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BROADBAND PLC APPLICATIONS

Working Group
D2.21

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WG D2.21

Broadband PLC Applications

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1 Introduction

Power Line Communications (PLC) is a broadband access technology that uses the low and medium voltage electricity grid to provide telecommunication services. Using the existing infrastructure allows for a rapid network roll out, especially considering that PLC technology and equipment installation has evolved considerably during the past years.

Currently, it constitutes a mature solution for providing a wide array of services such as Internet access, telephony, multimedia and audiovisual services, in-home services, energy related applications, etc.

Energy-related services based on PLC is a line of work inside SC D2 which has not yet been started, representing a field where the power service could benefit from this new technology, as it could increase its operating efficiency and infrastructure usage and incorporate its portfolio of value added services in different areas. The PLC network could also be used as a high performance metropolitan IP backbone telecommunication solution, complementing other telecommunication networks.

The compatibility and synergies between different applications may improve technological feasibility, the reason why research into these matters is considered of great importance and value for the future of PLC.

1.1 Background

In October 2002, a new working group, called WG14-“Broadband PLC”, was launched inside SC D2 of CIGRE with the objective of analyzing two items: medium voltage broadband power line communications (PLC) and energy-related services based on PLC. The first line of action was assessed in the TB285-“White Paper on Medium Voltage PLC Networks”, ref. [2]. The second line of action was put off.

Later on, it was decided to create a new working group inside the SC D2 as well, called WG21-“Broadband PLC Applications”, with the aim of completing the work done on PLC to date ..It was thus decided to resume the initial idea of preparing a technical brochure about energy-related services based on PLC, giving extensive information about how PLC can play an important role in the distribution power grids of the present and of the future.

The initial WG21 meeting was held in Lisbon on 23 September 2005.

1.2 Scope of the document

At present, there is increasing social concern with and problems regarding the quality of the power energy supply, as the recent incidents which occurred in US and Canada, Italy, UK and most recently in North and South of Spain showed. These incidents have focussed attention on electricity companies, calling into question the quality level of the electricity service. Many people think power utilities have to invest much more money in improving distribution network, in increasing power generation, etc. Even though the electricity transmission network was involved in the first incidents (and therefore would remain outside the scope of this document) it is worth mentioning that the repercussion of the phenomenon related to the electrical energy supply outages affects an increasing number of people. In addition, its potential to generate catastrophic effects is ever greater, as our society becomes more and more dependent on this power supply and considers it should always be available.

It can therefore be stated that the capacity to increase the quality of supply is mainly dependent on the company’s capacity to design a flexible medium voltage network. Currently and due to pressure from society to obtain maximum security with regard to supply, companies' efforts are aimed at providing their network with the communication capacity that will allow them to operate and reconfigure the medium voltage network in case of an incident at any point of the network. This involves quite considerable investment in telecommunications infrastructure that not all companies can afford, so the differences between what is considered an adequate service are enormous between one geographic area and another.

At present power grid architecture follows a pyramidal model, from the high voltage (HV) transport network through medium voltage (MV) distribution networks down to low voltage (LV) access networks. Consequently, utilities have put more effort in increasing network automation starting from the top of the pyramid and going down to the following stages. Nowadays, most of the utilities have automated most of the HV/MV substations, providing fully mesh HV and MV networks whenever it is possible. Nevertheless, automation in MV networks is still low although it is now increasing. Although MV networks are meshed, backup reconfiguration is still carried out manually. One of the main barriers to increasing MV network automation is the lack of a telecommunications network in this part of the grid. A fibre optic network has been usually deployed to HV/MV substations, but fibre optic deployment for MV/LV substations is not cost-effective; GPRS communications based on public operators are provisional solutions, but this cannot be considered an optimal solution (coverage problems, public operator dependence, limited bandwidth, etc.); radio-based solutions have coverage problems as well and usually need frequency allocation (which implies an additional fee) This brief reflection points out some of the difficulties in providing not only automation but also many other core applications over medium voltage.

Moreover, there is an increasing interest in Europe regarding AMR (Automatic Meter Reading). Some initiatives made by National Administrations request the deployment of electronic meters by utilities that feature management capabilities. Even though AMR is related to LV network, the huge telecommunications requirements can have synergies with medium voltage telecommunication networks.

This document analyses how PLC could be used in providing broadband telecommunication solutions for core-business applications for both medium voltage and low voltage, offering a future-proof telecommunications infrastructure capable of aggregating different services.

1.3 Structure of the document

During the SC D2 WG21 kick-off meeting it was decided to draw up a questionnaire with some key questions about PLC and Core Applications to be issued as a starting point to find out the vision of each of the partners within CIGRÉ. This questionnaire (see Annex A) has been a helping tool to highlight the matters to be investigated and analysed within the framework of this group. A deeper analysis of the results is carried out in chapter 2 of this document.

Chapter 3 shows a glance at the PLC Technology. Broadband PLC (Powerline Communications) is a technology offering great potential for Energy-related services. It can provide a bi-directional, broadband communications platform capable of delivering real-time data in order to be used in a wide range of applications for the utility such us Automatic Meter Reading and Management, Demand Side Management, Telecontrol and other Medium Voltage network applications. Further information on PLC technology can be found in [1], [2] and [3].

Chapters 4 to chapter 7 describe the core-business applications under the scope of this document. Apart from the service description, case studies from some of the utilities and companies taking part in this WG21 are included. Special attention is paid to the AMR (Automatic Meter Reading) service and to EMS (Electricity Management System) Applications, which are assessed in chapters 6 and 7, respectively.

Chapter 8 describes the concept of smart grids – the grids of the future – analysing what they are, the requirements they have and how PLC can help to reach those goals. Finally, some economic information supporting the previous analysis throughout the document is provided in chapter 9.

2 Main Conclusions of the Questionnaire

In order to understand the applicability of PLC technology, a questionnaire concerning technology interest and use was carried out in the last quarter of 2005, the results of which are presented below.

The questionnaire was addressed to the effective and observer members of Cigré SC D2, as well as to several manufacturers.

The questionnaire sent was divided into three main topics.

1. **Broadband Powerline Technology**, focusing on how mature the utilities and manufacturers feel this technology, and which applications they foresee to using the technology for;
2. **Narrowband Powerline technology**, focusing on the more mature and less powerful but less expensive NB-PLC technology.
3. **Possible core applications**, focusing on the idea each utility and manufacturer has of possible and interesting applications to use these technologies for.

Twenty answers to the questionnaire were received, with the following distribution:

Utilities	85%
Manufacturers	15%
Africa	20%
America	5%
Asia	5%
Europe	70%

2.1 Broadband PLC technology

Regarding Broadband Powerline Technology the results of the questionnaire are detailed in the table below:

		1	2	3	4	5	Weighted average answer
1.	**BROADBAND POWERLINE TECHNOLOGY**						
1.1	**How mature are the existing BPLC systems?** *1-Not mature, 5-Clearly Mature*	0%	5%	45%	30%	20%	**3,7**
1.2	**Is BPLC technology mature enough to be used by Power Utilities in their core applications?** *1-Not mature, 5-Clearly Mature*	5%	20%	25%	30%	20%	**3,4**
1.3	**What is your degree of concern regarding EMC issues?** *1-Very concerned, 5-Not concerned*	10%	20%	25%	25%	20%	**3,3**
1.4	**What can we expect from the standardization institutions and from the regulatory bodies for the next 2 years?** *1-Very concerned, 5-Not concerned*	15%	20%	45%	15%	5%	**2,8**
1.5	**What can we expect from the standardization institutions and from the regulatory bodies for the next 2 years?** *1-Nothing, 5-A lot*	0%	35%	40%	20%	5%	**3,0**
			Yes		No		
1.6	**Does your company have any BPLC deployment?**		35%		65%		**No**
1.7	**If yes, how many Homes Passed have you covered until today?** *1-Less than 1.000, 2-Less than 1.000, 3-Less than 10.000, 4-Less than 50.000, 5-More than 50.000*	43%	0%	14%	0%	43%	**3,0**
			Yes		No		
1.8	**If no, do you have any plans to deploy BPLC in the near future?**		23%		77%		**No**

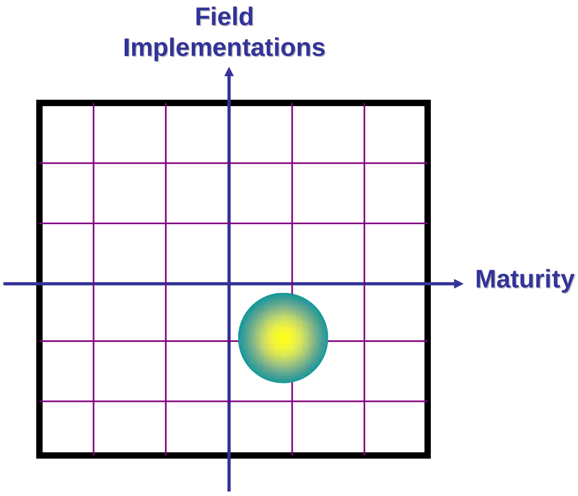
With these results we can make some basic statements. The first seems to be that it is clear that for the vast majority of utilities Broadband PLC is a stable and mature technology without any concerns in the EMC area.

EMC does not seem to be a major concern since the majority answered that they were not concerned with this issue.

A regulatory void is predicted by most of the respondents. This is probably due to the fact that PLC is a technology that falls in the middle of two traditionally separate worlds. Therefore some difficulty is expected in such a slow pace area such as regulation. This however is not foreseen as troublesome.

Probably due to the fact that most utilities halted their telecom interventions in the years 2001-2005, there are still a lot of utilities that have not deployed or do not intend to deploy PLC in the near future.

The main results of this part of the questionnaire can be depicted in the following graph:



2.2 Narrowband PLC technology

Regarding Narrowband PLC technology, the results of the questionnaire are detailed in the table below:

		1	2	3	4	5	Weighted average answer
2.	**NARROWBAND POWERLINE over LV and/or MV distribution lines**						
2.1	**How mature are the existing NPLC systems?** *1-Not mature, 5-Clearly Mature*	0%	11%	47%	11%	32%	**3,6**
2.2	**Is NPLC technology mature enough to be used by Power Utilities in their core applications?** *1-Not mature, 5-Clearly Mature*	11%	16%	26%	21%	26%	**3,4**
			Yes		No		
2.3	**Does your company have any NPLC deployment?**		39%		61%		**No**
		1	2	3	4	5	
2.4	**If yes, how many Homes Passed have you covered until today?** *1-Less than 1.000, 2-Less than 1.000, 3-Less than 10.000, 4-Less than 50.000, 5-More than 50.000*	29%	0%	57%	0%	14%	**2,7**
			Yes		No		
2.5	**If no, do you have any plans to deploy NBPLC in the near future?**		18%		82%		**No**

Also with this technology, maturity is not a concern. However, we can see that there are not many companies with deployments of this technology in their grids as well as seeing that there are not many companies envisaging that deployment in the near future.

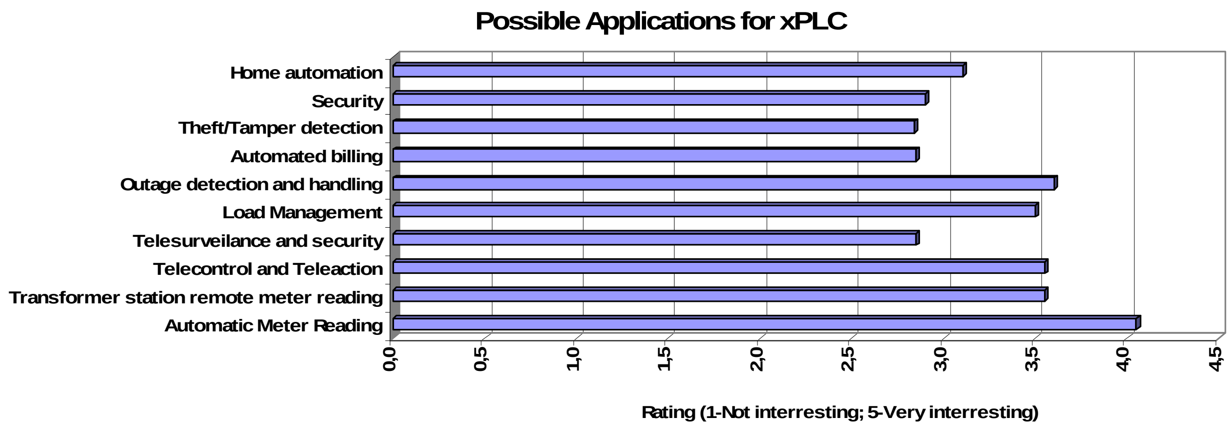
This picture may change if we consider the fact that due to energy regulation utilities may be forced to improve their grid manageability and customer billing control and therefore may be forced to introduce some communication mechanisms in their networks. This will probably require xPLC installation.

2.3 Possible Applications

Regarding the possible applications of these technologies the results of the questionnaire are detailed in the table below:

		1	2	3	4	5	Weighted average answer
3.	**POSSIBLE CORE APPLICATIONS**						
	Please rate from 1 to 5 (1 is lowest interest and 5 is highest interest) the following applications:						
3.1	**Automatic Meter Reading** *Metering the energy in the clients house*	10%	0%	5%	45%	40%	**4,1**
3.2	**Transformer station energy remote meter reading** *Metering the energy consumption in the transformer station*	15%	5%	15%	40%	25%	**3,6**
3.3	**Telecontrol and Teleaction** *Environmental conditions metering, Switch activation, etc.*	10%	20%	10%	25%	35%	**3,6**
3.4	**Telesurveilance and security** *Transformer and sub-station video surveillance. Speacial sites surveillance*	15%	15%	50%	10%	10%	**2,9**
3.5	**Load Management** *Load monitoring of special power sites*	10%	15%	25%	15%	35%	**3,5**
3.6	**Outage detection and handling** *Remote control the MV/LV network and prehemptive detection of outages*	10%	10%	20%	30%	30%	**3,6**
3.7	**Automated billing** *Automatic billing and web available invoice*	35%	5%	25%	10%	25%	**2,9**
3.8	**Theft/Tamper detection** *Usin load management and monitoring, detect non-technical losses*	32%	21%	5%	16%	26%	**2,8**
4.	**OTHER APPLICATIONS (BESIDES TELECOM AND CORE)**						
	Please rate from 1 to 5 (1 is lowest interest and 5 is highest interest) the following applications:						
4.1	**Security** *In-house security monitoring*	25%	25%	10%	15%	25%	**2,9**
4.2	**Home automation** *In-house home aplliances automation*	21%	21%	11%	21%	26%	**3,1**

The result of the ratings stated by each of the respondents can be depicted in the following graph:



As can easily be seen, AMR (Automatic Meter Reading) is, by far, the most popular application followed by the type of applications we can classify as ***Grid Control*** applications (TS remote meter reading, Tele-control and Tele-action, load management and outage detection).

Applications related to the customer home are rated less. However, that may be due to historic reasons.

We must remember that only very recently has the liberalization of the energy market been discussed and therefore creating new services and application to bind the customer are still not the main priority inside utilities.

3 Powerline Communications Technology

3.1 PLC system

Powerline Communications (PLC) is a technology that allows us to meet existing demand by using current electrical network infrastructures. It is only necessary to prepare part of the electrical infrastructure so that it can transmit regular low frequency signals and others up to 30 MHz, without the electrical efficiency being affected. The low frequency signals (50 or 60 Hz depending on the network) are responsible for transmitting the energy, while the higher frequency signals can transmit data through the electric lines.

The advantage of PLC in comparison with other data transmission systems and broadband services is that it can offer these services on a currently existing infrastructure. It is only necessary to adapt the data signals to this physical medium.

Electrical companies have been using narrowband PLC technology for a long time to exchange information between substations, typically to transmit simple orders and to provide voice channel for maintenance purposes. Narrow band technology has basically been used for Automated Meter Reading (AMR) and Demand Side Management (DSM) services.

Differing from the well known analogue and digital PLC systems based on CENELEC band (3-148.5 kHz) that provide narrowband applications, Broadband PLC uses higher frequencies ranging from 1 to 30 MHz.

Utilities have followed the latest generations of Broadband Powerline Communications (PLC) technology using Low Voltage (LV) and Medium Voltage (MV) distribution networks for transporting high rate telecommunication signals with great interest and thoroughly tested them. New modulation techniques mainly based on Orthogonal Frequency Division Multiplexing (OFDM) are used to achieve Mbps bandwidth. There are chips offering at least 200 Mbps raw throughput.

Typical applications provided by broadband PLC technology in current deployments are telecom services to final users such as broadband Internet access or voice (VoIP) and public services. In addition, or alternatively, utilities can use it for their own needs, especially to meet new challenges.

3.2 Network Topology

Broadband PLC technology usually aims at providing access and distribution communications from a conventional telecomm backbone to the customer premises.

In accordance with figure 3-1, three levels of the PLC network can be differentiated [1]:

- The PLC Access Network
- The PLC Distribution Network
- The Services Provision network

The LV grid serves as the access part of the telecommunications network where the PLC technology is used. This level interconnects the PLC modems, or CPEs (Customer Premises Equipment), through the LV lines with the PLC Transformer Equipment (TE).

The distribution network interconnects the PLC TEs installed in the MV/LV substations.

At some point in the PLC Distribution Network it is necessary to interconnect to the Services Provision network, which can be a telecommunications operator providing Internet and Telephony services, as depicted in figure 3-1, and/or the utility own network providing services related to core applications.

