SMART COMMUNICATIONS IN DEMAND MANAGEMENT

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ABSTRACT SUMMARY

Demand Management concepts are required in their Electrical Sector, in order to improve their generation profile, environmental impact and overall consumption thanks to educational information among population. This is our proposal for the Communication Architecture.

The power generation plants can not be adapted to the variability of the Demand Requirements, especially if the alternative / distributed energy is significant in the country power generation profile. The domestic consumption is very significant in a country, with the added difficulty of being a consolidation of home loads demand with high geographical dispersion and non homogeneous distribution. In this scenario, our proposal is to develop an innovative and robust Information & Communication Technologies scheme to create a common environment for the current agents in the Sector, allowing different Business Models to be implemented. This will allow them to agree with the user different Service Level Agreements, consumption behavior and compensation. As a long term result, we expect to provide an educational tool: the daily detailed information will help population to understand the important impact of their effort in the Environment Protection and their contribution to the country economy.

- ***MATRIX DEFINITION:*** *The smart network will be implemented taking into account the electrical network configuration and characteristics, so that the different OSI levels are now defined within the power distribution scheme, as a matrix. This will help us to maintain a CBA (Current Best Approach) at different levels and locations, so that the latest solutions and protocols (BPL, Tetra Release 2, WiMAX) could coexist with traditional technologies (PLC, GSM/GPRS, Tetra) and at the same time, be tested and deployed without impacting the rest of the definition.*

- ***COST EFFECTIVENESS, RELIABLE AND INNOVATIVE:*** *these criteria are used to select the CBA technology at every position in the matrix, to ensure the business model supports the effort to deploy the project country wide, the trust in the network and its capabilities, and the latest status of the art in open, compatible, plug & play technology.*

- ***LAST MILE PENETRATION AND SCALABILITY:*** *this architecture will be used to manage the population consumption profile, regardless distances and distribution. And the aggregation levels will be flexible enough to support newly added links, to be able to grow step by step without traffic congestion.*

- ***NEW BUSINESS CASES AND SERVICES:*** *this matrix is allowing the Application Level to support new added value services and develop dynamical business cases, as soon as they arise at different stages and serving different group of interested users. Telecontrol, telemetering,… are just the beginning.*

INTRODUCTION

The power generation plants can not be adapted to the variability of the Demand Requirements, especially if the alternative / distributed energy is significant in the country power generation profile. As an example, past March 27th, Spain reached a maximum of 24% of the Peninsular Power generation coming from wind production (209.480 MWh).

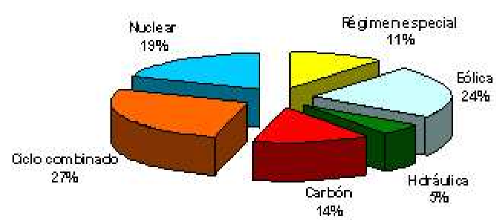

Figure 1. Power Generation Mix in Spain, March 27th. Note 24% Wind Power [8].

The challenge is now how to match the power generation mix and their different intrinsical characteristics with the aggregated demand. Currently in Spain we are facing this kind of Demand Curves, that are also similar to the rest of the European networks:

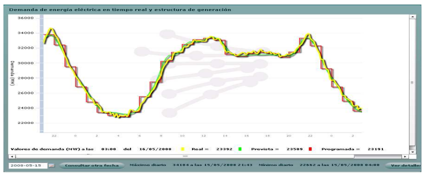

Figure 2. Daily Demand Curve in Spain [8].

How to move the load to the minimum consumption hours? Solving this question we could make a sustainable growth of our current year to year demand and also leverage the possible issues of network operation and management, as we could have a plainer curve.

The domestic consumption is very significant in a country, with the added difficulty of being a consolidation of home loads demand with high geographical dispersion and non homogeneous distribution. On top of this home demand, we of course have to consider Industry Sector and Commercials that in most cases could be managed in point to point contacts, due to the lower number of big consumers.

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In this scenario, our proposal is to develop an innovative and robust Information & Communication Technologies scheme to create a common environment for the current agents in the Sector, allowing different Business Models to be implemented. For instance, the System Operator could send / receive different orders or messages to the Distribution Operator with different priorities. This will allow them to agree with the user different Service Level Agreements, consumption behaviour and compensation. As a long term result, we expect to provide an educational tool: the daily detailed information will help population to understand the important impact of their effort in the Environment Protection and their contribution to the country economy.

