DISTRIBUTION NETWORK AS COMMUNICATION SYSTEM

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ABSTRACT

This paper proposes, using the Distribution Network (DN), the deployment of a common communication architecture to support different electrical services. The aim of the architecture proposed is to simplify the development of future smart grids in the current electrical systems.

INTRODUCTION

Since the beginning of the industrial age, the economic growth involves an increase in the energy demands. To satisfy this society need, the electrical operators have deployed a large distribution network. Also, the energy resources are located along wide areas. Thus, the operators have to solve an important issue: manage a large electrical system to approach this necessity [1].

This management model requires a reliable and interoperable communication system. The best way to fulfil all these requirements is developing a private communication system [2].

Hence the electrical operators have been using, whenever possible, different communication systems over their own DN for different management services.

For example, the SCADA systems use an optical network deployed over the DN. IEC 61850 standard describes a communication architecture to deploy in a substation. Also, an automatic metering service can be used by the operator through a private communication system [3].

However, in the last years a problem has been detected: inflexibility to support new services. The current communication systems deployed over the DN are oriented to support specific services, so that, the development of new services over the DN or even add new agents may result very expensive.

In this context, it appears the term 'Smart Grid'. A Smart Grid consists of a broadband communication system that uses a set of sensors and distributed computing. Thanks to the 'Smart Grid', the DN will turn into a reliable, self-healing, fully controllable and asset efficient electrical system.

This paper presents part of the research in progress done by GAD Project [4]. The aim of this Spanish project, leaded by Iberdrola, is to develop a system to adjust the residential consumption according with the electical system's state and generation.

An overview of the DN architecture is shown in the first section of this paper. In the next sections, it is discussed about the DN as communication system (components and technologies that can be used) that eases the implementation of a Smart Grid in it. Finally, an use case sets an example of GAD System's operation.

DISTRIBUTION NETWORK ARCHITECTURE

The DN is in charge of transferring the electricity power from the Transport Network (TN) to the end consumers. The Distribution Network Operator (DNO) operates, administrates and maintains this DN through several Control Centers.

Topology

The DN consists of Medium Voltage Distribution Network (MVDN) and Low Voltage Distribution Network (LVDN). The DNO can also administrate part of the TN, called High Voltage Distribution Network (HVDN), as represented in Figure 1.

The HVDN, MVDN and LVDN are fully connected; although the DN has a tree topology, due to the network management, is hierarchical. Thus, the DN topology is dynamic: the electric power path may change in presence of some events (fails, new agents...).
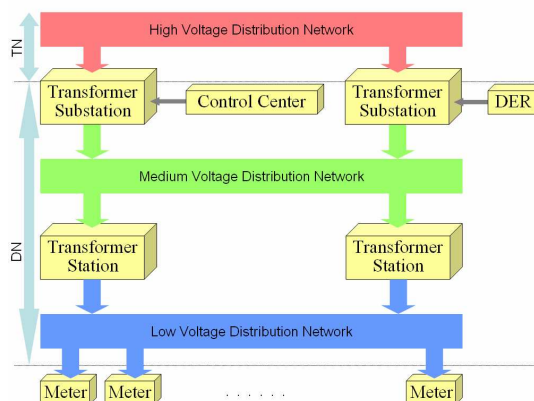

Figure 1: Distribution Network architecture

Components

The main components of the DN are: Control Centers, Transformer Substations, Distributed Energy Resources (DER), Transformer Stations and Electricity Meters.

The Control Center is the root node of the DN topology. The DNO manages the DN through this component: monitoring, administration and control functions are executed in the Control Centers.

The Transformer Substations (HV/MV Stations) and the Transformer Stations (MV/LV Stations) have a similar function: interconnect networks of different voltages. These components have several control mechanisms to avoid critical network failures (circuit breakers, relays, etc.).

The DER components should be small or medium energy sources (such as microhydropower, wind turbines, solar panels...) located along wide areas. They are connected to the DN through Transformer Substations.

Finally, the Electricity Meters measure the consumer's consumption.

DN COMMUNICATION ARCHITECTURE

It is possible to define a communication architecture over the DN Architecture detecting the communication's needs of the different DN components.

The backbone used in the communications includes HVDN, Transformer Substations, MVDN, Transformer Station and LVDN; thus, the DN topology must be transparent to the communication service.

The Control Centers act as the network manager, so they need to communicate with the rest of the DN components or DN agents. As a result, the Control Centers will use a gateway to establish communications with other DN agents. The Access Node used by each Control Center is located in the nearest Transformer Substation.

Also, each DN component may have different communication profiles, so the Control Centers should apply the appropriate profile for each service required by the DNO.

The Transformer Substations and the Transformer Station have two communication roles: backbone components and DN agents.