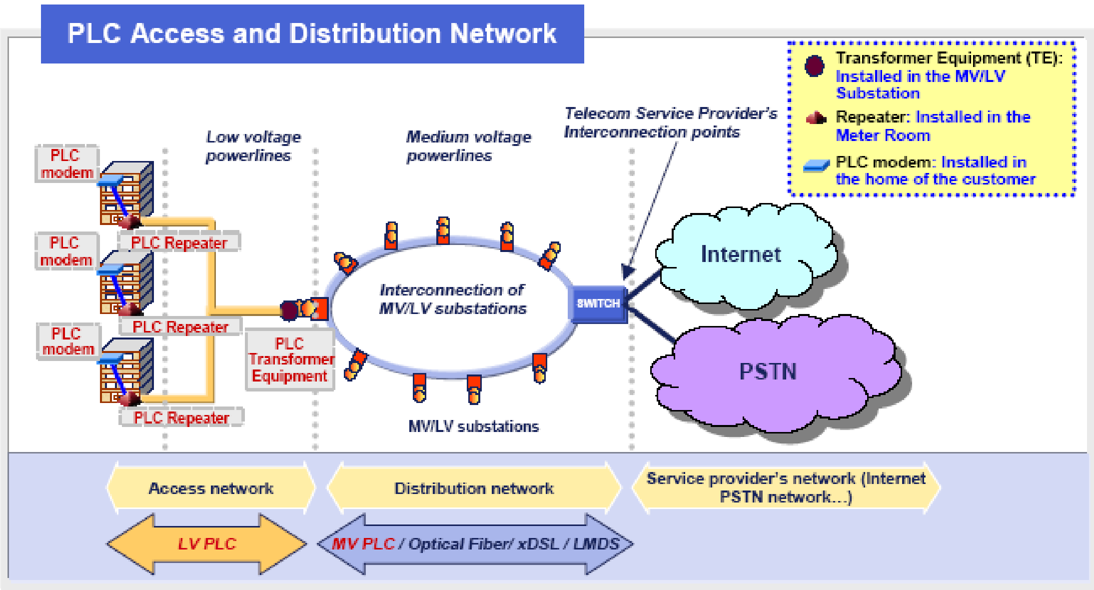


Fig. 3-1 Access Network Topology (Source: Endesa Net Factory)

3.3 PLC Equipment

Broadband PLC technology uses different equipment along the power grid to provide services. Depending on the part of the grid where they are installed (MV or LV grid) and the function performed (Master, Endpoint), a typical PLC network consists of:

- MV master, MV repeater, MV endpoint
- LV master, LV repeater, LV CPE

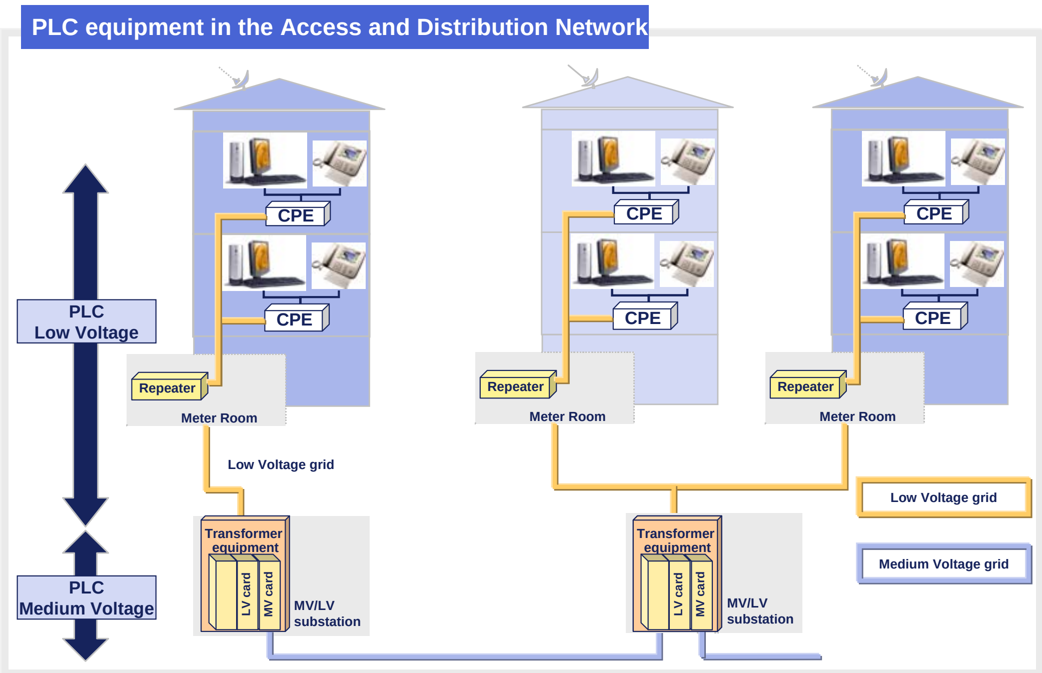


Figure 3-2 PLC Equipment in the Access and Distribution Network (Source: PLC Utilities Alliance, PUA-2004)

As the power grid is a shared physical medium, medium access control is carried out by master nodes that control the repeaters and slaves. There are two patterns of medium access:

- Based on frequency division: different links use different frequency bands;
- Based on time division: links belonging to the same time domain use the same frequency bands, and share the bandwidth according to a time slot pattern.

In addition to Access PLC, there are also other broadband PLC systems very focused on In-home communications, providing telecommunications services within the customer premises grid. The coexistence between both technologies is a very important matter and the most important international standardization bodies, such as IEEE and. CENELEC, are currently working to define a coexistence method.

More detailed information concerning PLC technology may be found in [1], [2] and [3].

3.4 Coupling Devices

Coupling devices are used to inject and recover the communication signal to and from power distribution lines, which are the transmission media in this application.

There are two kinds of coupling methods. Direct access to the distribution line by means of connection of a capacitor or accessing by magnetic action so that no electrical connection is needed.

Both types of coupling devices are widely described in the CIGRE publication, issued on December 2005, WHITE PAPER ON MEDIUM VOLTAGE POWERLINE COMMUNICATION (PLC) NETWORKS, ref. [2], which is the result of the work done in Working Group D2.14.

Given that all the technical details are provided in this publication, only a brief summary of these devices will be included here.

Capacitive coupling

This is achieved by means of connection of a capacitor to the distribution conductor and to the tuning elements included in the device. Basically, the system works as a four-pole device, like a filter, where the main goal is to match the characteristic impedance of the distribution cable and the impedance of the communication terminal. The efficiency of this method is given in terms of return loss and composite loss within the operating frequency range. Because of this direct connection to the distribution line, protection elements, like a drain coil and surge arresters, are usually included in the system.

In this type of coupling the isolation characteristic and related topics are of primary concern.

Figure 3-3 Capacitive coupling

Inductive coupling

In this case the operating principle is based on a current transformer. A magnetic core is clamped around the distribution cable and the signal is applied to a signal winding so by means of magnetic action the signal is coupled as a current to the distribution media. Depending on the type and constitution of the conductors, overhead lines or underground cables which in turn could be shielded or non-shielded, different types of magnetic couplers and different mounting arrangements are used.

An important feature of this coupling method is the capacity of the magnetic core to withstand high values of current intensity in the distribution conductor without provoking magnetic saturation to the core itself.

Figure 3-4 Inductive coupling

3.5 Opera project

OPERA stands for Open PLC Research Alliance and aims to develop a new generation PLC access standard to accelerate the adoption of low cost, high performance broadband access PLC [12].

The OPERA specification for BPL access applications adopted in 2006 is based on DS2's 200Mbps technology and was developed by a consortium of 37 companies. This specification, the only open, global specification for access BPL, generated valuable contributions that have been submitted to the Powerline standardization work underway in both the Institute of Electrical and Electronics Engineers (IEEE) and the European Telecommunications Standards Institute (ETSI)

The second phase of the OPERA project (2007-2008) has 26 partners including electricity utilities, OEM manufacturers, technology providers, universities, engineering and consultancy companies, and telecom operators. OPERA is co-financed by the European Union under the Sixth R&D Framework Program (FP6), and specifically addresses the theme "Broadband for all", which falls under the responsibility of the Information Society and Technologies Directorate General (www.ist-opera.org).

The objective of OPERA Phase II (OPERA 2) is to catalyze the deployment of low cost broadband access applications over electricity networks for a wide range of applications and employ cases that include:

- Broadband Internet Access
- Telephony
- New intelligent grid services (Smartgrid)
- Video over IP
- Video on demand
- Smart Home
- Security
- E-learning
- E-Health

The OPERA 2 project organization is similar to other European financed projects and includes four entities: Steering Committee, Technical Committee, Working Groups and the General Assembly.

The consortium supporting the project is led by the Spanish utility Iberdrola.

The project has installed three field trials in Linz, Lisbon and Madrid, and in January 2008 these were running successfully and providing services, such as Internet Access, Telephone, IPTV and others to customers.

Referring to January 2008, the following list of deliverables had been accomplished:

Number	Deliverable Name
D2	Programmable Band Pass Filter
D8	EMC Measurement Report on Efficiency of EMC Mitigation Mechanisms
D11	Reference guide on the description of field trials and test procedures
D12	Preliminary results of the performed tests
D13	Reference Guide on the design of an Integrated PLC Network including the adaptation to allow the Carriers' Carrier model
D14	PLC field trials, Deployments and Installation Issues
D20	Requirements on OPERA for Implementation of Multipurpose PLC networks including EMS
D23	Services Test Specification
D25	Whitepaper: Electricity Management Systems
D27	First draft of OPERA specification version 2
D38	Web page: permanent updates and maintenance
D42	Portable show room
D50	Brochures and posters
D51	Whitepaper: OPERA technology
D52	Whitepaper: comparison of Access Technologies
D55	IPR guideline: Annex I legal Protection
D56	Project presentation

3.6 Standardization

For the moment, there is no standard for Broadband PLC but there are several independent and proprietary initiatives which have evolved performances and functionalities found in the current technology. In order to overcome this situation, working group P1901 has been set up by the IEEE to define a standard for PLC.

The project the working group will develop is a standard for broadband devices (>100Mbit/s on the physical layer) over power lines. The standard will consider the transmission of signals below 100MHz and will be applied to any PLC devices working in the following environments:

- Access PLC, to allow last mile connexion by broadband services (>1500m to the user);
- In-home PLC, for devices used for in home LANs and other data distribution (<100m between devices);

The standard will also define detailed mechanisms for the co-existence and interoperability of different PLC devices, assuring suitable bandwidth and service quality. Aspects related to the security required to assure communications privacy will also be considered.

At the time of conclusion of the present TB, the target for the IEEE baseline approval was July 2008. A suitable migration plan for the OPERA system will be prepared as soon as the IEEE P1901 baseline is accepted.

4 Applications and Services

4.1 Definition

Once an electrical infrastructure is planned, engineered, deployed and ready for service by an electrical company, a considerable number of applications can be supplied to customers. The application definition should firstly take into consideration the different steps involved in the total energy chain and, secondly, the customer's requirements for guaranteeing new electrical challenges. The following picture shows the most general energy chain, from the generation centres to the final electrical customers, passing through the delivery segment.

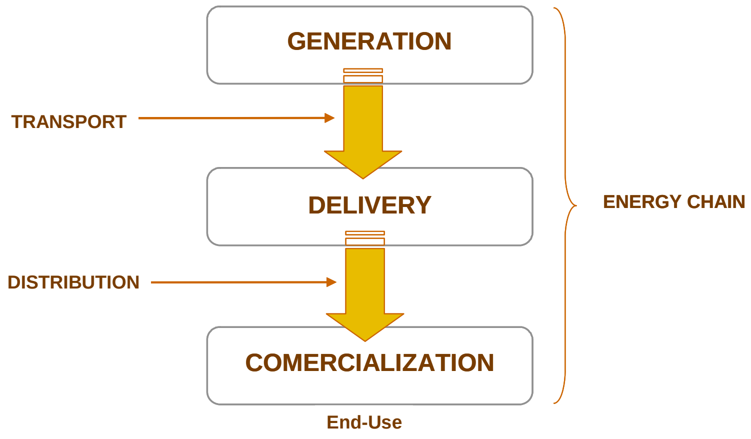


Figure 4-1 Energy chain

The first question we ought to answer in order to understand application definition is regarding service clarification. Electrical service refers to all the activities carried out by electrical companies for guaranteeing customer requirements to fulfil specific needs or to maintain widespread satisfaction and perception attitudes. But who are the customers in this process? Nowadays, Utilities' customers reside not only at the end of the energy chain (external end-user customers in the utility commercialisation business branch) but also inside companies (internal customers, belonging to the whole energy chain: three business branches). The former feels the service as a good directly delivered by the power supply company in terms of quality and new added value functionalities and, on the other hand, the later takes into consideration new core applications allowing the use of best company competitive practices in order to increase the value of their total assets.

Current trends resulting from regulatory statements have forced Utilities to provide in-depth analysis of, the potential impact on their infrastructure and customer services, trying to imagine the benefits and disadvantages of applying these recommendations or not.

The next figure summarises the main regulatory considerations and activities that could apply to Utilities nowadays: activities oriented to maximizing power supply and product quality, demand response and energy saving policies and finally, regulation aspects for distribution generation and micro generation challenges.

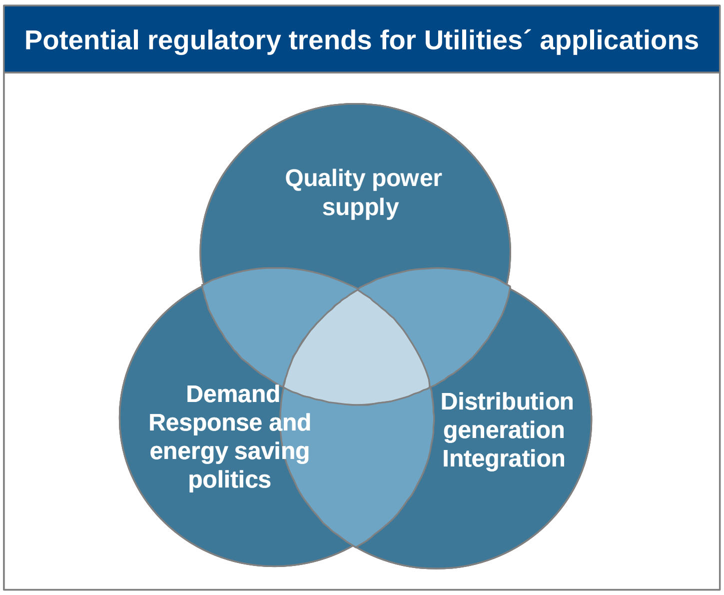


Figure 4-2 Potential regulatory trends for Utilities' applications

- **Power and product Power Supply:**
  - Maintenance and Operation of more sophisticated activities such as CBM maintenance.
  - Relevant reduction in Total Interruption Time equivalent to Installed Power.
  - More telecontrolled transformer substations.
  - Advanced models for failure detection and faster repositioning and recovery procedures.
  - Increasing the information made available to all work force teams.

- **Demand Response and energy saving policies:**
  - EEC Demand Response programs.
  - Energy efficiency.
  - Implement smart metering tools and systems.
  - Reduce the technical losses in the Distribution infrastructure.
  - Different tariff hour ranges.
  - Clarification of CO_2 and NO_x limits.
  - Evaluation of a new potential tariff framework regarding energy efficiency distribution
  - Climate Change trends.

- **Distributed Generation integration:**
  - Potential new specific normative situation for renewable energy plants.
  - Obtain more information about all energy flow in more electrical nodes.
  - New prediction techniques for total energy generated.
  - To control and telecontrol all the new renewable and microgeneration power plants.
  - To develop more communications network with electrical nodes in order to facilitate DG integration.

All of these challenges will condition the future status of the utilities' services and applications that should be implemented. Before considering a particular technology for offering these services, it is necessary to make some remarks about requirements, procedures modifications and of course, customer expectations from the internal point of view (electrical company) and the external one, basically that conditioned by regulatory recommendations and mandatory laws.

Once all these characteristics have been analysed and taken into consideration, the final step is to select the most appropriate technology to satisfy the main features restrictions. PLC is a general multipurpose technology that can allow utilities to achieve their subsequent electrical expectations and goals. The main question here is to clarify the most appropriate PLC technology. PLC technology is a present-day technology mature enough to provide BB and NB services over the common electrical infrastructure.

The final decision will only depend on all the physical features needed and selected for the supported services, on selected assumptions for regulatory trends as well as the road map concerning the number of services offered with the same telecom network architecture (as in the following figure).

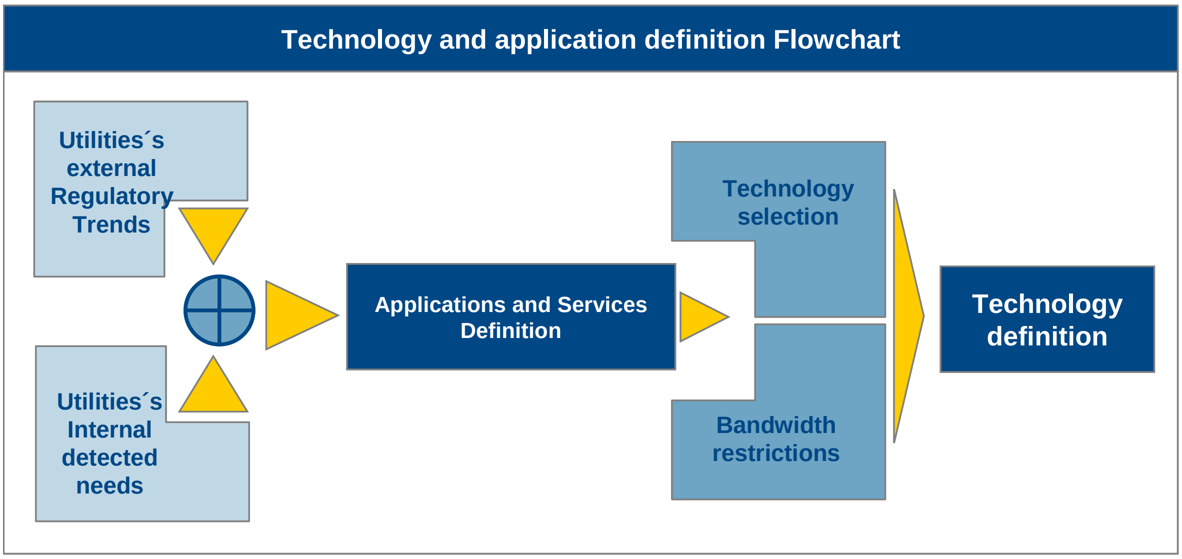


Fig. 4-3-Technology and application definition flowchart

One of the most important activities in the global application definition flowchart is the services definition needs. They are the main issue that finally leads the Utilities to select a particular PLC technology, BB or NB.

4.2 Broadband PLC Applications for External End-Users

External End-User Broadband PLC services enable all the new functionalities that a Utility could provide using PLC technology to their customers. Of course, these kinds of services are mainly offered by using LV infrastructures and in some cases, by the use of PLC over the MV grid. At the moment, only the two final energy chain steps are involved in all these BB PLC applications: Delivery (Transmission and Distribution) and End-Use (Commercialization branch).

At first, Broadband PLC end-user services were focused on Telecommunications Internet Access and immediately afterwards on VoIP. In a second stage, a wide range of services and applications have been provided by PLC in different fields:

- Internet Broadband Access, with transmission ratios similar to other competitive access technologies.
- Telephony and VoIP applications.
- In-Home advanced applications: In-home services, telesurveillance, multimedia services, residential gateways for electrical value added services.

Trying to analyze the total end-user customer base of a single Utility, it is necessary to note not only users connected with the company through their energy supply contract (electrical customer), but also all the users belonging to third parties such as operators, local administrators, City Councils, municipalities and other small services companies (telecoms, gas, water, etc). In these new cases, the use of LV infrastructure, extending also to the use of MV Infrastructure allows utilities to offer new BB applications such as the following:

- Integrated Measurement services (gas, water, etc.),
- Last mile connectivity and in home services,
- Control services for urban buildings,
- Road and traffic signalling,
- Urban telesurveillance and security systems and policies,
- Broadband internet access, etc.

4.3 Broadband PLC Applications for Internal End-Users

Direct applications for Broadband PLC services are focused on internal utility uses. In this sense, the three steps of the energy chain are involved. The main advantages that we can obtain from the applications of PLC technology in the Utilities are profit in terms of efficiency throughout the process and activities in the daily operation and maintenance of the electrical infrastructure. The complete information that we can obtain and gather concerning all the elements deployed in the electrical grid with the use of BB PLC is a fact.

One of the newest trends for Internal Broadband applications using PLC technology concerns the capability of detecting and predicting infrastructure failures in advance, taking into the consideration the main PLC features:

- Bi-directional communications,
- Real-Time capability,
- Always on availability,
- Response Time,
- Security.

For all of these reasons, integration in the Utility of the PLC monitoring system and Telecommunications Centre as well the MV and LV Network Management and Control Centres are needed.

In this sense, a new definition of core applications will occur: an internal service and management tool for improving service and product quality, making operational and maintenance processes improvements and generating more efficiency, enabling very fast reaction and maximising cost savings and leading to higher customer satisfaction.

The application and use of PLC technology offer Utilities the key to a new world of energy-related services, taking the PLC into account as a potential player in next systems generation and the deployment of the new smart grids challenge.

The following table shows the average coverage of twelve electrical services for automating the MV and LV electrical network, in terms of technical requirements and service cataloguing (critical, desirable and non critical) for Utilities.