Matrix Definition:

The smart network will be implemented taking into account the electrical network configuration and characteristics, so that the different OSI levels are now defined within the power distribution scheme, as a matrix. This will help us to maintain a CBA (Current Best Approach) at different levels and locations, so that the latest solutions and protocols (BPL, Tetra Release 2, WiMAX) could coexist with traditional technologies (PLC, GSM/GPRS, Tetra) and at the same time, be tested and deployed without impacting the rest of the definition.

The idea behind is to be able to implement in any position of the communication matrix the latest status of the art / available technology, and for instance, we could apply similar protocols to the mobile cellular networks, with dynamical routing. This kind of protocols could be especially useful in the communication links that need to be related to the Electrical Substations and Transformation Centres, in which PLC technologies could help to minimize the impact in the business model.

This also implies an additional effort to ensure standard and robust interfaces between the different telecommunication centers and layers in this network.

A key function of these protocols is to ensure no impact in the distribution of the electrical network could arise due to normal operations, and no impact due to this operations (specially topology related) could affect the telecommunication network. The network should adapt to this Operations, automatically, reconfiguring and delinking electrical and telecom operations in the distribution network.

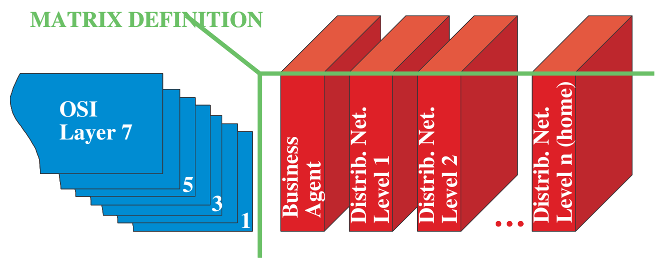

Figure 3. Communication Matrix [7].

Cost Effectiveness, Reliable and Innovative:

These criteria are used to select the CBA technology at every position in the matrix, to ensure the business model supports the effort to deploy the project country wide, the trust in the network and its capabilities, and the latest status of the art in open, compatible, plug & play technology.

This is a must almost in every project that we could define, reuse the current technologies and facilities that already exist, and at the same time, define a flexible structure that could support migrations to different functionalities in a "step by step" philosophy, at a very competitive cost.

This implies that the Smart Grid could be built based on current facilities (e.g. PLC techs where no other telecom is available) and in a medium / long term, once the business model has proved its feasibility and new functionalities are required, a new parallel telecommunication network could be implemented.

As the matrix definition would allow different technologies to coexist, they can be selected also depending on the business model and service level required. For instance, a Medium Voltage deployment in rural areas could be not cost effective, but radio technologies could be more suitable. To ensure heterogeneous communication network will be reliable, an adaptation layer must be defined, as an interface between the network technology and the SmartGrid protocol architecture.

The proposal is to divide in two groups the structure of the protocols, so that the lowest part consists of the physical layer and related protocols, and the upper part consists of a number of layers with the different agent communications (transport to application, according to OSI model). Between these parts, we will define the convergence layer that supports a certain transport layer (E.g. TCP, UDP, …), to the required Smart Grid standard transport layer. This approach guarantees backward compatibility and future migrations, as for instance, TCP/IPv4 over SDH or IP over PLC, GPRS,… could be deployed right now, and new techs like IPv6 could be deployed in a later stage.

Different services could be implemented within this Smart Grid Communication Network, delinking or prioritizing them to optimize the communication resources (e.g. technical interventions over business information), so that Quality of the Electrical Network is preserved (falls prevention, load management, tarification processes).

Last mile Penetration and Scalability:

One of the key factors that allow a wide coverage of SmartGrids communication capabilities for demand-side management is a suitable user access network [2] [4].

From the many alternatives available to provide this access, PLC technologies are the best suited to the business models of electricity distribution utilities [5]. These technologies provide total ubiquity, already-deployed physical communication medium and a narrow bandwidth exclusively reserved for utilities.

The narrow bandwidth available (from 3 kHz to 95 kHz in Europe, CENELEC A band) marks the low-voltage distribution network as the bottleneck of the whole communication system. To overcome the severity of these limitations and provide appropriate communication services, some important requirements are put into the physical- and link-layer levels of PLC technology in use.