These components have several control mechanisms in their installation. So the Control Centers need to communicate with them to control those mechanisms and to monitor them. Each Transformer Substation or Transformer Station should have a Customer-Premise Equipment (CPE) that allows establishing the communication with the Control Centers.

Besides, these components are located inside of the communication backbone, interconnecting two or more networks. So that, these locations should have a router device to enable an intelligent communication addressing in the communication architecture.

The DER components are end communication agents. The DNO ought to know the energy produced by each DER agent and control the whole power production. So the DER must have a CPE to enable the communication with the Control Centers.

The Electricity Meters store consumer information: consumption, load curve and other datas. DNO must read this information to invoice the electricity service, detect energy peaks or other management issues. When Electricity Meters are connected to a communication architecture, they are called Automatic Metering Readers (AMR).

Finally, the DN communication architecture should allow the addition of new agents or component easily.

NETWORK LAYER

According to OSI model, this layer must ensure an end-to-end packet delivery, from the source to the destination.

According to the "smart grid" services, the network layer should fulfil the following requirements: must support current and future services, should be independent from network technologies, allow unicast, multicast and broadcast services, ease network reconfiguration, scalable architecture, and should offer Quality-of-Service (QoS): latency, jitter, delay and other parameters.

Internet Protocol (IP) fulfils these requirements. In addition, IP technology is being used in the convergence networks projects, guaranteeing an interconnection of "Smart Grids" with other networks [5].

Although the IPv4 extensions allow multicast traffic (IGMP) or certain QoS, IPv6 includes these services and new features: more addresses, mobility, security, etc [6].

In this manner, IPv6 ensures the support of future services in the architectural proposed. In the other hand, this network layer can be developed over almost every network technology available.
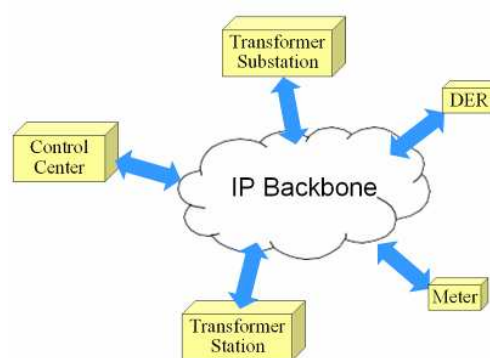

Figure 2: DN components are connected to IP Backbone

Figure 2 shows the connection of the DN components to the one communication Backbone.

DN SERVICES

Nowadays, there are two main services for the operators: SCADA service and Automatic Metering service. Each service has its own communication architecture, increasing the DNO costs.

SCADA and Automatic Metering services can be deployed over the same IP network, reducing the deployment and maintenance costs. Once the IP network is working, it is easy and cost-effective to deploy a new service, as Energy

Management Systems.

In these cases, where several services share the same network, the latency and jitter requirements are very important. Control Centers must reserve the necessary network resources and implement QoS mechanisms to achieve these requirements.

NETWORK TECHNOLOGIES

Some network technologies, used on DN, are reviewed in this section.

When optical fibres are deployed along the DN (chiefly in HVDN and MVDN), DNO can use SONET or SDH protocols as network technology. These protocols guarantee a small latency and high data rate.

Broadband PowerLine communications (BPL) technology can be used in MVDN, LVDN or in-home network. There are some legacy BPL protocols and there also is an IEEE project (IEEE P1901) working in an open standard protocol for LVDN and in-home network [7]. This technology is oriented to multimedia services, being possible to establish QoS parameters in the communications.

PRIME project, leaded also by Iberdrola, is developing an open standard protocol. This standard will use a PLC technology for LVDN communications in the CENELEC A Band. The minimum data rate is 20 Kbps and the maximum is 128 Kbps [8].

Wireless communications are available for DN segments where the medium cannot support PLC technology or the population density is low or due to other reasons. WiMAX technology or Public Land Mobile Networwks (PLMN) are the main possibilities for wireless communication for HVDN, MVDN or LVDN. Also, ZigBee technology could be the main choice for in-home network deployment.
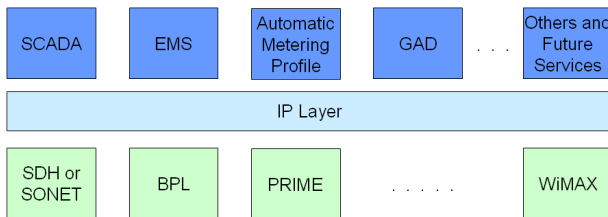
Figure 3: IP Layer supports several electrical systems over different network technologies

Finally, Machine-to-Machie (M2M) services offered by the telecomunications operators can be a possibility while a new broadband technology is being deploying over an area or when, for example, a link is too busy to fulfil with the latency requirement [9]. In this case, the public communication networks will be used.