Electrical Services for MV and LV electrical network														
	SERVICES	**Critical (1)**	**Desirable (2)**	**Non Critical (3)**	**Priority**	**Bandwidth**	**Traffic Type**	**Latency**	**Jitter**	**BER**	**UPS**	**Time of network recovery**	**% coverage**
1	**Telecontrol**	X			Yes	9.6 kbit/s	Random	< 0,5 s	NA	NA	Yes	< 1 s	10 to 15%
2	**Telecontrol (Fault detection)**	X			Yes	9.6 kbit/s	Random	NA	NA	NA	Yes	< 15 s	> 50%
3	**Operational Telephony**	X			Yes	8 kbit/s	Random	< 0,5 s	< 30 ms	1E-03	Yes	< 15 s	< 10%
4	**Corporative application access**		X		No	2 Mbit/s	Random	< 1 s	NA	1E-05	Yes	NA	< 10%
5	**Video surveillance**		X		No	256 kbit/s	Continuous	< 1 s	NA	1E-04	Yes	NA	< 10%
6	**Video supervision**		X		No	64 kbit/s	Periodic	NA	NA	1E-04	Yes	NA	< 10%
7	**Alarm management (Temp., humidity, gas, flooding etc)**		X		Yes	9.6 kbit/s	Random	< 30 s	NA	NA	Yes	< 15 s	10 to 15%
8	**Telemeasurement. Product and Power quality**			X	No	9.6 kbit/s	Periodic	NA	NA	NA	No	NA	> 30%
9	**Protection Telemeasurement (oscillogram download)**			X	No	64 kbit/s	Random	< 1 s	NA	1E-05	No	NA	< 10%
10	**Operation/Supervision TELECOM network**			X	No	(4)	Continuous	< 1 s	NA	1E-04	No	NA	10 to 15%
11	**AMM and AMR**		X		No	(5)	Periodic	NA	NA	NA	No	NA	> 95%
12	**Load Management**		X		No	2 Mbit/s	Periodic	< 1 s	NA	NA	No	< 1 s	10 to 15%

NOTES:

(1) Redundancy of Physical telecom. network and continuous power supply.
(2) Availability not dependent on power supply
(3) Medium and Long-term non-availability allowed.
(4) This depends on the number of facilities installed and the Operation and Supervision purposes
(5) This depends on network architecture

4.4 Protocols and services transported over a PLC network

It has been stated that a broadband PLC network makes it possible to deploy an IP network that supports any kind of IP protocol or traffic. Out of all these different types of traffic that can be transported over a TCP/IP network the most commonly known and considered when talking about data transported using broadband PLC technology is customer services traffic such as broadband Internet Access or Voice over IP, but for the utilities there is also a wider range of possibilities that can be considered in advance such as all the protocols needed to support real time telecontrol and AMR. It must be considered that as well as all of the types of IP traffic for applications that could be transported, the network also provide enough capacity to transport other management services and applications such as SNMP (Simple Network Management Protocol) or dedicated traffic using different virtual LANs (IEEE 802.1Q) and/or prioritizing (IEEE 802.1p) the traffic.

As with PLC technology there is the possibility of having an IP network and an access point in every place where there is electrical infrastructure, the utilities have the opportunity of communicating any point of its "electrical infrastructure" for maintenance, monitoring, billing, metering and operational purposes. So, in order to develop this statement further and taking into account that the use of the PLC technologies is more suitable for MV secondary distribution network and LV access network, this section will explain in a little more detail some trends in the use of protocols that can be transported over a PLC network.

4.4.1 Distribution Network

Development of new data communication standards and data models can be divided into three levels: 1) standards and models within the control centre, 2) standards and models between control centres and substations and 3) standards and models within and between substations. In the event of using broadband PLC technology for the MV distribution network, this third level can be extended to standards for MV/LV transformer stations communications.

The future architecture to be created by IEC TC57 describes the standard for communication within the substation, between substations and between substations and control centres. The full standard regarding the reference architecture is still under development and at this moment not all IEC 61850 interfaces and objects have been described. For communication between control centres the IEC60870-6 (TASE.1 and TASE.2/ICCP) standard was finished more than a decade ago and TASE.2 is commonly used all over the world. The TC57 reference architecture foresees that the CIM (IEC61968 and IEC61970) will be the standard for data exchange within the control centre enabling integration between multiple expert systems from the planning, operation and maintenance departments.

In addition to IEC it is important to be aware of several de-facto standards. Besides IEC60870-5, which is very commonly used in Europe and Asia, the US described the DNP protocol. DNP is very commonly used in the US, Latin America and Australia. DNP and IEC60870-5 are very common and support the same functions. The trend in Europe is to focus on IEC standards and so DNP is very little used. For control centre – control centre communication the Elcom-90 protocol was created in the Nordic countries. Nowadays many utilities in North-west Europe still use this protocol. Availability of products and knowledge however force more and more companies to switch to its IEC competitor TASE.2. In The Netherlands, Belgium and Denmark utilities are migrating to IEC60870-6. The trend is that within a five to ten year period no new products will be available anymore that support Elcom-90 and so only TASE.2 will be used. A third solution, besides International standards and de-facto standards, is the use of proprietary solutions.

A clear trend in order to extend telecontrol services to the MV distribution network using an IP network is to use IEC 60870-5-104, the internationally accepted protocol.

Other PLC services could be used using the existing Distribution network besides telecontrol services. These services are described in more detail in the following sections of the document:

- MV Core Applications: Utility application centralized ripple control, Substation monitoring and power quality, distributed energy control, Partial Discharge applications,
- Automation Distribution Applications: Telemeasurement, Fault Detections and Telecontrol.
- Other Value Added Services: Operational Telephony, Video surveillance, video supervision, Alarm management, etc.

4.4.2 Access Network

At this point the services that can be supported using PLC technology are principally services related to the customer, i.e. AMR services, bidirectional communication between the customer and the utility, demand management and load management.

Although some of these services have been developed with the purpose of using Narrow Band PLC technologies, there are greater opportunities if a broadband PLC transport technology is used in order to develop new capabilities and services aimed at implementing the Smart Grid scenario.

Nowadays is difficult to find protocol stack architectures and data models totally oriented towards the requirements of AMI. A (non exhaustive) list of standardization committees relevant for AMI includes: :

- IEC (and CENELEC) TC 13, Electrical energy measurement, tariff and load control;
- CEN TC 294, Communication systems for meters and remote reading of meters (Note: covers utility meters other than electricity),
- IEC TC 57: Power systems management and associated information exchange;
- CLC TC 205: Home and Building Electronic Systems (HBES);
- CLC/SC 205A: Mains communicating systems;
- ANSI C12: Electrical measuring equipment;
- ISO/IEC JTC 1/SC 25/WG 1 Home electronic systems;
- DLMS User Association;
- Zigbee Alliance;
- M-Bus Association;
- KNX Association;
- Euridis Association.

Regarding the IEC TC 13 standards (IEC 62056 DLMS /COSEM), this suite specifies an application model using object-oriented techniques for electricity metering. For utility metering other than electricity, the standards specified by IEC TC 13 have been adopted and extended by CEN TC 294 (EN 13757-1).

The DLMS/COSEM model offers a standard protocol solution for communication with Smart Meters. It specifies:

- An application model: The COSEM object model covers all energy types: electricity, gas, hot/cold water, heat.
- Communication profiles and protocols: DLMS/COSEM currently specifies three communication profiles, based on a collapsed OSI model and popular internet standards:
    - 3-layer, HDLC based, connection oriented profile for data exchange via PSTN, GSM.
    - TCP/IP based profile, for data exchange via an IP network which can be directly supported by broadband PLC technology.
    - Profiles for Power line carrier (S-FSK).
    - The top layer, i.e. the Application layer, is common to all communication profiles.
- Standards for twisted pair.
- Data security.
- Conformance testing.

4.5 Specific cases

The application and use of PLC technology offer Utilities the key to a new world of energy-related services, taking the PLC into account as a potential player in next systems generation and the deployment of the new smart grids challenge.

The following chapters, Chapters 5, 6 and 7, include some specific cases and examples, both in NB and BB, using PLC technology in different European utilities using an MV and LV infrastructure.

5 MV Core applications

Medium Voltage Core applications are a wide field consisting of interesting possible services. In times of new quality requirements and intense market pressure the utilities operating MV and LV grids need to be flexible, smart and rapid. New challenges have to be managed and solved quickly. The MV grid plays a crucial role in providing reliable service to the customers and optimised workflows.

Both needs require up to date data and knowledge of what is going on in the MV grid. Therefore the collection and analysis of working parameters is essential. The second part of these requirements can be covered by enhanced remote control services, which provide the operator with new tools for service creation, fault management and maintenance.

This chapter provides some examples regarding the multiple possibilities Broadband PLC (BB-PLC) is providing for MV core applications. Beside the substitution of classic telecommunication cabling or outdated technology, new innovative services can be created by using BB-PLC.

An overview of the different types of BB- PLC services is provided, starting with classic centralised ripple control application and substation-monitoring and then looking at BB-PLC as general communication path for utility control, including distributed energy generators and concluding with quality measurements of MV lines by correlating the HF signals of BB-PLC with the occurrence of line failures.

The whole chapter is rounded off by two case studies from PPC and ENDESA companies.

5.1 Utility application centralised ripple control

The basic application ripple control today has different tasks such as:

- Consumer load control;
- Load management (heating, pumps, industrial cooling systems);
- Street Light control;
- Traffic sign light control;
- Tariff switching;
- Reactive power compensation.

Based on a Broadband Powerline network PPC is nowadays working with dedicated Powerline modems to apply the above function on the network. In this way a central control server is able to communicate in a bidirectional manner with the receivers. So the switching of each receiver is dedicated and manageable and the switch status is indicated by colours (see Figure 5-2). In contrast with the ripple control systems today, where only unidirectional communication is possible, the Broadband Powerline solution has bidirectional possibilities and can control the action itself.

Comparing the communication path on the network, the mature ripple control has no encryption or similar mechanism, whereas using BPL enables safe transmission with dedicated security protocols for higher security demands.

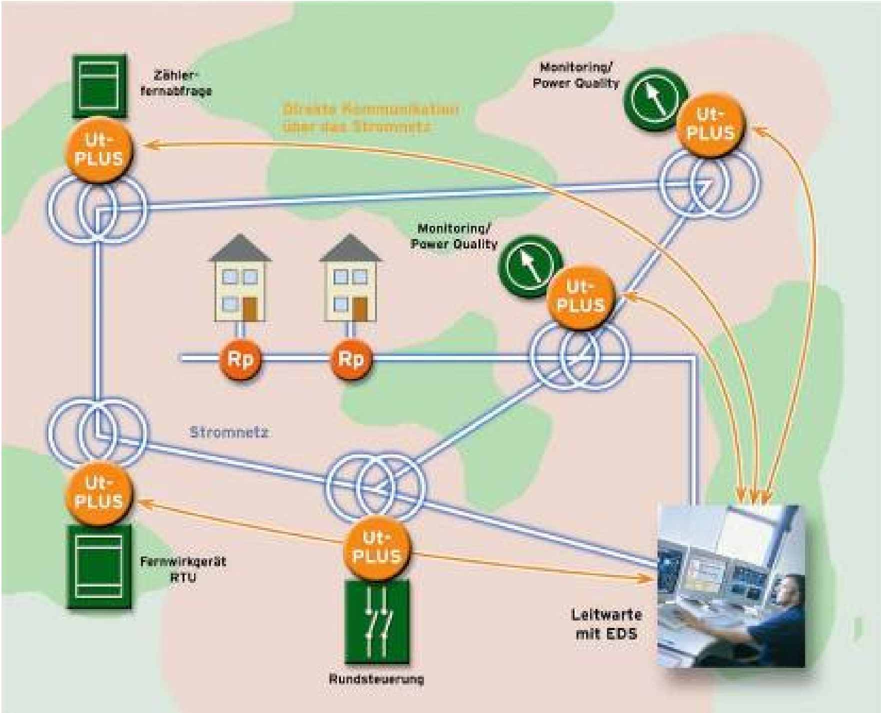


Figure 5-1 : Utility application in the distribution grid with BB-PLC

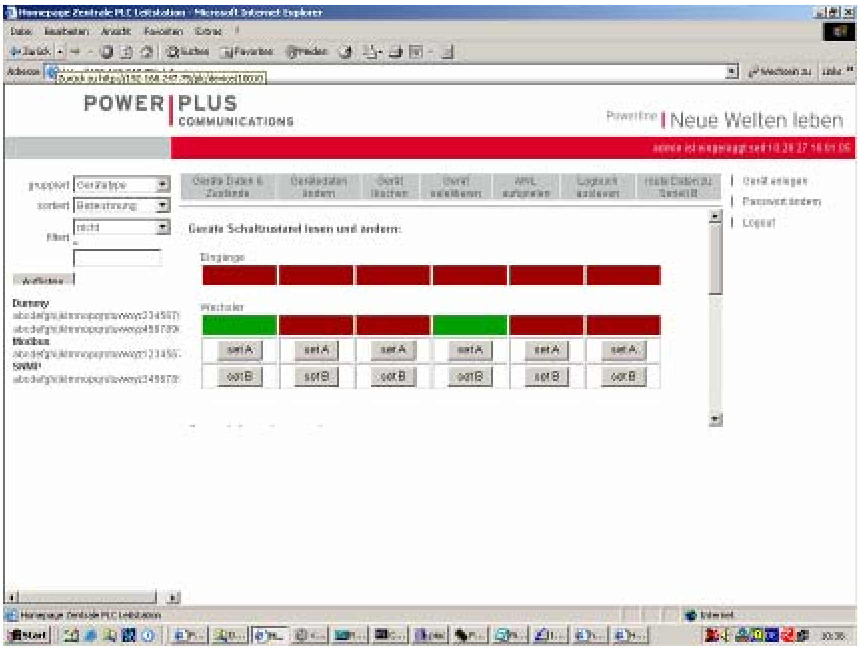


Figure 5-2 : Control button and Status of ripple control receivers with broadband PLC

5.2 Substation monitoring and power quality

For asset management and network control, monitoring in the transformer station is required. Judging the load of the transformer station has mainly been carried out at key points.
Furthermore, changing the service schedule from periodic to individual maintenance requires relevant data for each item in the transformer station. New maintenance guidelines can now be developed with real data and not estimated information. As shown in Figure 5-3 new equipment with Powerline communication has been installed in a transformer station to obtain reliable load data.

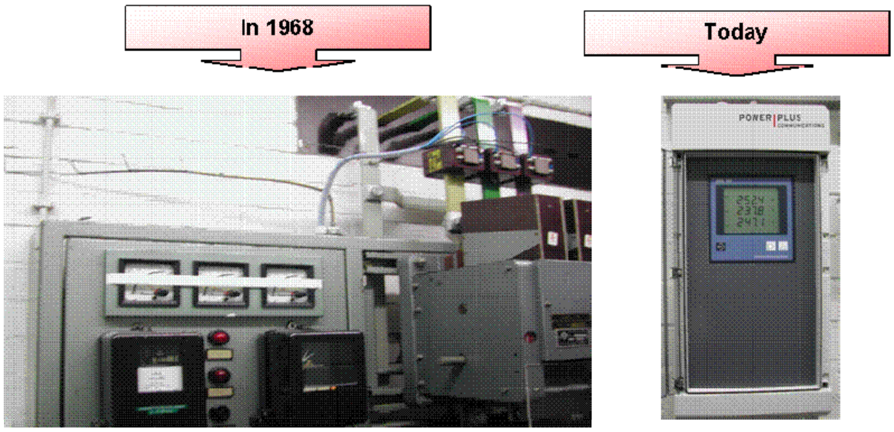


Figure 5-3 : Upgrading Transformer Station to Intelligent Measurement Points with BB-PLC

Due to modern Broadband Powerline Technology the actual load values from the transformer stations are online on the desk of the grid planner. This is provided through BB-PLC with standardised IP protocols connected to the citywide fibre optic backbone. A direct communication path up to the central control room of the MVV Energie AG in Germany was built. The transparent data technology for the Broadband Powerline has enabled a virtual private network to the transformer station and guidelines for secure and reliable communication centering on the utility have been met. Access to the information was based on web access technology in the PPC data server. As such the office LAN becomes a communication path for utility processing data.

5.3 Broadband Powerline as communication path for utility control

Using PLC communication as a communication path for substation control has extended network use and saves capital expenditure on more control applications. Today IP based substation control protocols such as IEC870-5-104/IEC61850 have come into use and are suitable for BB-PLC. The remote terminal units usually control the status of the breakers, switches and tap changers. In Figure 5-4 the RTU equipment has been installed in a transformer station with BB-PLC.

Figure 5-4 : Broadband PLC with RTU-Equipment

5.4 Broadband Powerline for distributed energy control

A local Powerline communication island for requirements of future distributed energy sources has been created in the low voltage grid at the Karlsruhe utility. The task was to connect electrical supplier and consumers in a low voltage grid containing data communication, to fulfil the requirements for load and generation management. The Powerline equipment was installed at the location of the generator and consumer units. The equipment was installed in the control panels or electricity grid with relatively little effort required. The communication itself works on standardized IP Protocols and is cost effective and fast to install.

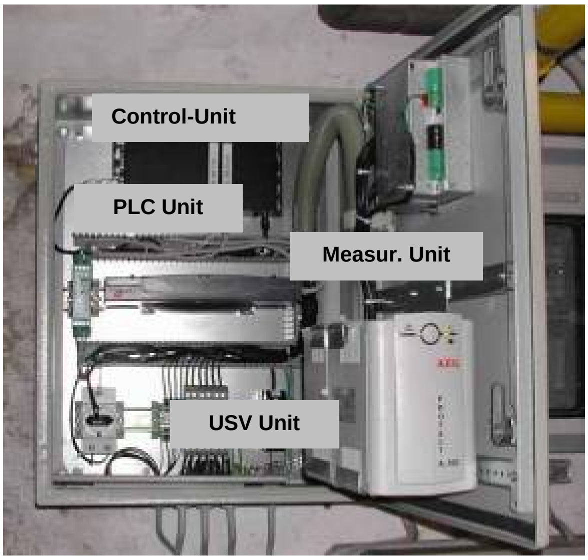


Figure 5-5 : Installed BB-PLC-System with distributed energy control unit

5.5 Partial Discharge applications

The use of a deployed PLC network forced the Endesa PLC group to try to innovate with regard to the quality of the electrical service offered through the MV and LV distribution grid. In this way the two last quarters of the year 2005 were dedicated to analyzing the possible relationship between PLC HF signal over MV and LV cables with some failure operational statistics being provided by the Network Maintenance Centre. Some correlation examples between PLC measurements which had been obtained and MV line failures offered Endesa a new innovative area for research: enhancing the operative life of the entire electrical infrastructure.

A graphic example can be seen in the figure 5-6.

At 4.23 am on 27 January 2007, a failure took place in the MV line between TS D0319 and TS D2589 that affected a further 20 TS which was due to a joint failure involving the three MV phases (a signal laboratory test confirmed the cause). Crossing this information with the PLC channel capacity and SNR PLC variations, the result showed that these effects were noticed in the PLC network in advance. Sharp SNR variations and a decrease in the average capacity of the PLC channel had occurred some hours previously. The use of MV PLC leaves an opportunity window open to carry out research on the newest diagnostic tools for the MV electrical infrastructure condition, by improving and enabling RCM techniques, minimizing economic maintenance costs and increasing electric supply quality. The integrated network topology and all the O&M core layer (figure 5-7) facilities provide an easy real laboratory for new R&D projects.