The physical layer must provide high bandwidth efficiency and strong reliability to obtain a BER (Bit Error Rate) low enough in the presence of strong impulsive noise and high level of background noise [3]. Moreover, as impedance and noise conditions change over time, physical protocol must adapt itself to changes in the phase of the signal as it traverses the medium. These requirements can be met by a differentially-modulated OFDM (Orthogonal Frequency Division Multiplexing) system [6]. Differential modulations are robust against phase changes in time-variant channels and the use of multiple orthogonal carriers assures high bandwidth efficiency. Several choices for single-carrier modulation and error correcting codes allow the system to adjust its transfer rate and BER in order to match a wide range of channel conditions.

Attenuation is another relevant drawback of PLC medium [1], so that intermediate devices that amplify signals are needed to increase user coverage.

As seen, the physical layer is crucial to achieve last-mile penetration. However, in order to manage the high number of potential users per Transformation Centre, a convenient physical layer is simply not enough. The link-layer protocol must use physical-layer capabilities carefully to avoid wasting valuable communication resources.

In demand-side management applications, interactive communication between system and consumer is driven mainly by issuing commands and receiving its responses. Commands are, in most cases, sent by the system to user devices, and user devices may or may not respond to those commands. If this interactivity is taken into account, and considering that, in PLC communications, there is commonly only one system device (the Transformation Centre communication device) and hundreds of user devices, a master-slave link-layer protocol may provide a convenient use of resources.

This master-slave link-layer protocol can differentiate services and reserve time-slots for critical command transmission, as those related to blackout prevention. As the PLC medium quality changes with time, user devices may reach more than one system device, each one with different transmission quality. The link-layer protocol should allow user devices to be managed by the system-device in range with the best communication quality with the user. That optimal system device may change with time. As a consequence, the registering process becomes dynamic. This functionality is commonly found in cellular mobile communications protocols.

Link-layer protocol is also the basic step for safe communications, using cryptography to authenticate users and avoid unauthorized access from other devices attached to the same PLC medium.

Due to bandwidth limitations, it is essential to avoid data redundancy in narrowband PLC communications. In many cases, the demand-side management application sends a single command to a group of user devices (i.e., to send an offer to consumers). The command is essentially the same for all the target devices. To avoid flooding the network with a lot of identical messages, each for a different user, the use of multicast and broadcast transmissions is a must.

Flooding the network with commands can be avoided by multicast and broadcast transmissions, but responses to those commands cannot make use of these solutions since responses are generally unique for each user device.
A high number of devices accessing the medium to send a response to a recently received command may degrade channel use due to signal collisions happening in the medium. A simple approach to mitigate this problem is the use of random processes to schedule the responses of user devices. The command sent by the system selects a random variable distribution and specifies its parameters, this information is then used by the user device to obtain its own

response time. As a consequence, user devices traffic is shaped according to the selected random distribution.

This solution controls the maximum number of user devices trying to access the medium simultaneously but introduces some uncertainty in the exact time a user device will provide its response. However, this uncertainty is statistically characterized, and its parameters are adjusted by the system, so that is it possible to anticipate overall system performance prior to command transmission.

New Business Cases and Services:

This matrix is allowing the Application Level to support new added value services and develop dynamical business cases, as soon as they arise at different stages and serving different group of interested users. Telecontrol, telemetering, are just the beginning.

We could think about future local distributed power generation, to allow these micro contributions to be added to the national distribution network.

Or new offers to a selected population group, depending on user profiles (e.g. bonus price for responsible consumption).

And a new generation of remote services from outsiders, to guarantee home installation is working in the finest way. For instance, the load management could include the information service as well, and auto-checks of the different home devices could be sent through the Smart Grid to ensure the right function (diagnostics, preventive maintenance, software upgrade, ...).

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The GAD project (Active Demand Management) is sponsored by the CDTI (Technological Development Centre of the Ministry of Industry, Tourism and Commerce of Spain), and financed by the INGENIO 2010 program. The objective of GAD project is to investigate and develop solutions to optimize the electrical consumption in low and medium voltage users. The promotion of the project comes from the National Strategical Consortium of the Electrical Active Demand Management; Iberdrola Distribución Eléctrica, S.A. is leading this group, and the rest of former companies are: Red Eléctrica de España, Unión Fenosa Distribución, Unión Fenosa Metra, Iberdrola, Orbis Tecnología Eléctrica, ZIV Media, DIMAT, Siemens, Fagor Electrodomésticos, BSH Electrodomésticos España, Ericsson España, GTD Sistemas de Información, Acceda Mundo Digital y Airzone. On top of this, fourteen Spanish research organizations are collaborating.

[8] Figures 1 and 2 coming from Red Eléctrica de España (https://demanda.ree.es/demanda.html).