Different technologies can be used in each DN segment, according with the channel characteristics or the communication or economical requirements. Despite of this technologies' variety, it is possible to use the DN architecture as a single communication architecture to support different services, as shown in Figure 3.

GAD PROJECT

In 2007, the Active Demand Management (GAD) project started in Spain [4]. The aim of the project is to develop a system to adjust the residential consumption to the electrical system's state, according with generation, failures, etc. In this way, it will be neccesary a real-time communication system.

This project is useful to show how new systems can be developed over the previosly proposed communication architecture.

New systems should define and publish communication specifications, thus Control Centers should plan the necessary communication resources for these systems.

Also, new agents or components can be defined in the new systems. These agents or components will easily plug into the DN.

For example, GAD project defines a new agent called Domestic Power Manager (DPM), as represented in Figure 4. This component will be plugged into customers' home subscribed to this system. DPM will receive from Control Center some information to manage the consumer's demand, for example:

– warnings about critical DN state: DPM will instantly reduce the consumption of end consumer.
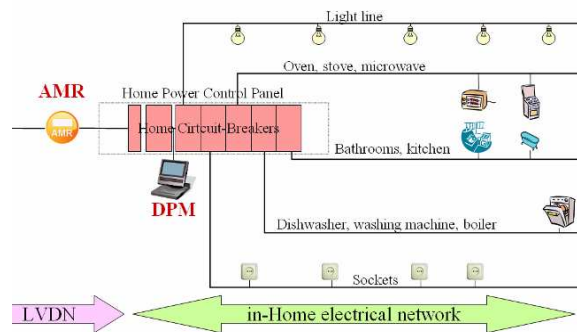– energy prices

Figure 4: Implementation in a Spanish home

Besides, DPM could delay or reject the device's turning on, according with the consumer preferences.

DPM will access to DN through the LVDN, registering automatically in the DNO Control Center just after its plugging in.

The proposed communication backbone (IPv6) allows these issues:

– transparent communication between Control Center and DPM.
– new components will be easily connected to IP networks, modifying automatically the routing algorithm.

Use Case

This section describes a possible scenario where the DNO must reduce the power consumption to guarantee the DN security, illustrated in the flowchart in Figure 5.

SCADA detects a critical failure in the DN (for example, DER agent catches fire, so that the power generation is

reduced). DNO calculates the current power consumption and resolves that this consumption may be reduced.

Thus, DNO uses the GAD service to warn all customers subscribed to GAD about this issue. Control Center broadcasts a warning command, reducing the maximum power consumption, through the DN backbone. Each DPM receives this command and calculates its customer's power consumption.
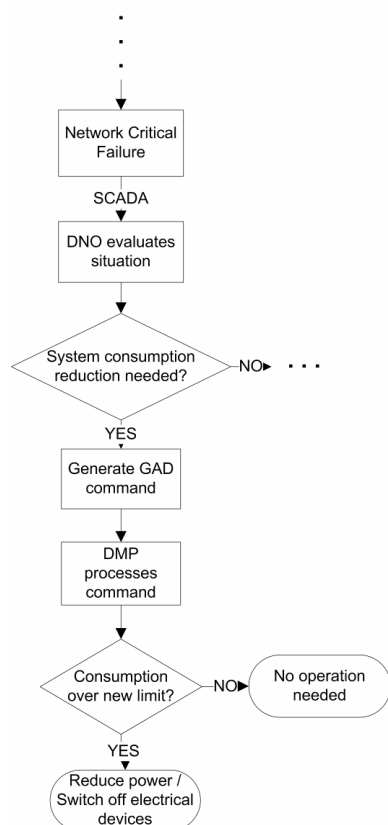

Figure 5: Use case's flowchart

If customer's consumption is over the maximum power consumption fixed by DNO, DPM must reduce the electrical devices' consumption or, even, turn off some devices to fulfil with the DNO command.

CONCLUSIONS

This paper describes a common communication architecture for supplying different services to a DNO. This study is being done by GAD project [4].

The key of this proposal is to establish an IP backbone over the DN. This backbone makes the technologies used over the DN independent from the services implemented by the DNO, reducing the deployment and maintenance costs.

Recently, the only way to get a broadband network over the DN is deploying an optical fiber network over the DN. Although almost all the DNO have deployed optical fibre from Control Centers to Transformer Station, it is very expensive to spread these fibres to the user's homes. Soon

the BPL open standard will be available for LVDN and in-home networks. Then it will be possible to have a real broadband network in the DN until the end consumers, symplifying the migration from DN to "Smart Grids".

Finally, the GAD example has illustrated how a new service can be easily developed over the proposed architecture, reducing the deployment costs.

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