HOW TO DESIGN A COMMUNICATION NETWORK
OVER DISTRIBUTION NETWORKS

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ABSTRACT
This paper presents some rules and criteria that are necessary to design correctly a communication network over Distributions Networks (DN). The paper also collects main communication requirements needed for Smart Grids.

INTRODUCTION
The GAD Project [1] is carrying out this work with the aim to develop an active Demand Management System (DMS). The work group (WG) responsible for communication established four stages to deploy the communication system needed for the active DMS:
− Define communication architecture.
− Specify communication requirements.
− Design a communication system.
− Develop a pilot system tests.

The communication architecture and some requirements were presented at the CIRED Seminar 2008 [2]. Since this event, the effort of this work group has been focused on the design of the communication system to support DMS and future services. One of the goals of the Design stage is to simulate this system, by checking if the proposed technologies fulfil the defined requirements. The simulation results could show some limitations of the selected technologies.

The paper is organized as follows: the second section shows a Smart Grid overview. The following section compares IPv6 protocol with IPv4 one. Design rules are discussed in the fourth section. The experience achieved in the GAD Project is used as example in the fifth section. The conclusions section shows the next milestones in the GAD Project.

SMART GRIDS OVERVIEW
During the last years, new services have been introduced in electrical networks to respond to new society needs. To support all these services a transformation of the power delivery infrastructure is needed. The international electrical community is working on this transformation of the current electrical networks in an intelligent grid, called Smart Grid [3].

Smart Grids will satisfy requirements of the existing and future services due to the following qualities:
− Allow interactive communication between operators and consumers.

− Balance energy generation and electrical demand.
− Improve power quality and grid security.
− Integrate Distributed Energy Resources (new generation models and storage systems).
− Provide self-healing mechanisms to prevent problems.
− Enable future services and market models.

The electrical community agree that:
− Smart Grids must be based on open standards, avoiding proprietary solutions.
− Smart Grids must be interoperable, enabling to exchange information between different operators.
− Smart Grids must support “Plug & Play” (P&P) devices, making easy network management.

Operators and society would be able to obtain many benefits by developing Smart Grids, but there is a problem: the old electrical networks are still widely deployed around the world. Because of this, associations are defining strategies to develop Smart Grids over the traditional electrical grids [4] [5]. Furthermore a guide has been published on how to develop a Smart Grid in six steps [5]. The inclusion of new services is an excellent opportunity for operators to update their installation thereby easing the Smart Grid arrival. In this sense, a new communication system for the support of these new services would be designed to fulfill with Smart Grid requirements.

There are at least three modern services that can be used in electrical networks: SCADA, Advanced Metering Service (AMS) and DMS. SCADA service is older than the others and operators have deployed it some years ago, most of them using proprietary systems.

Any new project considered by electrical operators should take the opportunity to analyze and develop a modern communication system in their networks.

IP PROTOCOLS
It would be advisable to deploy one communication network for all the Smart Grid services. This would imply that only one management system would be necessary to administrate all the network resources.

On the other hand, it is probable that distribution operators have deployed, over some DN segments, network technologies for services that are already in use. For example, in some DN, the SCADA service can be used from Control Centre to Transformer Substation over SDH technology, while other DN could have a remote metering service over GPRS or PLC technology. For these mentioned services, it will be also necessary to create one network

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The network layer fulfils these two functions. Therefore the main requirements that must be fulfilled by the chosen protocol are:

1. Support different services: automatic metering, demand response, self-healing, distributed resources management, security services, others and future services.
2. Work with different network technologies: the network protocol will have a specific convergence layer for each network technology existing in DN.
3. Satisfy different QoS features [2]: each supported service needs specific Quality-of-Service parameters (latency, jitter, delay, others).
4. Be an open standard.

The experience and studies that have been performed [2] [7] recommend the use of IP protocol stack in the common network layer of Smart Grids. This protocol is widely used in data networks and the most of the network technologies have defined a convergence layer for it.

There are two versions of this popular protocol, IPv4 and IPv6. The main differences between them are:

- IPv6 address field is longer than IPv4 one. The number of devices connected to a network can be higher.
- IPv6 header incorporates two fields to manage QoS: Traffic classes (establishes packet priority) and Flow label (for real time requirements). Original IPv4 didn’t have any kind of QoS, so it was necessary to define new protocols in TCP/IP Stack for this purpose.
- IPv6 must incorporate IPsec as security mechanism. IPv4 didn’t specify any kind of security, so that it was necessary to define IPsec Protocol.
- IPv6 eases the use of P&P device.
- IPv6 allows anycast and multicast communications. IPv4 needs IGMP to manage these communications.

IPv6 responds better to Smart Grid requirements. But not all applied network technologies have defined a convergence layer for IPv6. The electrical services and systems also define communication protocols (for example, DLMS) and these do not define convergence layers for IPv6 either. Because of the novelty of IPv6, most of the protocols used in electrical services don’t have support for it.