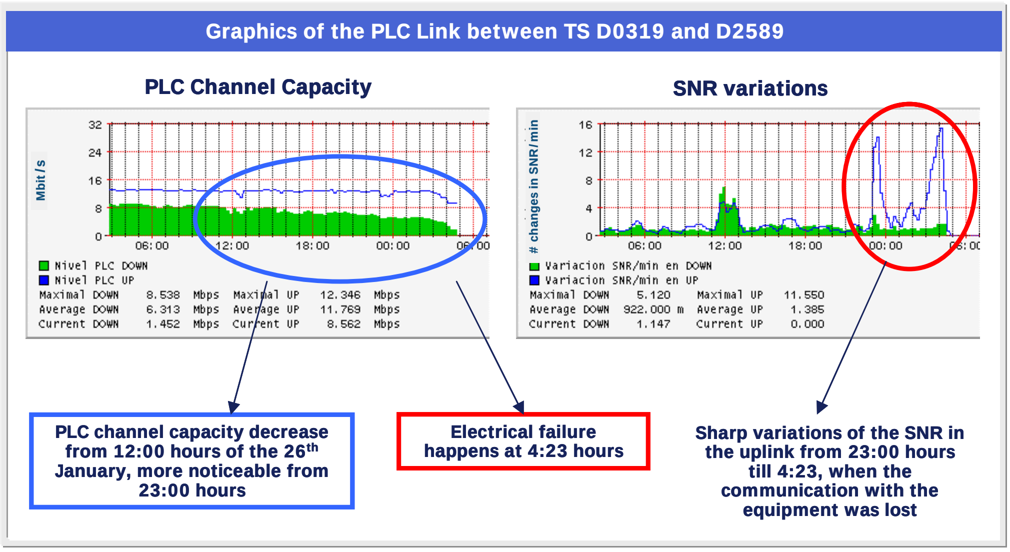


Figure 5-6: PLC MV link failure

In this regard, a new pilot involving 15 TS has been developed to analyse the possibility of learning about Predictive and RCM maintenance models as well as learning about possible insulating material degradation and partial discharges phenomenon. For these two purposes not only are real time monitoring systems needed, but also an integrated solution with the Network Maintenance Centre along with full historical quality measurement by an expert system being included.

All the equipment for this new step is based on the 2G DS2 chipset, and trying to integrate as many functionalities in the same rack as possible. A detailed stage analysis has reached a positive conclusion regarding using PLC network architecture as an operational tool which is a transparent and transport medium for gathering distribution information from remote locations to only one or two centralized points in charge of diagnostic and effective innovation maintenance. The most recent stage in this project finished the complete TS installation of the PLC units, including PLC modules for transmission over MV lines, as well as inductive PLC RF and 50Hz signal coupling units, back-up power supply batteries, digital and analogue acquisition inputs and digital outputs. The whole Network topology architecture for these 75 TS is shown in the following figure (Figure 5-7). It consists of a redundant architecture that matches together on three rings completing four MV lines between 3 Substations (SS) and one MV distribution centre (DC).

PLC equipments are using broadband communications for embedding quality measurement and remote units functions. The use of analogue inputs for instantaneous and real time power consumption readings, current measurements, temperature range for elements (transformer oil, the transformer's environmental location, etc.) and digital inputs for some critical alarm monitoring functions (digital sensors, presence detectors, theft detectors, short circuit current detectors, etc.) gives utilities a very wide means of increasing operating efficiency and infrastructure usage, whereas some embedded PLC digital outputs open up a direct path for remote action over external servos or switches of the electrical infrastructure.

The most advanced goal in the Electrical Distribution Network is the possibility of adjusting Distribution demand goals with Electrical Generation objectives, offering a high quality service to electrical customer. This specific goal is more difficult as more infrastructure elements are presented with different investments policies and different priority regarding network use is carried out. The future innovation program in Endesa's PLC project will try to analyse an effective investment model based on degradation research element properties, and mainly the degradation in the insulating coverage of MV lines and cabinets (MV cells).

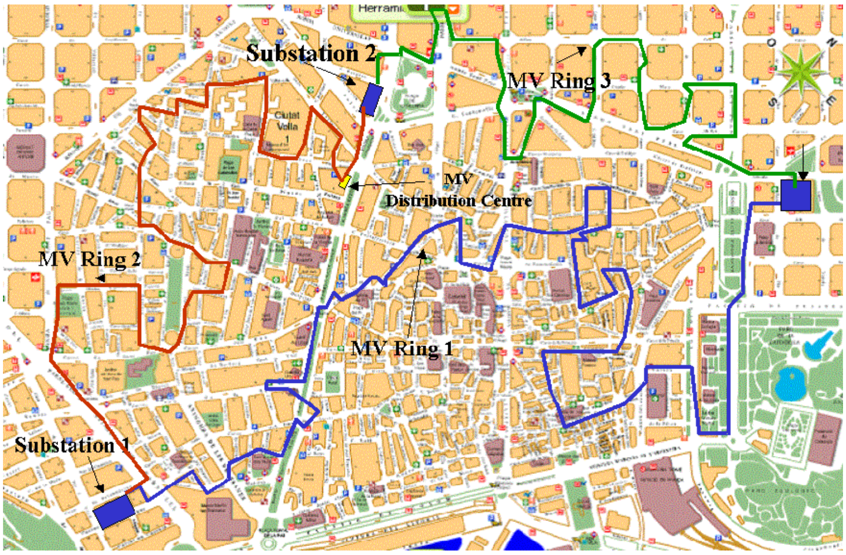


Figure 5-7: MV PLC trial for first step QMD applications

The operation and maintenance procedures due to the estimated insulating properties of the infrastructure allows the utilities to reduce cost and focuses on more accurate future investment, adjust traffic load and obtain a more effective use of the deployed infrastructure, thus increasing the life time of the elements involved.

The number of infrastructure topological changes is in most cases, directly related to the insulating materials of the elements. Such degradation represents the physical state of its base material, and of course taking into account these characteristics it is possible to predict, check, modify or act over the electrical configuration topology, and have enough time to avoid some outages and reduce or postponing maintenance costs.

To reach the objectives mentioned, a partial discharged (PD) signal analysis is needed. First of all, sensors connected to PLC equipment are required and an "on line" real time transmission using an ever-present telecommunication medium is essential. Then, the problem detected needs to be more accurately identified, including PD source and finally it needs to distinguish between critical and non-relevant PD phenomenon.

As soon as the PD (Partial Discharge) source has been detected and catalogued, the right maintenance procedure is launched and the budget is more effectively applied, offering higher reliability, greater efficiency and allowing the operation of the Electrical Distribution Network to be close to its utmost capabilities.

The figure 5-8 represents the block diagram developed for the new PD application:

The current efforts regarding the Distribution Core business include converting the current Electrical Distribution Network into an intelligent network to be as smart as possible, including innovative maintenance procedures combined with the autonomous diagnosis of information and systems tools.

5.6 Energy related services with Broadband PLC – PPC Case Study

A utility company provides electrical energy to their customers over the transmission and distribution grid. The tasks for the utilities have remained the same for decades. The main tasks are controlling the electricity flow, fault protection, measurement, adjustment and balancing of energy for different clientele. The energy supply has to be at a high level in terms of quality and reliance since customers demand zero outages. Utility efforts nowadays are increasing, due to different deregulation issues and market requirements.

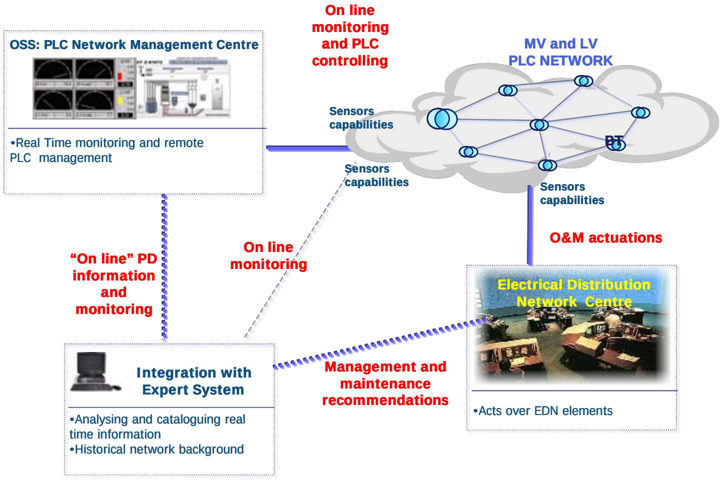


Figure 5-8: Network blocks architecture for PD applications

The utility assignments displayed in Figure 5-9 are carried out with different main systems and therefore require a respective engineering task.

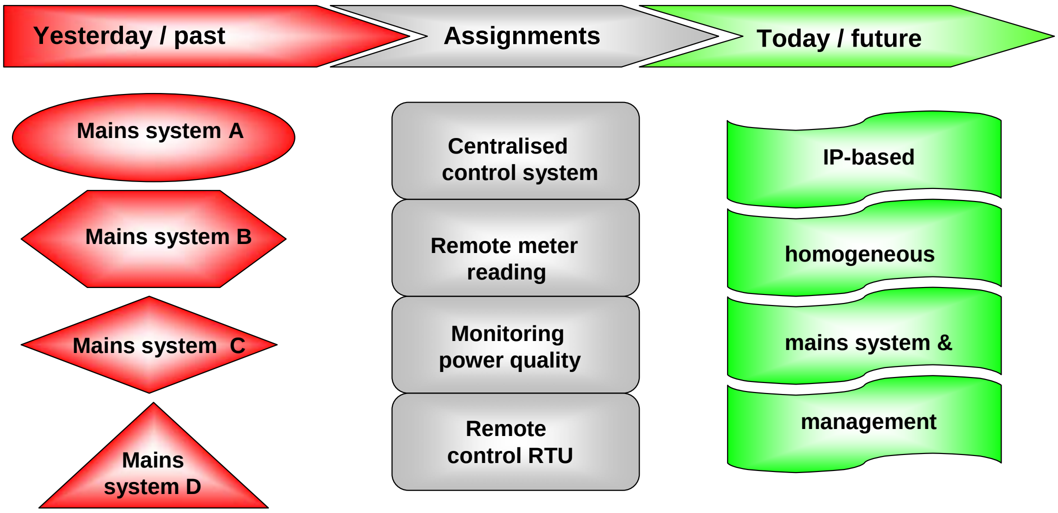


Figure 5-9: Assignments for utilities in the transmission/distribution grids

Power PLUS Communication AG (PPC) successfully applied different applications in process control in the field of energy related services. The base of these applications is always the communication network on the distribution grid which connects stations. Local islands solutions have also been carried out for low- and medium voltage. Together with the customers in Germany, namely the utility in the city of Mannheim (MVV Energie AG) and the utility in the city of Karlsruhe and customers in Switzerland, using the utility of the city of Zürich, these new solutions have been applied.

5.7 Energy related services with Broadband PLC – Endesa Case Study

The Endesa Utility has been following and testing PLC technical advances related to the use of LV access network and MV distribution cables for PLC end users applications in the last five years , These include VoIP and Internet Access services. Two massive commercial PLC trials in Barcelona and Zaragoza cities confirmed the viability of the use of MV and LV PLC technology to build a reliable and secure telecommunications network to provide these kinds of applications.

However, once a telecommunications network has been deployed over electrical grids it is also possible to use this opportunity to provide corporate services, opening up new innovative guidelines in order to increase the value of the asset by carrying out researching into relevant R&D&I projects.

This special scenario should be developed during the next few years and Endesa's PLC efforts will be focussed on these main goals. The following text and figures clarify all these design details including the network architecture and its functionalities.

A telecommunications network and its topology architecture appear once a need is well defined. Endesa`s PLC experience has established a profitable communications and transmission medium for broadband applications, not only ones for end users, but also for internal and utilities aspects. In this sense, the first step in this scenario started with the use of a PLC transmission network over MV and LV grids to offer remote management, corporate voice connections, and telecontrol orders for operating and managing the electrical MV and LV grids, especially in controlling MV switch-gears.

This application was focused on all the current MV PLC deployment concerning more than 100 Transformers Substations at Barcelona locations in a 10000 passed homes area and about 400 meter rooms or buildings (see figure 5-10).

This stage started with the use of MV grids as a virtual network for connecting different RTU (Remote Terminal Unit) equipment, and some QMD (Quality Measurements Devices) to PLC 1G equipment, providing more advantages than other transmission technologies such are PSTN, GSM/GPRS or leased lines regarding their availability, installation time, starting up time, management process and so on. The reason for these new applications is to take more profit from the installation deployed by integrating more added value services. The network topology is connected to the Distribution Control Centre, receiving RTU and QMD traffic directly from the deployed Broadband PLC network devices and the OSS (Operational System Support) belonging to the PLC Network Operation Centre.

The architecture described shares O&M procedures to operate the Broadband PLC network not only for Telecommunications customers but also for distribution applications. Its main goal is to maximize network properties including the following: Bi-directionality, real-time capability, availability, security and system integration information in order to conform to the new RCM (Reliability Centred Maintenance) model.

All of these services are offered using the same PLC network deployment, without focusing on a specific PLC network design or architecture.

Moving forward with PLC services and enhancing the value of the electrical infrastructure, we can notice other types of Powerline services that need dedicated and not shared network transmission architecture. A more detailed analysis regarding design criteria, costs and expected feature is necessary in relation to this. Short circuit current, failure detection or detailed failure location are services that require a different network design due to their specific functionality features: since as soon as a failure appears, a just in time real time maintenance procedure by the Electrical Distribution Centre is necessary to enable recovery and to comply with QoS customer agreements. Short circuit failure frequently occurs once an electric cable is cut down and effective MAC (Medium Access Control) or Link protocols should be well defined and implemented in order to solve cable failure by multipath routing transmission techniques.

Both of the two kinds of different PLC architecture (a dedicated electrical infrastructure and a shared telecom one) are ready for creating non- restricted PLC services such are AMR, QMD, AMM or DSM, while faulty current detectors and the maintenance procedures involved require more specific network design and transmission features.

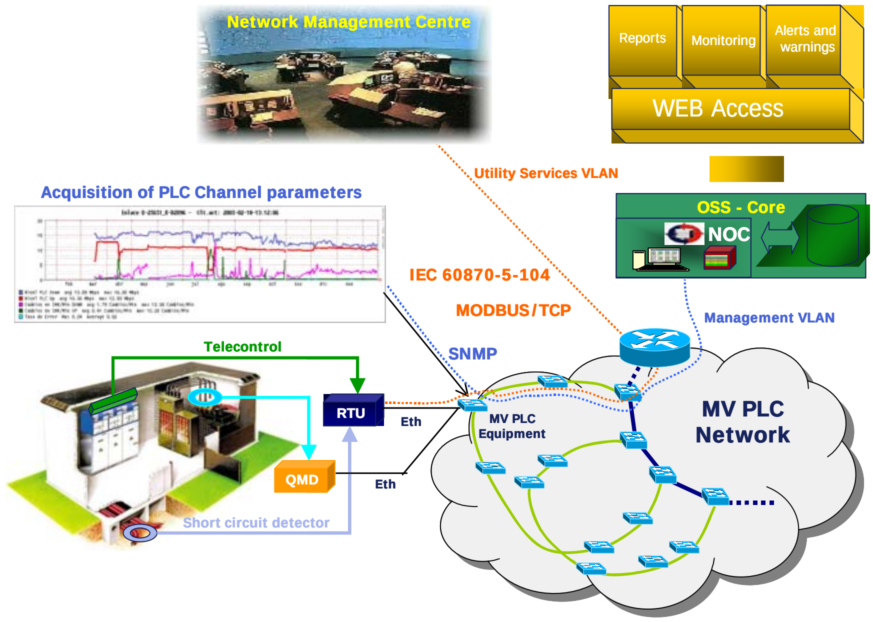


Figure 5-10. Core Applications Architecture

Using the deployed infra-structure at a further level, Endesa's second step in its efforts in this regard will be focused on evaluating a predictive process using on line capacity monitoring enabled by PLC technology.

Analyzing all these Maintenance objectives we can clarify the four Management Operating models to be found in O&M trends:

- Corrective Maintenance: acts only when a failure appears and its aim is to solve this. The sooner the right previous stage has been recovered, the more effective is the corrective action.
- Preventive Maintenance: action regarding provider's recommendations and in accordance with the useful life cycle of the elements and materials used.
- Predictive Maintenance: maintenance model based mainly on continuous monitoring of the conditions of the elements (CBM) and establishing mismatches with data based Information Systems.
- Reliability Centred Maintenance (RCM): maintenance policies based on technical conditions, risk conditions and subjective ones, including background and historical behaviour of the elements involved in one segment or embedded equipment, legal economic punishment, environmental regulations, etc.

In recent years Endesa's utility maintenance efforts were dedicated towards the lower Maintenance levels (corrective and preventive). Nowadays, current strategies are focused on the two newest: the predictive and RCM ones, looking forward towards a reduction of the average outage time and enhanced operative life of the components.

6 AMR Applications

AMR stands for *Automatic Meter Reading* or *Automated Meter Reading.* Basically it refers to the set of technologies that allow the collection of metering data from individual electricity meters to a central location via communication systems. As opposed to *manual* meter reading, AMR is able to collect data on regular intervals, even on a real-time basis.

Although the discussion in this chapter refers to AMR concepts, it must be said that over the past few years there has been a transition from the classic AMR approach to *Advanced Meter Management* (AMM). The transition has been driven by both technological and data management considerations. The biggest single technological change that has enabled this transition is the added functionality made possible by continuous-flow bidirectional communication to the meter endpoints. The new feature that AMM provides is easy to understand: while receiving readings from the meters is still clearly the biggest change and provides the largest perceived benefit for the utility, significant benefits can be obtained from *the new functionalities themselves* provided by this technological advance. Additionally, in many cases the tools to perform analyses using information from the meter data warehouse were never implemented or did not meet the vision of what was intended. This led to a number of initiatives that had previously implemented AMR looking at implementing a fully functional meter data management (MDM) system to realize that vision. AMM incorporates the AMR business case transformational benefits from multiple parts of the business, including customer service, operations, finance and technology.

The four key components of an AMM implementation are:

- Meter data management.- MDM functionality comprises the central integration hub for AMM environments. It is the single point of management, processing and integration to back-end legacy systems within an AMM environment. The MDM is thus positioned as a mission-critical system within the utility, providing increased efficiencies where much of the functionality provided would have previously been achieved with point-to-point interfaces and duplicative operational processes;
- Communications and collection;
- Installation; and
- Program management.

6.1 Brief history of AMR

As long ago as 1838, remote electricity supply metering was proposed by English inventor Edward Davy, for the purpose of checking the voltage levels of batteries at unmanned sites on the London-Liverpool telegraph system.

Of course in the beginning these proposals had little practical impact. It is curious to note that one of the first patents on remote reading of electricity meters was made in 1897 by J. Routin and C.E.L. Brown and it specifically proposed a power line as transmission medium. Several other systems devised throughout the following decades relied on the telegraph or the telephone for the transmission of simple meter readings.

Probably the first important testing of AMR technology was made in 1962, when AT&T and Westinghouse conducted trials along with a group of US utilities. After some successful experiments, AT&T offered to provide phone system-based AMR services at two dollars per meter. That price was found to be four times more than the monthly cost of having a person read the meter.

It was not until the nineteen eighties that AMR systems based on different technologies (primarily radio) were deployed by utilities (not only electricity but also gas and water) all around the world. The technology finally demonstrated its economic feasibility and for the last twenty years the AMR market has been steadily growing to a current calculated total of nearly 100 million meters installed worldwide.

One of the major drivers for the ongoing success of AMR is gradual utility market deregulation which started first in the US and then came to Europe. Deregulation has brought new players into the marketplace, companies willing to make substantial investments in expanding product capabilities and services driven by fixed network AMR systems. Utilities are increasingly looking to AMR devices as a means of recruiting new customers, retaining old customers, providing a better service at lower cost, as well as supplying a variety of value added services to their commercial customers.

