and web services.
- Security standards to be applied will be based on IPSec standards and IEC-62351 recommendations.

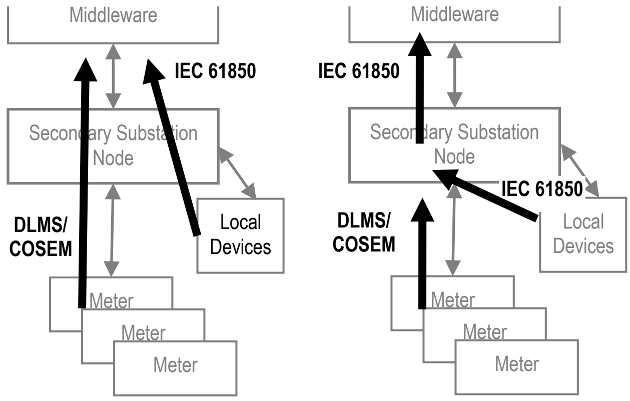

Figure 3: Protocol options for SSN integration. Left: mixed-protocol approach. Right: 61850 only approach

STATUS AND CONCLUSSIONS

OpenNode's general requirements and use cases are already completed as well as the Middleware and SSN specification and detailed design. Communication architecture is already defined too including the evaluation and selection of standards.
Currently the development of both the SSNs and the MW are on an early stage and the data models, protocols and interfaces definition is about to be completed. The first prototypes of SSNs and the Middleware reference implementation is expected to be completed by the end of September 2012.
OpenNode has the ability to successfully integrate and give support to the requirements and technologies involved and needed for the development of the now present Smart Grid. OpenNode is not just an AMM/AMI, DSM, DER or PEV integration project. It is the facilitator that can make true these advanced Smart Grid features and give support to the ones to come.

REFERENCES

[1] OpenNode, http://www.opennode.eu/
[2] BBC NEWS, 2006, "Bid to overhaul Europe power grid", BBC NEWS, http://news.bbc.co.uk/go/pr/fr/-/2/hi/europe/6117880.stm
[3] OpenMeter, http://www.openmeter.com/
[4] Address project, http://www.addressfp7.org/
[5] IEC, 2009. "61970-301 Energy management system application program interface (EMS-API) – Part 301: Common information model (CIM) base".
[6] NOSQL Databases, http://nosql-database.org/
[7] A. Lakshman, 2008, "Cassandra – A structured storage system on a P2P Network", Facebook, http://www.facebook.com/note.php?note_id=24413138919