To solve this problem there are two main solutions:

1. Development IPv6 convergence layers for the protocols used in link and application layers.
2. Creation of a mixed network: IPv4 and IPv6 should coexist.

The first solution allows operators to apply a modern communication network; IPv6 networks would support current services and future ones. But it has two important disadvantages:

- Complex solution. It would be necessary to define a convergence layer for each protocol used in Smart Grid services.
- Increase the deployment time. It would be necessary to develop the new convergence layers defined and check their correct behaviour.
But this change is not easy and makes necessary a careful planning of the future transition procedure [8].

DESIGN RULES
The steps to design correctly the communication network for Smart Grids should be:
- Detect the communication needs of main Smart Grids services. Although the communication network would be designed for a specific service, it is advisable to perform this study to detect the more restrictive requirements in a Smart Grid. The communication network must satisfy the service data flows and their temporal needs.
- Specify the communication requirements making difference between mandatory requirements and optional (or recommended) ones. This classification distinguishes between the requirements for the specific service to deploy (mandatory) and the requirements for future electrical services (optional).
- Analyze the communication technologies used by the working DN services. Nowadays most of the Distribution Operators are using some services (for example, SCADA or remote metering). This analysis helps to reduce the deployment cost reusing existing technologies although it may complicate the design work.
- Select network technologies for DN segments without communication infrastructure or where the existing technologies don’t fulfil with the requirements. It is advisable to select the newest technologies, because the future services would have more restrictive requirement.
- Structure the electrical grid as a communication system using the chosen network protocol. For example, when using an IP protocol it is important to assign the addresses: assigned addresses can create several subnetworks along the grid, easing future network growths (scalable network).

At this point, the communication network has been designed. If the choice were an old network protocol (IPv4) or a mixed network solution (IPv4/IPv6), the designers would plan the network update, thinking in the Smart Grid goal, to a modern solution.

GAD PROJECT EXPERIENCE.
The GAD Project [1] has the aim to develop an active DMS. There are different work groups specialized in different areas (for example, there is a hardware WG responsible for the design and development of new devices, as Domestic Power Manager, needed for this service). This section is focused on the communication WG. The aim of this WG is to define a communication network with open standard protocols to support the active DMS. The WG was launched in 2007. In that year, the work was focused on the study of different communication solutions in the Smart Grid experiences. Thanks to that study, the WG could detect the main needs of the Smart Grid services. Last year, this study was used to define communication architecture [2] and to specify the communication requirements for the network.

Following the study results, the group uses Iberdrola grids, as example of electrical grid, due to the fact that Iberdrola is a partner and the leader of this project. In this case, the WG has detected several technologies that are used for different services. There is an optical network available in some segments of Medium Voltage DN. This technology satisfies the communication system, so it can be reused in the active DMS. The WG decided to use PRIME technology in the Low Voltage DN, the same communication network that will be used by the AMS. BPL technology could be used in the rest of the DN segments, in the cases where it is possible. In other cases, the wireless communication technologies will be used. By applying the existing optical network and PLC technologies, the deployment cost will be reduced. But, nowadays, PRIME technology has not defined a convergence layer to IPv6 [10]. The active DMS will use DLMS/COSEM specification to establish the communication between Distribution Operators and the electrical consumers. COSEM protocols don’t consider the convergence layer for IPv6 either.

Therefore the proposed solution is to use the IPv4 protocol in a communication, as defined by the DLMS specification, creating a transparent IPv4 network that can be deployed over optical networks.

CONCLUSIONS
This paper summarizes the work done by the GAD Project during the last two years, showing the followed network design rules and the main decisions taken to develop a communication system over distribution networks. Distribution operators need modern services to manage and control their electrical grids, the DER and the demand response dependent on power generation. These services need a reliable communication network to satisfy the operator requirements. This context is an excellent opportunity to bring Smart Grid concept closer to the DN. The communication engineers should have to bear this idea in mind in the design procedure. IPv6 protocol seems to be the best network technology to support these services. This protocol also allows using
different physical medium in the same communication system. However it is a recent protocol, so some link protocols do not support IPv6 communications. In order to reduce the designing time, the solution is to create a mixed network where the IPv4 and IPv6 protocols coexist. This solution should be developed in parallel with an updated plan for the network evolution to only one IPv6 network.

In the GAD Project, due to time limitations and the aim to use open standards, the communication work group has defined an IPv6 tunnel over optical network to allow a transparent communication between operator and consumers.

The simulation results will be available in March 2009, showing the efficiency of this communication system. Finally, a pilot system tests will be developed next year.

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Moreover, fourteen Spanish research organizations are collaborating, CITIC is one of the R&D Centers working in the GAD Project. Its task inside this project is related to the communication group. CEDETEL and Universidad de Alcalá de Henares are also members of this work group, both coordinated by Ericsson, Siemens and Orbis.

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