6.2 Advantages of AMR

Some of the benefits that AMR offers include:

- improved accuracy of meter readings,
- reduces the need for estimated readings,
- greater amounts of information, more than monthly energy and demand, can be collected,
- functions in bad weather,
- overcomes difficult access to customer property and dangerous situations,
- automatic meter tampering detection,
- improved energy theft identification,
- immediate and automatic outage notification,
- rapid response to read requests,
- just-in-time meter replacement,
- increase in general operational efficiency (less costs).

Also, the liberalisation of electricity markets has made other AMR advantages clear for utilities:

- sales of new high added value services,
- reduction of energy losses and customer disputes,
- improvement of customer service and increasing customer retention,
- improvement of energy load forecasting accuracy; which impacts on proactive energy management and control, and benefits negotiations concerning long-term power purchase contracts ,
- gives the ability to establish complete demand-side management programs and incentives to reduce energy use,
- allows development of more billing options/dynamic rate structures to shave peak loads, and put into place knowledge-driven conservation programs and content value management innovations that empower consumers to take charge of and reduce their energy use.

Altogether, it is clear that by collecting more advanced metering data, a utility can build a body of knowledge to develop an entirely new portfolio of dynamic rate structures and incentive programs, real-time pricing packages and interruptible rates that can be targeted to specific customers to significantly improve load management capabilities and reduce peak demand when distribution system conditions become critical.

Of course these benefits are all present in AMR through PLC. Specifically PLC offers some advantages over fixed telephone/wireless solutions:

- it uses the existing voltage network,
- it covers all customers by definition. Coverage is not an issue,
- it is very cost-effective both for establishment and operation, nowadays surpassing other alternatives,
- lifetime is not limited,
- the utility does not depend on other operator's services (so cost and end-customer support are more controlled),
- In the case of broadband PLC, it allows clear synergies and seamless integration with the smart grid concept that will prevail in the coming years.

According to a report presented to the US Department of Energy, if we take the perspective of different participants in the electricity market, the following is a simple scheme representing the expected impact of AMR. The utility and the consumers are the two main winners.

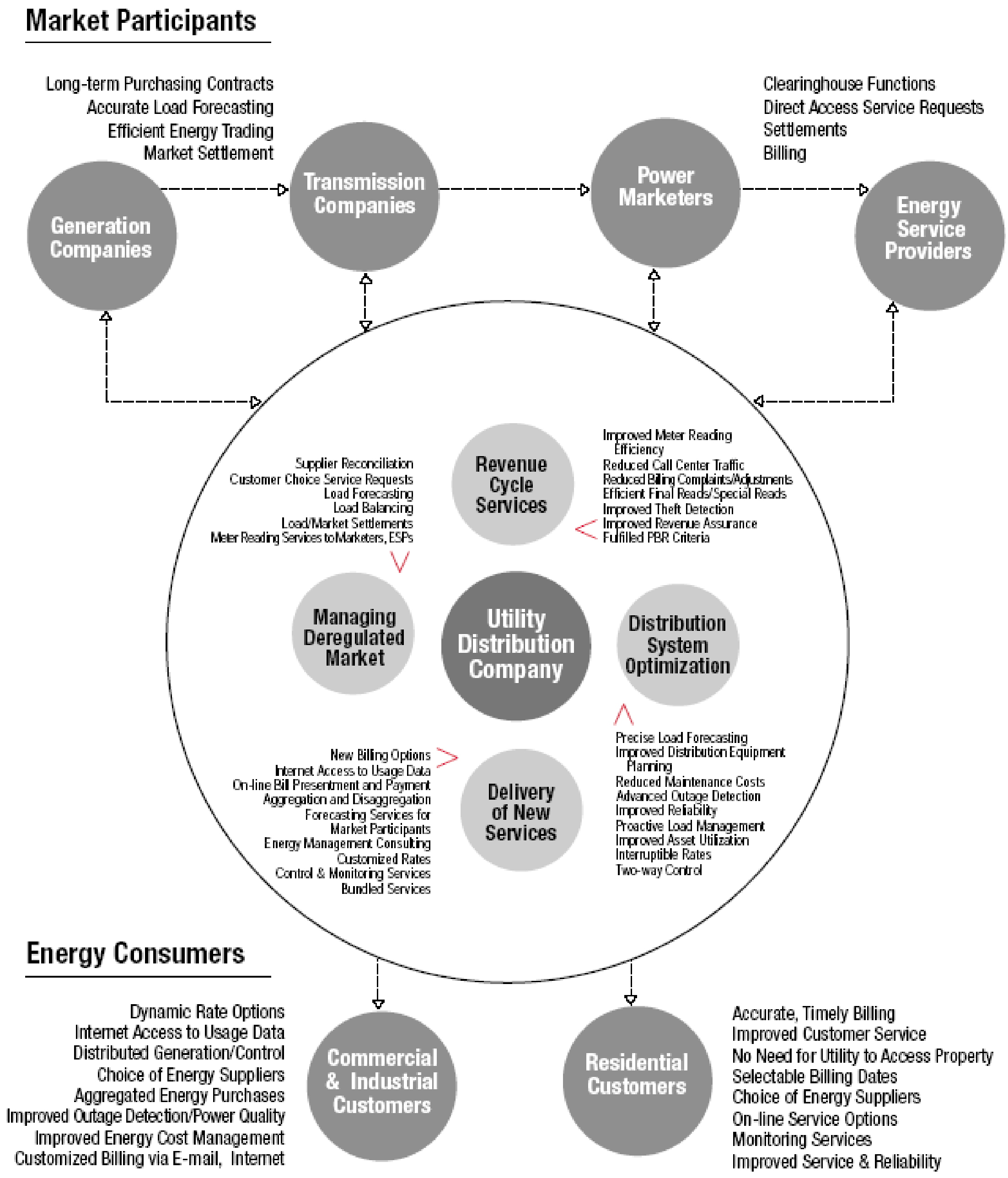


Figure 6-1 : AMR Impact

6.3 AMR experiences

6.3.1 Remote meter reading on BB-PLC (PPC Experience)

The retrieving of energy data from electricity networks presents different views from the utility and customer side.

As a utility there is the task of:

- measurement (synchronised, unsynchronised by time, spontaneous),
- measurement data for different purposes ,
- settlement based on measured data,
- action based on measured data .

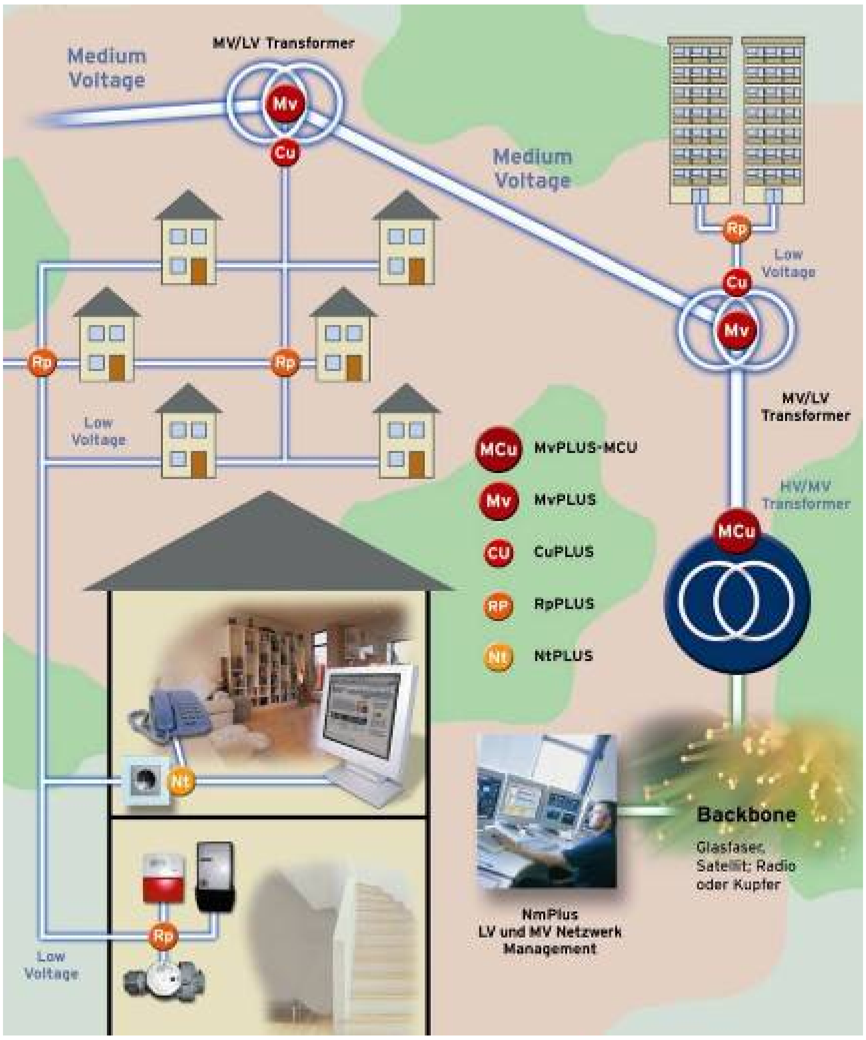


Figure 6-2 : Household metering with Broadband PLC

The utility retrieves the data by different system technologies for the purpose of controlling, settlement and monitoring. Depending on the customer type (household see Figure 6-2) the data has to be an access period between once a year to every 15min, or up to real-time monitoring. Due to the heterogeneous systems and different applications the data can not be aggregated and managed for modern utility needs. Therefore the data retrieving and storage inside the utility becomes a higher priority and the most important advantage.

The scaleable Energy Data Server (EDS) based on the BB-PLC IP Networks has the task of retrieving storing and providing the energy data for other application systems. A user role model in the EDS-Server ensures access to the data (see Figure 6-3).

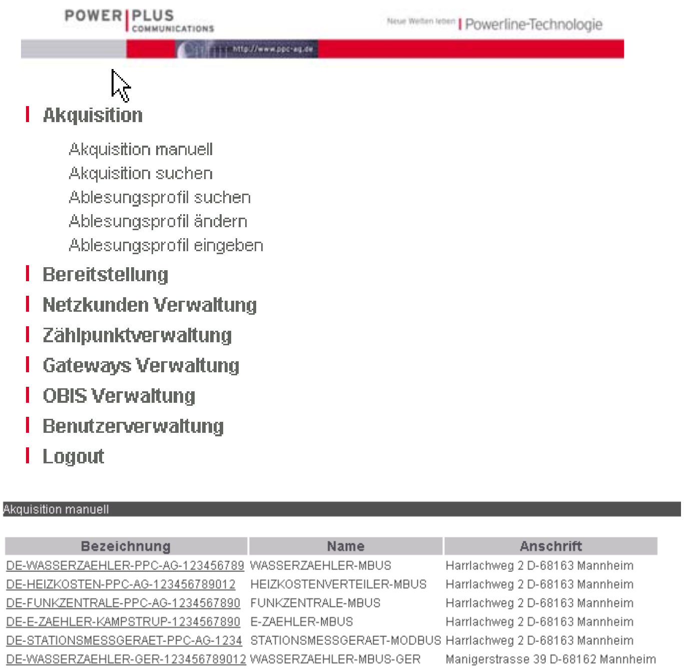


Figure 6-3 : EDS main menu with measuring points

The EDS Server is able to retrieve measurement data from household and industrial customers. The city of Zürich is testing this new potential of BB-PLC. In contrast to normal solutions the PPC-System has the possibility to connect the meter directly to the BB-PLC Network. Complex and costly gateway solutions have been prevented.

The installation effort for this solution is the same as installing a meter. In the shortest period of time communication to the meter is achieved. Not only can electricity meters be integrated, but also other media such as water, heat and gas meters are connectable. In the EDS-Server from PPC the actual metering values are shown in a compact way, which is easy to structure and ready to provide data. Depending on the requirements, the reading period can vary between minutes and months, and even the current values are selectable. Without any delay, the meter data is provided automatically or manually triggered to the operator. The EDS-Server has a multi-user architecture and due to the web-based technology, other divisions of the company are able to have access for their related role. Even customer service or the billing department are able to access the retrieved data for their customer activities. The Server therefore reduces the time for complaints, failures and optimises the whole process for private and industrial customers.

The EDS-Server information is relevant for almost every company department in the utility. Of course the system has an important modelling role. An overview of relevant users and access frequency is possible and allows cost allocation for different departments. Expenses arising for the EDS-Server with respect to other communication solutions are very low. The transport of the data over the existing power grid allows for permanent connection with the metering units as well as stable connectivity everywhere.

Figure 6-4 : EDS-Server measured values

When load profiles from non-intelligent metering points are necessary, an automated request from the EDS-Server with an interval of 15 minutes is used. The load-profile is stored in the EDS-Server, without having oversized metering devices. Even tariff switching can be carried out alternatively with the load profiles. This ensures having new tariffs downloaded to the household customer.

Figure 6-5 : Electricity meter installed with BB-Powerline

6.3.2 Remote meter reading on BB-PLC (Endesa's experience)

Endesa's efforts with regard to AMR and BB-PLC are focussed on building a trial involving700 meters in a single ring of 5 Transformer Substations (Figure 6-6) in the Barcelona area (Molins de Rei village).

All of these transformers are connected together with the use of MV BB PLC and the edges are closed with two leading broadband technologies, WiMAX and ADSL, allowing access to LAN servers for monitoring and management functions. The coexistence and migration to IP protocols is a fact and the trial has demonstrated viability of integrating networks belonging to different external operators and BB technologies.

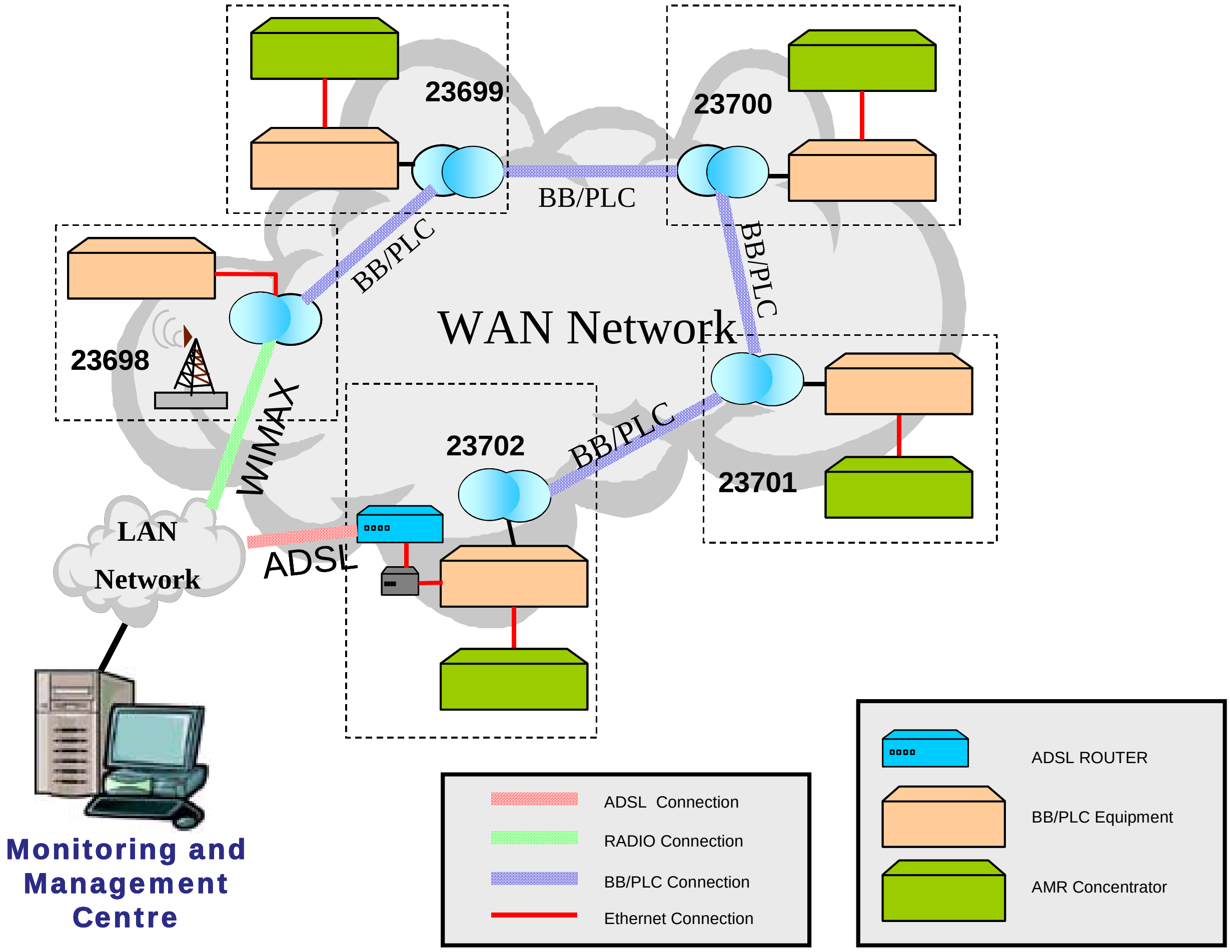


Figure 6-6 WAN Network for Endesa's AMR Project

The services planned for the trial described will offer not only remote meter reading but also settlement actions: activating/deactivating customer supply of electric power, tamper detections and load management. As soon as all the customer AMR equipment has been installed, more new services will be implemented over the network described, enhancing the presence of smart grid facilities over the current electrical infrastructure.

6.3.3 AMR pilot on coexisting NB and BB PLC (Iberdrola Example)

Iberdrola installed a small AMR pilot in Madrid in October 2005, with the aim of testing NB AMR technology inside an area in which BB PLC was already deployed. The idea was to test different scenarios, check the reliability of equipment and demonstrate the coexistence between the two technologies. The meters were provided by Mexican manufacturer IUSA, working in close collaboration with BB PLC system provider Mitsubishi Electric.

The trial was conducted within a BB PLC cluster in which a specific underground Transforming Substation, *Sanchinarro 25*, was selected. Sanchinarro 25 is a medium-sized TS which is connected via Medium Voltage BB PLC to the Iberdrola network. Due to its constraints, other backbone wireless technologies do not perform correctly inside the TS. Also, with the area being it a new construction area located in the surroundings of Madrid, xDSL is not available for customers, so many of them are customers of Iberdrola's BB PLC solution.

Just MV BB PLC was tested to serve as a backbone connection for the NB PLC that was used for AMR. The possibility of also using LV BB PLC was considered, but as NB PLC offers great coverage, installing just a single AMR *concentrator* at the TS allowed all the meters in the LV cell to be reached directly, thus making NB PLC the most cost-effective solution for this test (at the expense of reduced speed, which would not permit value-added services). Just one injection point at the busbar was needed for the AMR concentrator to reach all the places measured. The distances to measured meter rooms were typical values for Madrid, usually ranging from 100 to 200m.

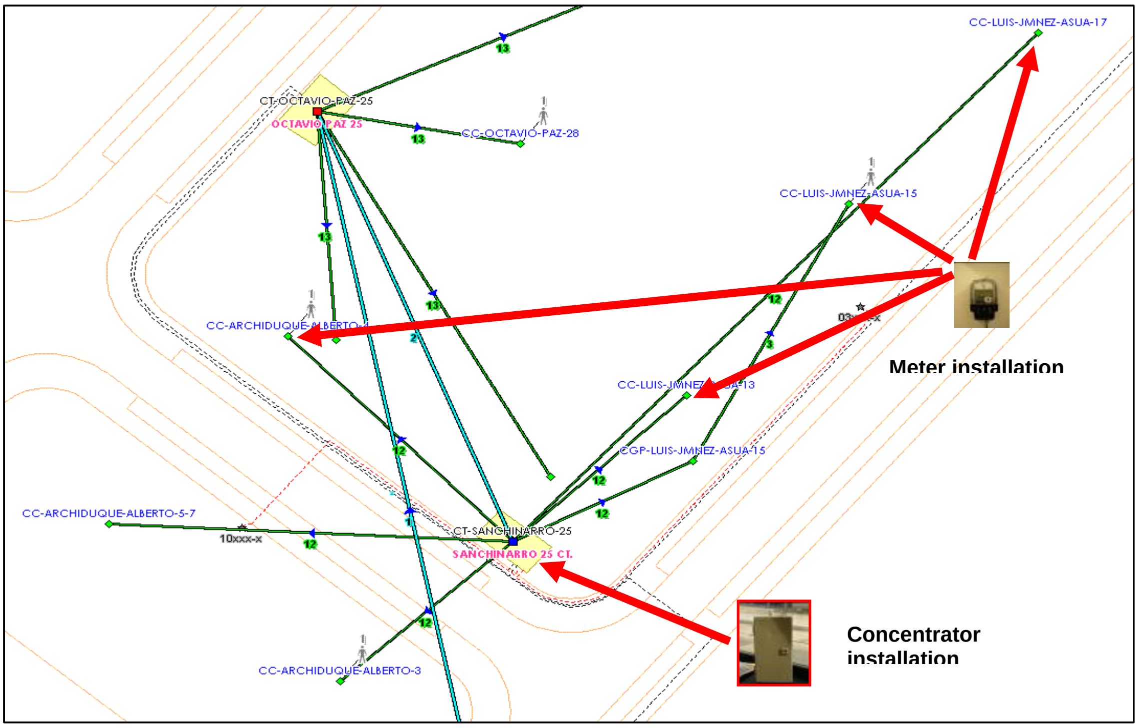


Figure 6.7 The Iberdrola AMR installation in Sanchinarro 25

A total of four buildings were tested, installing 6 meters in the meter room of each building.

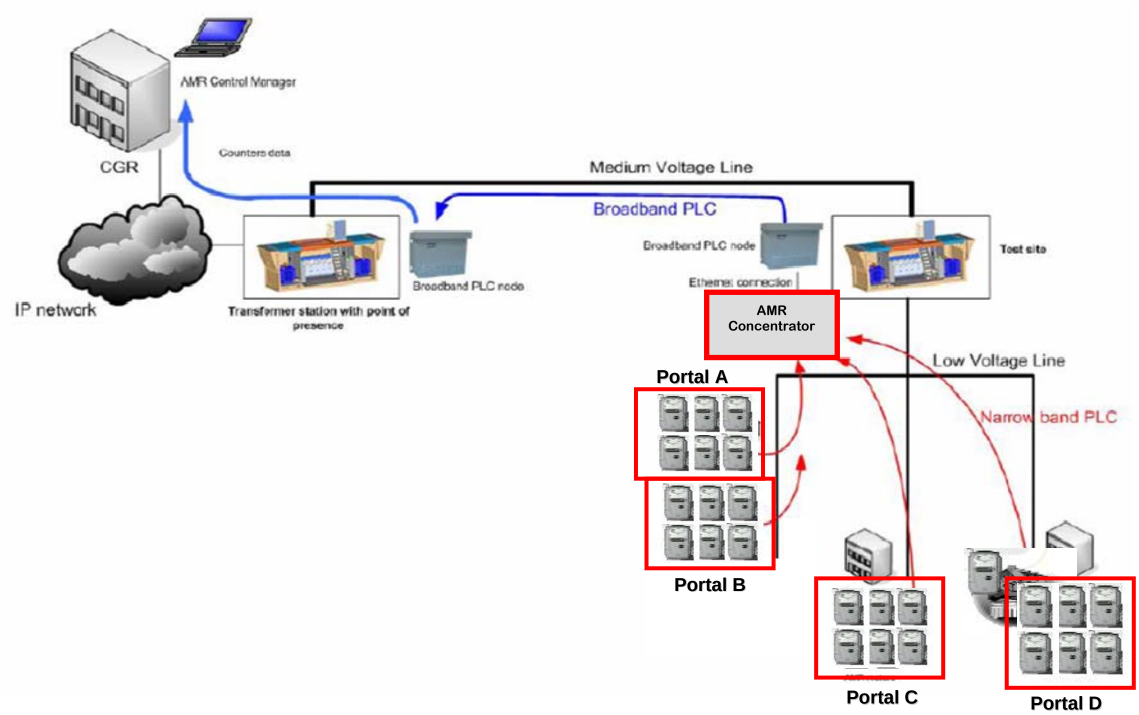


Figure 6-8 The IberdrolaPLC Network plan for AMR in Sanchinarro 25

The AMR concentrator that communicates with all meters connects directly to the BB PLC Mitsubishi MV equipment via the Ethernet, and standard configurations are possible in both PLC systems, so in that regard the coexistence and integration of both technologies was absolutely seamless.

Complete NB PLC installation on a BB PLC Network which had already been deployed took slightly more than one working day of a small team of two people, including physical connection of the 24 meters, extensive measuring to check connectivity between equipment, provisioning within the Network Operations Centre (NOC) and additional verifications. The whole trial was up and running soon afterwards. The actual installation of the meters was performed by Iberdrola staff with no knowledge of PLC, and absolutely no help from the equipment manufacturers. The conclusion reached was that the installation of these meters is exactly the same as any other meters.

No impact was detected on the performance of the BB PLC Network, after comparison of throughputs in the BB cluster before and after NB installation. Four of the 24 customers were also BB PLC customers and they noticed no decrease in performance. The NB and BB PLC Networks were totally coexistent.

The meters tested have the ability to perform remote readings and connections/disconnections. The data collected was mainly kWh consumption, all types of power (total, active, reactive), voltage and current levels, frequency, Power Factor etc.

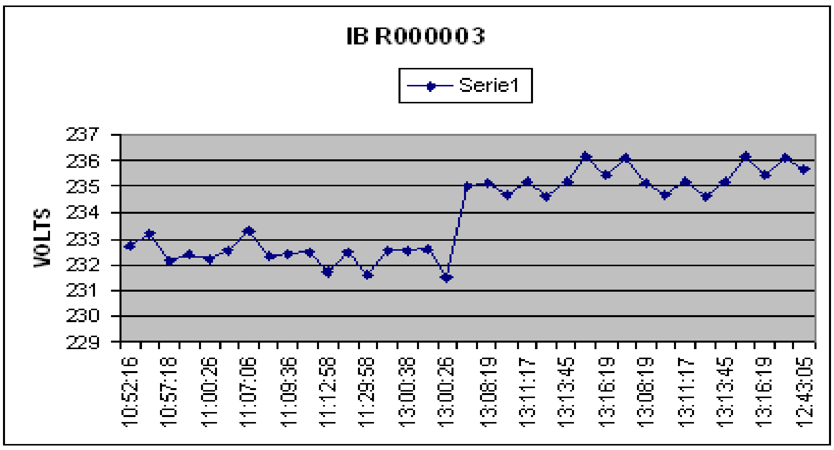


Figure 6-9 Sample voltage profile of customer 000003 (one reading per minute)

The management system at the NOC is able to provide dated statistical reports of consumption profiles and quality of service profiles per customer. These are presented as standard files for database applications (Excel and Access were tested). The periods of readings for these profiles are configurable. 1 week, 2 weeks and 1 month were tested. The management system also makes an estimation of the quality of the NB PLC communication, and remotely configures all the parameters of the AMR concentrator.

Summarizing all the results, the test allowed Iberdrola to confirm the feasibility of BB PLC as a powerful transport solution for various end-customer services, specifically automated meter reading and load profile management. The special characteristics of such on-field deployment were analyzed, concluding that both systems perform in plug&play and seamless ways.

The reliability of readings taken was *almost* 100%, although no less than 100% would be necessary for massive substitutions of old electromechanical meters.

Iberdrola is currently considering the installation of several more PLC AMR tests. One of these is currently under evaluation which comprises of 1000 meters in Bilbao, using ZIV's NB PLC AMR technology. In the near future, more manufacturers will be tested in trials involving some thousands of meters.

6.3.4 Other experiences

AMR is probably the PLC application with the largest number of trials and/or deployments worldwide. It is calculated that one fourth of AMR trials use PLC, to give a total of more than 1,000 projects currently up and running. A short review of some of the most interesting experiences regarding PLC AMR technology will be made in the following paragraphs.

In **Europe**, there is a large number of utilities involved in PLC trials or deployments in some way, and an important number of them have already tested or plan to test AMR services using the electrical infrastructure. NB PLC is the preferred choice at the access branch, due to economic reasons. The biggest implementation up to now was carried out by Enel in Italy, which has installed some 30 million NB PLC-enabled meters and over 250000 data concentrators, using technology from the California company Echelon.

The Swedish utility Vattenfall also uses the Echelon system and has recently signed a contract with Telvent in Spain for the supply and installation of up to 700 000 intelligent meters by 2009. Enel and Vattenfall are probably the biggest players in this area, but many other large European utilities (e.g. Dutch utility Nuon with 25 000 Echelon meters) are also present.

Almost every country inside the EU has already witnessed at least modest trials of this technology, and it is safe to say that this is the "first experience" of preference by the utilities to obtain knowledge of the possibilities of PLC for the future SmartGrids throughout Europe.

In the **US** there are three other significant manufacturers of NB PLC AMR technology, which are Hunt Technologies, DCSI and Cannon Technologies**.** Current Technologies is actively promoting BB PLC for AMR uses, and its contract with TXU in Texas to provide services to 2 million customers will represent the biggest PLC AMR installation in North America. Dozens of smaller utilities in the US have already satisfactorily installed PLC AMR pilots.

China is also aggressively pushing for PLC AMR. A specific Chinese forum for PLC AMR was established in 2005 with more than 30 companies which includes top meter manufacturers, system integrators and technology vendors. This huge market is probably the one with the greatest expectancies for growth in PLC AMR in future years.

7 Distribution Automation Applications

7.1 Automation in Distribution Networks

The development of digital technology and communication in the last few years has initiated a process of modernisation and automation with regard to electrical installations. This process started with the most expensive elements (transmission substations, power plants), in which the total amount investment enabled, as a marginal cost, the implementation of expensive equipment for data collection and analysis or for the execution of automatic sequences that would make system operation easier. The level of criticism concerning those sites is that they require high investments and a high level of automation.

With the higher efficiency and the lower cost of Intelligent Electronic Devices (IEDs), solutions based on this type of equipment have migrated from larger plants down to smaller and smaller ones.

Currently, it is possible to have not only a uniform solution for all problems associated with substation automation but also to export these solutions to the lowest levels of voltage used by distribution utilities and thus obtain economic and technological advantages when compared to traditional solutions.

One of the main advantages of this type of concept is that it enables us to design the system in a distributive manner. This concept also allows us, at the design stage to face problems separately, and hence we can design an integrated solution for each of these. This means major savings on the total cost of the project, as the protection, control and position measuring equipment themselves carry out data collection, operation and in some cases even carry out the automatic functions, so the additional investment is reduced to a communications network within the installation.

Given that, the communications network is already established in many installations and about to be established in others. In the case of PLC communication, automation distribution establishes an important added value at a marginal cost.

The main goal of distribution automation is to improve the quality of the distribution network's service through reducing the duration and importance of incidents, therefore making it possible for part of the affected power to be recovered and thereby reducing the time of the local operation. As the duration and importance of interruptions is reduced, automation will directly contribute to improve supply continuity. For example, in Spain the concept of TIEPI (interruption time equivalent to installed power) is used to measure supply continuity. The lower the TIEPI is, the better the power supply continuity is.

Fault indicator systems as well as automatic network restoration systems are becoming very important, as they are a very useful tool to reduce the outage time and the coverage of the affected area.

However, nowadays most distribution networks have not yet been automated. Utilities are now starting to deploy automation systems in distribution networks in order to achieve a percentage of 20-25% with regard to installations. This percentage provides an excellent level of automation. Further investment in distribution automation implies less improvement of the power supply service, and is difficult to justify. Nevertheless, there are other services that can be implemented over distribution networks that can be very attractive in terms of being deployed, and cover a larger portion of the network. This is the case with fault indicators.

Distribution automation is based on bringing control and measurement equipment closer to the electric point in order to collect status, measurement data, etc, and use the communications network to send the information collected from each point to the remote control, either to the substation control unit, maintenance and analysis stations or SCADAs. The capacity of the IEDs becomes particularly relevant for the execution of actions based on distributed intelligence.

The distribution network installations that may form part of distribution automation are mainly the distribution stations and transformer substations. The evolution of automation is also tending towards aerial network re-closers and remote control switchgears due to their important contribution in improving the quality of the service, optimizing the location of the fault and keeping the minimum possible area out of service, thus reducing the area affected.

Looking briefly at Transformer Substation automation (those substations that convert from medium to low voltage), the following characteristics can be highlighted:

- IEDs are close to each electric position. IEDs that are in each cell are control and measuring elements. Each IED only has the functions required for that position. This customized sizing allows us to achieve an optimum cost/performance configuration adapted to each installation.
- PLC communications network. Use of the current networks to communicate with Substation Control Units, SCADAs. etc,. in order to send them the information collected in each IED and to receive commands from them, hence with this communications network we can get to points of the network that used to be impossible to get to (underground networks and transformation centres with practically no communications access or space).

7.2 Advantages of Distribution Automation

Using this new philosophy has the following technical advantages:

- There is more information available in the remote control centre in order to make decisions quickly and accurately: The communications network allows us to have a large quantity of information from the Remote control position such as statuses, measurements, fault passage indicators, etc. in real time. This can be carried out by using very few resources from the PLC network as the information sent to the remote control uses very little bandwidth.
- The possibility of remotely executing commands: In installations that may be controlled remotely, the operator will be able to execute commands remotely without having to travel to the place where an incident has occurred. This saves actuation time and avoids dislocation to the installation except for maintenance purposes.
- Reducing actuation time: Having all the necessary information in the remote control unit such as fault passage indicators and the presence of voltage, reduces actuation times before eventualities as this information allows us to locate the element causing the incident in less time than with traditional solutions. The operator will therefore be able to act directly on the incident either remotely or by travelling to it, when necessary.
- Maintenance task programming: With all the data available from the system's different elements such as the number of operations by cut-off elements, the converter’s temperature and pressure, etc. their maintenance can be programmed, which reduces incidents caused by wear and tear of the elements such as switches and the transformer.
- Distribution network access points practically impossible to get to until now: With PLC communication we can reach any point of the MV electrical network both for data collection and for sending signals, which means improving the quality of service by being able to act quickly before any event.
- Improvement of the quality of service: As can be concluded from the previous points, distribution automation results in improving the quality of supply due to:
    - Reducing the number of incidents,
    - Reducing the area affected,
    - Reducing the time taken to locate the incident and therefore the time taken to restore the network to normal.
- Added value to the PLC communications network: All the previously mentioned services add value to the PLC communications network as they provide a large number of technical and economic advantages, using very few resources from networks that are already installed or being installed.

All the aforementioned technical advantages bring direct economic advantages at a marginal cost:

- Low installation cost: The following characteristics make it possible for the installation cost to be low:
    - Integration of control and measurement functions in every single position, hence reducing the cost of the cells as push-buttons, relays, timers, wiring, measurement, converters, etc. are no longer necessary.
    - Reduction in commissioning times as the system is totally tested by the manufacturer prior to provisioning.

- Use of the existing communications network

- Improvement of the quality of supply: Improving the quality of supply means a great saving by the electric companies due to:
  - Reducing possible sanctions
  - Improving the nonsupplied Energy parameter

7.3 Communications requirements

One of the main drivers of distribution automation is telecommunications technology. Distribution automation deployment and telecommunications network deployment are carried out in parallel. There are different approaches to providing telecommunication services for automation, but most of the utilities tend to adopt a privately- owned telecommunications network instead of using an outsourcing model. Nevertheless, due to the fact that the number of distribution network sites is huge and very disperse, it is not easy to find a single solution that provide communications for all the possible scenarios. Instead, it is likely that a hybrid solution is adopted. The reason is that the cost of deploying a private network for medium voltage distribution automation is very high, whereas the possibility of using mobile communications, such as GSM/GPRS based on public operators, is cheaper, although the utility loses control over such a critical service.

The strategy to follow by each utility will depend on its main plans and medium and long-term policies, but decisions based on cost reduction in order to guarantee appropriate SLA are preferred. From this point of view solutions based on public operators are more competitive (provided that the service matches the availability and functional requirements requested by each utility).

In order to have a better understanding of the possible telecommunication solutions for distribution automation, the following is a chart showing the telecommunications requirements of telecontrol and fault detection. This information is available in the document “La tecnología PLC: Gestión eficiente de la infraestructura eléctrica de Distribución” drawn up by the Telecommunications Co-ordination Working Group of the Spanish UNESA entity, ref. [3].

SERVICES FOR MV AND LV POWER GRID AUTOMATION								
AUTOMATION SERVICE	**Critical**	**Notncritical**	**Prioritization**	**Bandwidth**	**Type of traffic**	**UPS**	**Network recovery time**	**Service coverage**
Telecontrol	X		Yes	9,6. kbit/s	Random	YES	< 1 s	10 - 15%
Fault detection	X		Yes	9.6 kbit/s	Random	YES	< 15 s	> 50%

Table 7-1 Services for Distribution Automation

As can be seen, the requirements in terms of bandwidth are not very stringent. However, the telecommunications network has to be reliable enough to provide these services as they are critical services that also require an uninterruptible power supply (UPS).

7.4 PLC solution for distribution automation

The next figure shows technological benchmarking to provide communications to distribution services. (source: “La tecnología PLC: Gestión eficiente de la infraestructura eléctrica de Distribución”, UNESA)

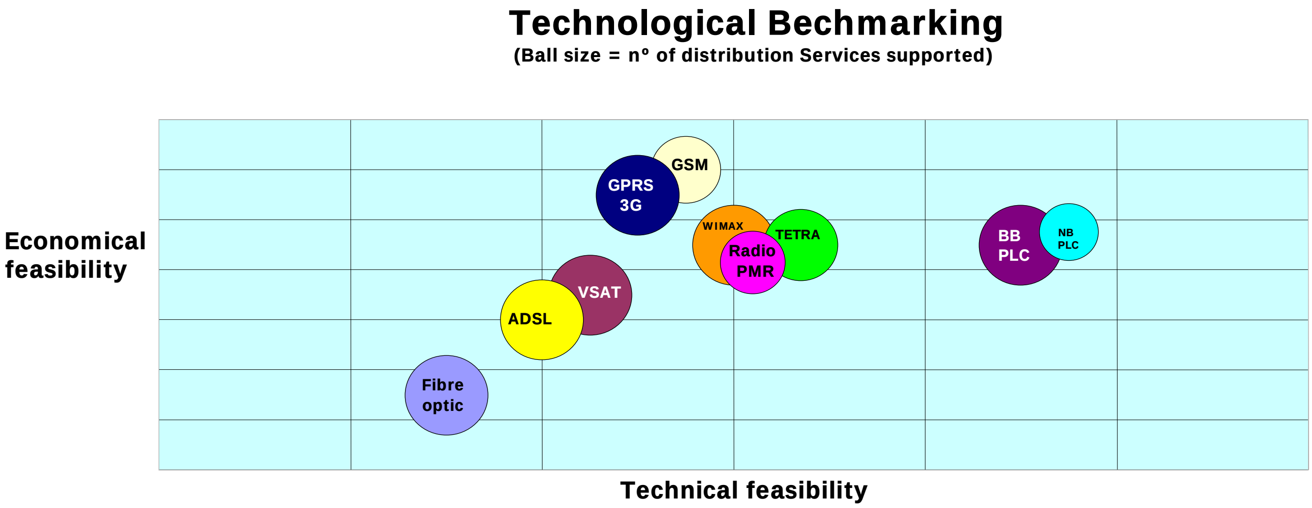


Figure 7-1 Technological benchmarking

All of the technologies shown in the picture can provide telecommunication services for power grid automation. However, not all fit the service requirement in the same way. Out of all of the above-mentioned technologies, perhaps GPRS will be one of the most selected technologies for implementing mass automation deployment. It is clear that this is the main competitor for PLC.

Broadband PLC is a global solution for an efficient management of the Distribution power grid. PLC technology allows the deployment of a real time, bi-directional, private telecommunications network that will contribute to power grid design and operational improvement.

The current state of the technology makes it appropriate to complement deployments with other technologies for automation purposes. However, there are still some issues regarding PLC technology that can be improved in order to be more competitive with regard to other technologies. Thus, it is necessary to look for more efficient and cost-effective coupling methods, which can transmit over longer distances with lower cost, independently of the state of the power grid, as well as being power grid operation proof. A way to improve performance and reduce cost is to integrate the coupling unit with the electrical equipment. It is also necessary to develop new network mesh type topologies, which are more flexible and robust, and routing protocols that perform more quickly, allowing for a network reconfiguration time of less than 1 second. It is recommended that a frequency range be used that works better in terms of noise, interference and attenuation. PLC networks need more stability and availability to fulfil critical service requirements.

These features will make the PLC network more competitive. Nevertheless, the current advantages of PLC such as being a private network, having a wide bandwidth, are difficult to support when competing with cost-effective solutions such as GPRS. PLC technology can be considered a good choice whenever there are several services to be aggregated, penetration is nearly 100%, and the service quality and availability provided by GPRS is a hurdle to its adoption.

A complete analysis of the technical solutions for distribution automation can be found in [3]

8 Smartgrid – Concept and deployment

Many people are talking about electricity grids in the future, the so-called **smart grids**. But what exactly does this concept of smart grids refer to? Why are they needed? This section tries to be an introduction to this new model of electrical networks.

8.1 Existing distribution grids

In the past, many small power plants were created to provide local electricity solutions. The power industry was made up of hundreds of different utilities. Later, those small companies found out that if they interconnected their grids with each other the resultant grid would provide electricity more efficiently and securely, as they could back up each network with the others. And this made larger utilities appear. Thus a decentralised electricity model with local generators gave way to larger generators supplying power to customers by means of high voltage transport networks and medium and low voltage distribution.

Nowadays, the electricity grid has a hierarchical, centralised structure, divided broadly into three segments: generation, delivery and end use. The delivery segment is the highway system for electricity, transporting power from the point of generation to the point of use through a vast infrastructure of poles, lines, switches, equipment and software. The electricity flows from one side to another top-down and one way. Thanks to the automation of power plants, substations and SCADAs systems, operators can gather information and control a large part of the grids. They are able to react to failures in the network, providing reliability and quality in the power supply, based on the information the Network Operation Centre of the utility receives from the different remote units, sensors and meters distributed along the grid (in fact, the information flows in one way, and the grid operator has to make the proper decisions to tackle an incidence). In the present day, most of these devices only cover the high voltage and medium voltage network (basically substations), but there is still a lack of control and automation at the transformer station level. Furthermore, even the increasing use of AMR is still in an early stage (trial phases) in most of the largest utilities all over the world.

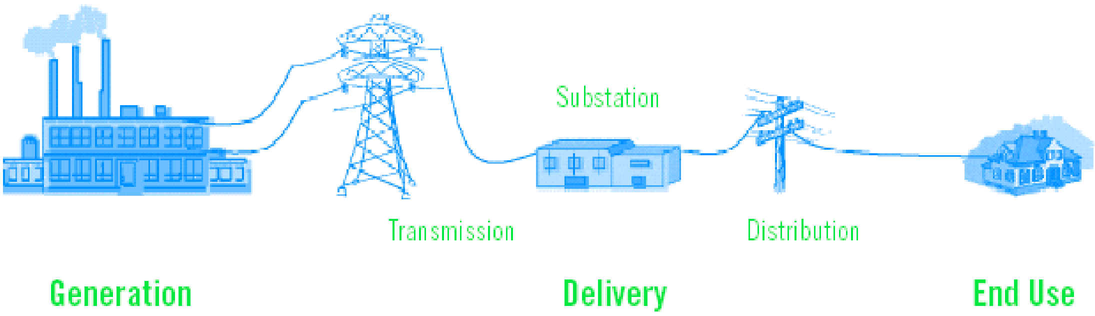


Fig. 8-1 Electricity power industry

Increasing concern regarding environmental degradation, the ever increasing demand for energy and the recent blackouts which occurred in some of the most economically developed countries have created a perspective of more responsible consumption, more reliable and secure grids and more efficient power distribution supply. As electricity is mostly a regulated activity, investments for improving its infrastructure are, to a great extent, dependent on each country's regulation. The regulatory basis establishes the minimum requirements the utilities have to fulfil by law. The return of additional investments would have to be made by increasing the electrical charge, but in a regulated marked the maximum price is fixed. So national regulation in the countries where there is no liberalised market has a key role in new advances (especially in those parts of the grid closer to the customer, e.g. AMR).

In the end, it seems necessary to accelerate research into new grid models, not just expand the existing grid model: a new model that can be adaptive, self-healing and compatible with on-site power distribution. According to Amanda Griscom's article in Grist Magazine, Energy experts from US compare the existing electrical grid structure with the way IBM designed computers in the 60's: "large, decentralised mainframes networked together in a hub-and-spoke arrangement". But those computers have evolved into "a modular, decentralised system in which distributed computers are networked together in such a way that if something goes wrong with one computer, it can be isolated from the rest. Like this distributed system, the energy grid of the future will be, if all goes well, impossible to shut down".

New technological advances in diverse fields allow utilities to reach these aforementioned objectives. New technologies for cleaner, renewable energy generation, such as reciprocating engines, micro-turbines, fuel cells, combined cycle, wind farms, solar panels, etc, are facilitating generation sources being installed nearer to the customers. Co-generators make this distribution more effective. Automation and metering units and sensors provide more control in order to prevent failures, and a way of obtaining more information about the demand profile. And of course, communications play a key role.

8.2 The smart electricity grid

Essentially, an intelligent grid is considered an electricity transmission and distribution system that is "smart" enough to detect potential problems, communicate such conditions to a central decision-maker (expert system), and automatically take measures to solve those problems. In other words, we can define a smart grid as the application of advanced technologies to the electric power system, including its complete value chain, from generation (generation level), to distribution (transport level) to consumption (end-use level) with the use of relevant sensors, advanced telecommunications computing and techniques of analysis, and power control electronic equipment to guarantee the long term operational process and best quality end user services, regarding availability, security, flexibility and costs. Figure 8-2 clarifies the key drivers for smart electricity at each of these three levels.

According to the report " Challenge and Opportunity: charting a new energy future", by the Energy Future Coalition, there are five concepts that define a smart distribution grid:

- A **self-healing** grid that will detect, anticipate and respond to problems, avoiding or mitigating outages and faults.
- **Security** from physical and cyber threats will increase due to the deployment of new technology that will allow better identification and response to manmade or natural disruptions.
- Use of **distributed generation**, allowing customers to interconnect DG technologies easily by means of standardised power and communications interfaces.
- Smart end-use energy management will allow customers to obtain **better control** of their own appliances and equipment.
- Greater throughput and **lower power cost** in the grid, by better harmonising local demand and the distribution, and fostering the lowest-cost generation resources.

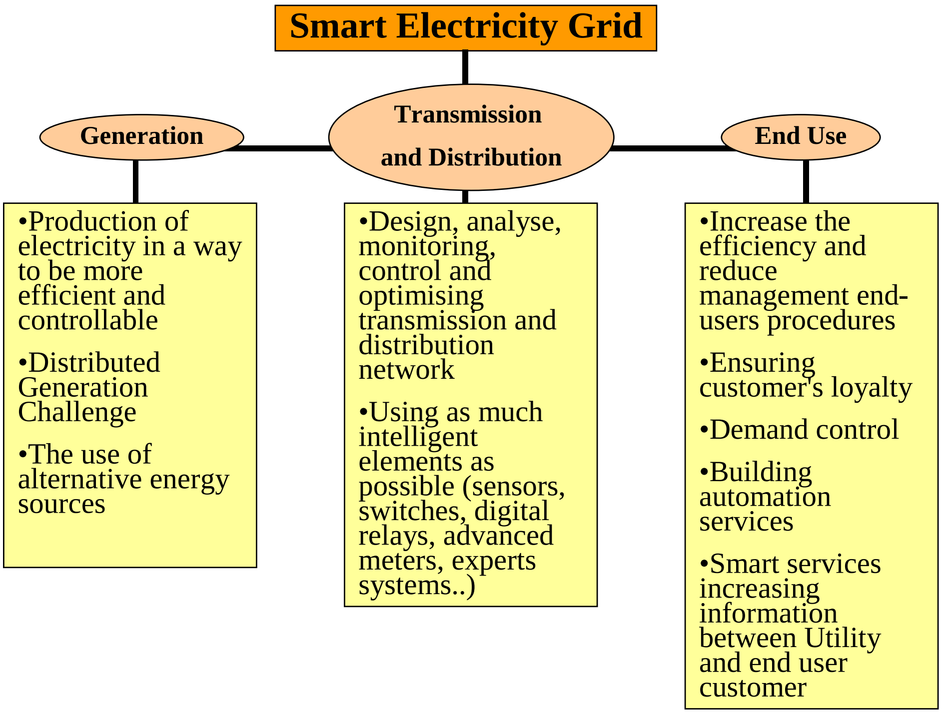


Fig 8-2. Key drivers for Smart Electricity Grids

Smart grids merge electrically related elements, such as traditional cutting-edge power engineering devices and smart sensors and monitoring devices, with IT technologies in order to be able to create the necessary infrastructure to improve the quality of existing services and to provide these to the customers. Having a look at the issues listed above, it can be stated that the objectives of the smart networks is to provide energy in a more efficient, cost-effective way, avoiding outages and service disruptions and ensuring the security of the grid and therefore service. In order to achieve that, the idea is to use clean energy sources closer to the customers, to have better knowledge of network consumption, to expand automation to more points within the network, to provide automation with advanced features to be able to reconfigure the electricity path depending on the status of the grid, and to involve the customer in demand management.

The three main efforts in the smart grids are to be carried out in the following areas, all of them developed over an integrated energy and communications architecture to support intelligent equipment and the data communications network:

- Real -time simulation and modelling capabilities,
- Consumer portal,
- Distributed Energy Resources in Advanced Distribution Automation.

8.2.1 Real-time simulation and modelling capabilities

One of the most important issues to be researched is the creation of a software tool that will be able to:

- gather real-time information from the widespread remote units and sensors within the delivery grid,
- carry out a fast simulation (based on the collected and stored data, matching results through expert systems)
- anticipate responses to events in real time.
- increase value by controlling management and investment models for electricity assets

The objective of these applications (real-time simulation, modelling) is to evaluate power system behaviour in real-time, prepare the power system to withstand credible combinations of contingencies, prevent wide-area blackouts, and accommodate fast recovery from an emergency state to a normal state by using self-healing capabilities. Existing control systems and future self-healing approaches differ in supervisory controls versus more automated controls, and the preservation of the self-protection equipment versus the preservation of the proper integrity of the whole system (generation-transmission-distribution-customer).

These applications are located not only in the centralised systems, but distributed devices will also be able to communicate with each other in order to take specific decisions (such as relay protection, remedial automation schemes ((RAS)), local controllers, and other distributed intelligence systems). This scheme is not the existing vertical one, in which the remote units communicate from top to bottom following a hierarchical structure, but there is peer-to peer horizontal communication . All these applications and system components operate in a co-ordinated manner and are adaptive to their actual situations.

8.2.2 Consumer portal

Another critical aspect in the smart grid is to have a bi-directional communications gateway to the user. This concept is called a Consumer Portal. This portal is a concept rather than something physical. It is an important part, as it will facilitate energy providers offering market services to the customers such as:

- Automatic Meter Reading with advanced features,
- Demand response, based on real time pricing and load control/load shed,
- Remote connect/disconnect procedures,
- Distributed Energy Resources (DER) interface and control,
- Outage detection and notification,
- Theft detection,
- Customer loyalty tools,
- Utility Back Office Software,
- Smart devices and appliances, adjusted to broadband transport capacities allowing soft physical media requirements.

This "direct access" to the customers results in a cost reduction through more efficient operation, reliability improvement through outage notification and better co-ordination with customer systems, additional revenues through new services, and a better knowledge of demand and power quality.
The consumer portal must be based on open standard protocols and communications technologies and applications deployed for non-related-energy services.

8.2.3 Distributed Energy Resources in Advanced Distribution Automation

Also known as DER/ADA, this field is focused on creating a standard communications protocol to enable information exchange between DER and other devices in the electric system. As DER, we can include technologies such us micro turbines, combustion turbines, reciprocating engines, Stirling engines, fuel cells, energy storage/UPS systems, photovoltaic systems, wind systems, hybrid systems and combined heat&power (CHP).

It is important to state that the smart grid initiatives should try to set or define an open standard-based architecture where data communications, smart automation equipment and computing are integrated, helping utilities to creating a smart platform to support the power delivery networks of the future. (turning the grids progressively into smart grids). But how and when this is done is a matter for each utility.. This effort cannot be made suddenly, but step by step, adding more and more smart capabilities onto the existing grids, based on IT (software integration, communications, etc). As was stated in an EPRI Journal "*the intelligent grid will come from the gradual confluence of innovative projects undertaken by individual companies*".

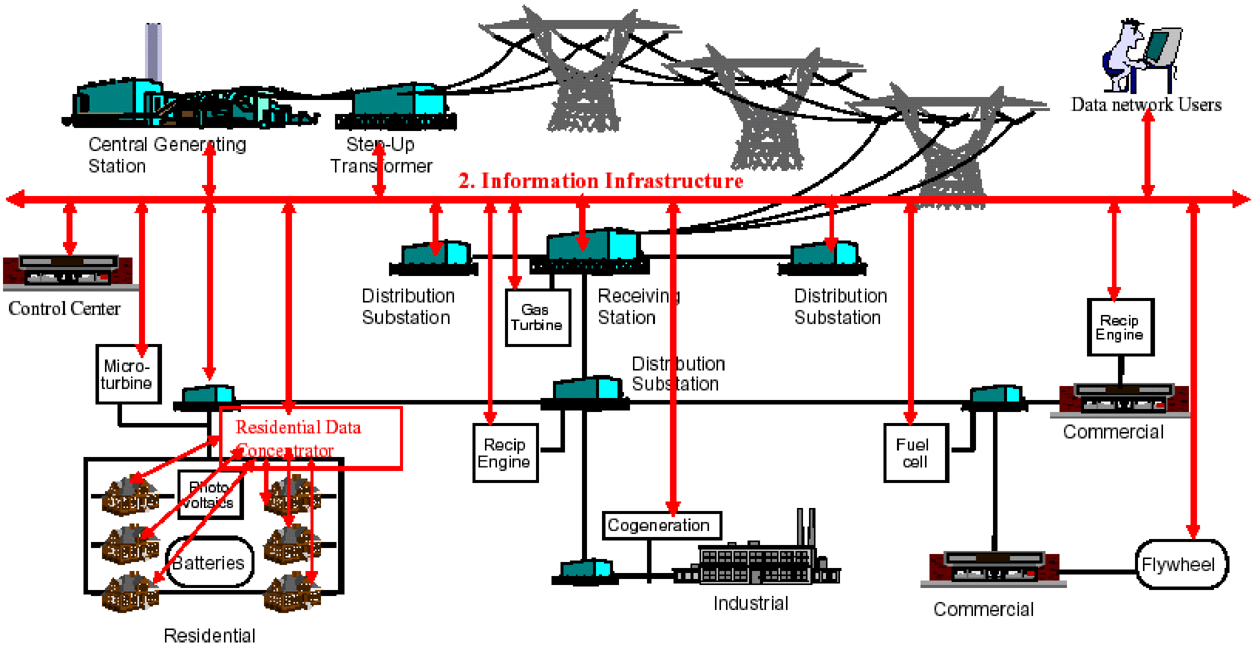


Fig. 8-2 Power and IT structure merging (Source: EPRI)

8.3 The role of PLC technology

Utilities have so far deployed significant telecommunications infrastructure, mostly based on fibre optic, to cover their communications needs for energy related services. These services, basically telecontrol, protection systems, have spread through basically all HV/MV substations. But the coverage in the medium voltage distribution grid is still low. This is mainly due to the huge number of transformer stations compared to the number of HV/MV substations. In fact, the deployment of communications infrastructure over the medium voltage grid is a task that most of the utilities are progressively undertaking.

Broadband PLC has a special role in this task. In short, Broadband PLC allows utilities to deploy an Ethernet-based telecommunications infrastructure over the medium voltage and low voltage grid. PLC provides real-time bidirectional communications for all the devices that can be installed in transformer stations, such as remote terminal units for telecontrol, diverse sensing and alarm devices. Similarly, PLC provides magnificent access through the low voltage grid to customers to facilitate the creation of a Consumer Portal (AMR services, etc).

Additionally, the intrinsic nature of PLC (the use of the electrical grid as a communications media) allows that technology to detect possible failures in the cables and other MV elements, which becomes a useful diagnosis tool in a Condition Based Maintenance (CBM) or Reliability Centred Maintenance (RCM) scheme. Although this feature is still at an experimental stage, some experiments have shown the possible correlation between PLC performance degradation and electrical network behaviour prior to a failure occurrence.

As mentioned above, PLC can play a key role in the creation of the communications infrastructure required by the smart distribution networks.

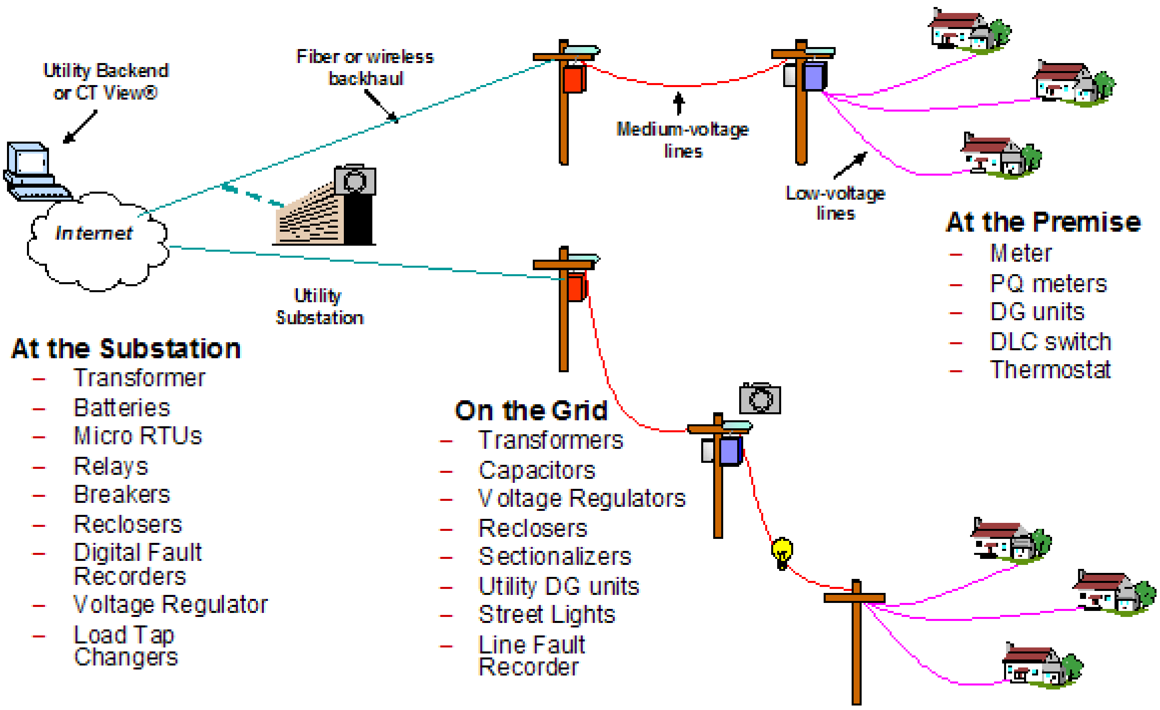


Fig. 8-3 Smart grids services over BPL (source: CURRENT technologies)

8.4 Intelligent Grid Initiatives and Deployments

8.4.1 Initiatives

- **IntelliGrid**

Maybe the most outstanding initiative regarding intelligent grids is the IntelliGrid Project. The IntelliGrid Consortium was created by EPRI to help the industry pave the way to the IntelliGrid vision of the power grid of the future. The partners in the IntelliGrid Consortium have collaboratively developed a vision for the power delivery system of the future. Its spirit and intention has remained unchanged since the start of the initiative. It is:

> *A new electric power delivery infrastructure that integrates advances in communications, computing and electronics to meet the energy needs of the future*

This vision is intended to be shared not only among IntelliGrid partners but also throughout the energy industry and public agencies. The IntelliGrid mission is:

> *The IntelliGrid Consortium will enable the development, integration and application of technologies to facilitate the transformation of the electric infrastructure to cost-effectively provide secure, high quality, reliable electricity products and services.*

- **European Commission**

The 6th Framework programme of the European Commission consists of two projects dealing with distributed generation: EU-Deep and IRED.

- EU-Deep, led by 8 European electricity utilities, aims to eliminate most of the technical and non-technical barriers that hinder a mass roll out of Distributed Energy Resources (DER).

- IRED stands for “Integration of Renewable Energy Resources and Distributed Generation into the European Grid” and is a cluster made up of 7 projects within the 5th framework programme dealing with Renewable Energy Resources (RES) and Distributed Generation (DG). The project aims to facilitate the integration of RES and DG into the European electricity grids, thus creating a competitive European industry in sustainable and reliable energy supply for the future.

- **SmartGrids**

  The European Technology Platform (ETP) SmartGrids was set up in 2005 to create a joint vision for the European networks of 2020 and beyond. The platform includes representatives from industry, transmission and distribution system operators, research bodies and regulators. It has identified clear objectives and proposes an ambitious strategy to make a reality of this vision for the benefits of Europe and its electricity customers.

  Objectives:

  - To develop a shared vision for the future which encourages the engagement of multiple, independent parties;
  - To identify research needs and build support for an increased public and private research effort regarding electricity networks;
  - To align ongoing RTD projects and new European, national and regional programmes on electricity transmission and distribution systems;
  - To draw conclusions and recommendations for follow-up actions and implementation of the strategic research agenda and deployment plan.

  A Shared Vision:

  The SmartGrids vision is about a bold programme of research, development and demonstration that charts a course towards an electricity supply network that meets the needs of Europe's future. Europe's electricity networks must be:

  - Flexible: fulfilling customers' needs whilst responding to the changes and challenges ahead;
  - Accessible: granting connection access to all network users, particularly for renewable power sources and high efficiency local generation with zero or low carbon emissions;
  - Reliable: assuring and improving security and quality of supply, consistent with the demands of the digital age with resilience to hazards and uncertainties;
  - Economic: providing best value through innovation, efficient energy management and 'level playing field' competition and regulation.

  The vision embraces the latest technologies to ensure success, whilst retaining the flexibility to adapt to further developments. Network technologies to increase power transfers and reduce energy losses will heighten the efficiency of supply, whilst power electronic technologies will improve supply quality.

  Advances in simulation tools will greatly assist the transfer of innovative technologies to practical application for the benefit of both customers and utilities. Developments in communications, metering and business systems will open up new opportunities at every level of the system to enable market signals to drive technical and commercial efficiency.

8.4.2 Deployments

- **CenterPoint Energy**, in collaboration with IBM, is carrying out a field trial using intelligent grid technology in three separated areas of Houston. The limited deployment of Intelligent Grid technology will involve CenterPoint Energy installing, testing and monitoring automated meter reading (AMR) of electric and natural gas meters, remote connection and disconnection of electric service, and automated outage detection and restoration. BPL (Broadband PLC) technology will be used for the data communications network.

- **TXU Electric Delivery**, a regulated subsidiary of TXU Corp, has launched a Smart Grid rollout using BPL technology from CURRENT Technologies. The BPL network will serve more than two million TXU Electric Delivery customers in the Greater Dallas-Fort Worth area and in other Texas communities. The "smart services" to be provided are: monitoring its electric distribution network remotely and in real time, automated outage and restoration detection as well as outage prevention, and automated meter reading of state-of-the-art BPL-enabled electricity meters.

- **Intelligrid Architecture in use or committed to use**
  - California Energy Commission: Dynamic pricing implementation.
  - U.S. department of Energy/ New York Power Authority: Eastern interconnection phasor measurement project
  - Salt River project: remedial action plan.
  - Electricité de France has identified three applications: re-designing system information for the new Distribution System Operator created to un-bundle activities; research activities with Con Edison in the CEIDS -FSM project; a research project to increase automation in substations.
  - Long Island Power Authority has identified 3 possible areas: advanced distribution automation; distributed resource control and management; demand response / distributed resource aggregation (possibly with NYISO)
  - EDP (Energias de Portugal) is studying and testing an innovative project, the so called INOVGRID, aligned with the internationally accepted vision for the electrical systems of the future. The driving forces of INOVGRID are:
    - Telemetering, to provide instruments and telemanagement functionalities to the:
      - Network users,
      - Agents of the liberalized market.
    - Microgeneration, to make the network suitable for generalized integration of distributed microgeneration, maintaining:
      - Network stability,
      - Operational security and
      - Supply availability
    - Smartgrid - to introduce more intelligence into several layers of the network, improving its:
      - Efficiency,
      - Operational security and
      - Quality of service.

9 Cost/Benefit considerations

One of the crucial aspects for the extended application and use of the Powerline technology is related to the economic profitability of the associated investments, namely when compared with alternative technologies.

As such, the WG has tried to collect relevant data amongst its members using a simple model of costs created to enable a suitable cost/benefit analysis. However, it has not been possible to obtain consistent and useful information.

Nevertheless, and considering the importance of this subject, the WG carried out research into this and a summary of the published and available information is presented in this chapter.

9.1 Commercial Applications

Over the last few years, several commercial trials supporting Broadband PLC technology have been launched by Power Utilities and their telecommunications subsidiaries, in Europe and USA, in general without the desired commercial success, due to several reasons.

Usually, the commercial service offered includes voice and Internet services, but the penetration reached by this commercial service has not been sufficient to justify investment and company efforts, in spite of the good quality of service and the customer's technical satisfaction. Typically, the commercial penetration has reached figures of around 5%, for business cases requiring penetrations above 10%.

Given this scenario, most of the promoters have suspended their trials and are focusing the technology application towards the support of core business services, as an interesting alternative to other technologies.

9.2 Core Applications: Spanish Study

UNESA, the Spanish Association for the Electric Industry, carried out a study [3] in order to analyse the impacts, in terms of the cost/benefits ratio, of using PLC systems to monitor the energy grid, and defined a simple model of costs that could be avoided by the existence of PLC systems in the MV network. The main findings and conclusions of this study are presented below.

The companies consolidated experience with current PLC technology has allowed the conclusion to be reached that this technology is suitable in urban areas, rather than in rural areas, since:

- In urban areas the distances between transformer stations are generally lower than in rural and semi-urban areas, where the PLC Technology finds network branches beyond its normal reach;
- In rural and sub-urban areas aerial lines are frequent, causing technical problems for PLC technology;
- The power grid has not been designed to support PLC technology; this fact implies that there is frequently the need to carefully plan PLC systems, in order to overcome existing constraints.

These characteristics are enough to concentrate Broadband PLC system applications in urban areas with high coverage ratios and infrastructures which are mostly subterranean. In high density urban areas the use of Narrowband PLC technology at the LV level does not make economic sense if we are limited to the AMR (Automatic Meter Reading) service.

Among several alternative technologies, the main competition in massive urban implementations is given by GPRS/3G technology, which is clearly more profitable for low coverage percentages. This means that the cost effectiveness of GPRS/3G is higher concerning investment expenditures (CAPEX).This fact, leads us to stress that:

- Considering that the initial investment costs of GPRS/3G are lower than those of PLC, it is necessary that the PLC equipment costs show an important adjustment;

- Initial economic investment efforts are also conditioned by coupling units prices (equipment and installation costs), that are necessary to accelerate efforts in order to obtain a cheaper solution for the complete broadband PLC system;
- The differential advantage of a 100% company owned infrastructure, offered by the PLC technology, as opposed to the GPRS/3G solution, may not be enough to justify the currently significant economic difference between the two technologies;
- For penetrations near 100%, PLC technology may be a real alternative whenever the quality and availability levels of GPRS/3G service are a barrier for critical provision of services.

As regards operational costs (OPEX), the main conclusion of the UNESA study is that the use of services provided by a telecommunications operator is penalized by monthly payments. Additionally, it is important to stress that:

- In the study evaluations, a flat rate for GPRS/3G services was considered, independently of the volume of transferred data;
- The study considered the GPRS/3G solution to be more mature and stable than the PLC solution, and assumed that that equipment involved no installation and functioning problems in the aggressive environment of substations. Higher maintenance costs for PLC technology were considered. This means that a greater PLC level of maturity may allow an important cost reduction in this expenditure typology;
- In spite of the higher maintenance costs for the PLC technology, its operational costs are clearly lower than those of GPRS/3G for 100% coverage;

Considering the economic study carried out UNESA and presented here, PLC technology may be positioned as the communications alternative best suited for penetration ratios near 100%, with higher added value for the Distribution Companies, due to the synergies that can appear in the exploitation and maintenance of superimposed infrastructures, with growth equal to the electrical grid and including the direct incorporation of new services.

Nevertheless, the current technological reality offers technical solutions supported by telecommunications operators which are a clear threat in the short term.

10 Conclusions

Electrical Utilities have for a long time been using narrow band PLC technology to exchange information between substations, typically to transmit simple orders and to provide voice channels for maintenance purposes. This narrow band technology has been used to support Automated Meter Reading (AMR) and Demand Side Management (DSM) services

Recently, Utilities have been following with great interest and thoroughly testing the latest generations of technology using Low Voltage and Medium Voltage distribution networks for transporting high level telecommunication signals.

Recent progress in PLC technology has made it capable of transporting tens of Mbit/s over the electricity grid.

Power Line Communications (PLC) is a proven, competitive technology, supported by utilities and manufacturers worldwide, which takes advantage of an existing infrastructure: the electrical power grid.

PLC technology offers great service potential with applications in different fields: Internet broadband access, telephony, multimedia and audiovisual services, in-home networking services, energy related applications for utilities, etc. In its current status, Broadband PLC can compete and/or complement existing access technologies on the market.

Typical applications provided by Broadband PLC technology in current deployments are telecom services to final users, such as broadband internet access or voice (VoIP) and public services. In addition, Utilities may also use this telecommunication network for their own needs, especially to meet new challenges.

In spite of the attractiveness of the public telecommunications business, at the European level, few of these initiatives have survived. The success of most commercial trials has been hampered for several reasons such as the competence of the telecommunications operators providing ADSL and the appearance of new services (for instance, IPTV and VoD) that are not easily provided by current PLC technology.

In the near future power distribution companies will face important challenges related to energy efficiency, quality of service, infrastructure telemanagement, through regulatory requirements or by cost reduction needs. PLC technology can provide them with an internal, privately-owned solution, allowing the transmission of significant data volume concerning the status of the electrical network.

In the meantime, core applications using Broadband PLC look more and more appealing due to:

- Pressure from electricity regulators to create the so-called intelligent grid

- The need for value-added services in the competitive context of the electricity sector

- Tuned network management to prevent faults and potential black outs

- The preparation of the next generation of meters

PLC adds to the traditional applications of telecommunication services of other electrical applications such as metering, surveillance, etc. A very important advantage of PLC technology is that it can be used as a diagnostic tool to detect potential failure in cables, isolators, switches and other MV infrastructure elements. This is possible because the PLC telecommunication channel is the electrical MV cable itself. The extension of cable lifespan and moving from a Programmed Maintenance scheme to a Condition Based Maintenance (CBM) saves costs and increases quality of supply.

One of the most important challenges for Utilities is to convert the current Electrical Distribution Network into an “intelligent” network, helping to meet predicted demand for electricity, to ensure efficient use of plants, equipment and resources and to manage Distributed Generation. Broadband Powerline Communications over the electrical grid could help build a bidirectional telecommunication network for that purpose.

Hopefully, and having concluded the IEEE and European (OPERA initiative) efforts, we will have a standard for PLC technology in the near future .

What we see then is a set of opportunities in the hands of many players (Utilities, telecom operators, electricity and telecom regulators, financial investors, municipalities, etc.) that have to get together if anything is to happen. Cooperation between these stakeholders has to happen first to make opportunities come true.

11 Acronyms

ADA	Advanced Distribution Automation
ADSL	Asymmetric Digital Subscriber Line
AMM	Advanced Meter Management
AMR	Automatic Meter Reading
ATM	Asynchronous Transfer Mode
BB-PLC	Broadband PLC
BER	Bit Error Rate
BPL	Broadband Power Line
CAPEX	CAPital EXpenditure
CBM	Condition Based Maintenance
CENELEC	Comité Européen de Normalisation Electrotechnique / European Committee for Electrotechnical Standardization
CISPR	Comité International Spécial des perturbations Radioélectriques / Special International Committee on Radio Interference
CODEC	Coder / Decoder
CPE	Customer Premises Equipment
DA	Distribution Automation
DEG	Distributed Energy Generation
DER	Distributed Energy Resources
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DSM	Demand Side Management
EDS	Energy Data Server
EMS	Electricity Management System
EP	Ethernet Performance
FDD	Frequency Division Duplexing
FTP	File Transfer Protocol
FTTB	Fibre to the Basement
GPRS/3G	General Packet Radio Service/3rd Generation
HE	Head End
HDSL	High bit-rate Digital Subscriber Line
HTTP	Hypertext Transfer Protocol
HV	High Voltage
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPTV	Internet Protocol Television
LAN	Local Area Network
LV	Low Voltage
MAC	Medium Access Control
MV	Medium Voltage
MVHE	Medium Voltage Head End
NB-PLC	Narrowband PLC
NOC	Network Operations Centre
NTU	Network Terminal Units
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplexing
OPERA	Open PLC European Research Alliance
OPEX	OPerational EXpenditures

OSS	Operational System Support
PD	Partial Discharge
PER	Packet Error Rate
PLC	Power Line Communication
PLR	Packet Loss Rate
PoP	Point of Presence
PPC	Power Plus Communications AG
PQ	Power Quality
PSN	Packet Switched Network
PSTN	Public Switched Telephone Network
PUA	Powerline Utilities Alliance
QMD	Quality Measurement Devices
QoS	Quality of Service
RCM	Reliability Centered Maintenance
REP	Repeater
RFC	Request for Comment
RTT	Round Trip Time
RTU	Remote Terminal Unit
R&D	Research and Development
R&D&I	Research and Development and Innovation
SCADA	Supervisory Control And Data Acquisition
SLA	Service Level Agreement
SMA/CR	Synchronous Multiple Access/Contention Resolution
SNR	Signal to Noise Ratio
STB	Set-top Box
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol Over Internet Protocol
TD	Time Division
TDM	Time Division Multiplexing
TDMoIP	Time Division Multiplexing over IP Networks
TDMoPLC	Time Division Multiplexing over PLC
TE	Transformer Equipment
TOS	Type Of Service
TS	Transformer Station
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
UNESA	The Spanish Association of Electric Utilities
UPA	Universal Powerline Association
UPS	Uninterruptible Power Supply
VLAN	Virtual Local Area Network
VoD	Video on Demand
VoIP	Voice over IP
VPN	Virtual Private Network
WAN	Wide Area Network

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ANNEX A

(Questionnaire issued to several members of CIGRÉ)

WD2.21 - Questionnaire - Core Aplications

Dear Colleagues,
During the Lisboa meeting of the WD2.21 we took the decision to request to the members of CIGRÉ an answer to a questionnaire regarding the key isues of BPLC (Broadband PowerLine Comunications).
Having said that, you are kindly requested to answer (until the 31st of October) to the following questionnaire marking the adequate box with "**X**".

1. BROADBAND POWERLINE TECHNOLOGY

1.1 How mature are the existing BPLC systems? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Not mature, 5-Clearly Mature

1.2 Is BPLC technology mature enough to be used by Power Utilities in their core applications? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Not mature, 5-Clearly Mature

1.3 What is your degree of concern regarding EMC issues? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Very concerned, 5-Not concerned

1.4 What can we expect from the standardization institutions and from the regulatory bodies for the next 2 years? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Very concerned, 5-Not concerned

1.5 What can we expect from the standardization institutions and from the regulatory bodies for the next 2 years? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Nothing, 5-A lot

1.6 Does your company have any BPLC deployment? — Yes ☐ No ☐

1.7 If yes, how many Homes Passed have you covered until today? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Less than 1.000, 2-Less than 1.000, 3-Less than 10.000, 4-Less than 50.000, 5-More than 50.000

1.8 If no, do you have any plans to deploy BPLC in the near future? — Yes ☐ No ☐

2. NARROWBAND POWERLINE over LV and/or MV distribution lines

2.1 How mature are the existing NPLC systems? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Not mature, 5-Clearly Mature

2.2 Is NPLC technology mature enough to be used by Power Utilities in their core applications? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Not mature, 5-Clearly Mature

2.3 Does your company have any NPLC deployment? — Yes ☐ No ☐

2.4 If yes, how many Homes Passed have you covered until today? — 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
1-Less than 1.000, 2-Less than 1.000, 3-Less than 10.000, 4-Less than 50.000, 5-More than 50.000

2.5 If no, do you have any plans to deploy NBPLC in the near future? — Yes ☐ No ☐

3. POSSIBLE CORE APPLICATIONS

Please rate from 1 to 5 (1 is lowest interest and 5 is highest interest) the following applications:

3.1 Automatic Meter Reading 1 2 3 4 5

Metering the energy in the clients house

3.2 Transformer station energy remote meter reading 1 2 3 4 5

Metering the energy consumption in the transformer station

3.3 Telecontrol and Teleaction 1 2 3 4 5

Environmental conditions metering, Switch activation, etc.

3.4 Telesurveilance and security 1 2 3 4 5

Transformer and sub-station video surveillance. Speacial sites surveillance

3.5 Load Management 1 2 3 4 5

Load monitoring of special power sites

3.6 Outage detection and handling 1 2 3 4 5

Remote control the MV/LV network and prehemptive detection of outages

3.7 Automated billing 1 2 3 4 5

Automatic billing and web available invoice

3.8 Theft/Tamper detection 1 2 3 4 5

Usin load management and monitoring, detect non-technical losses

1 2 3 4 5

4. OTHER APPLICATIONS (BESIDES TELECOM AND CORE)

Please rate from 1 to 5 (1 is lowest interest and 5 is highest interest) the following applications:

4.1 Security 1 2 3 4 5

In-house security monitoring

4.2 Home automation 1 2 3 4 5

In-house home aplliances automation

4.3 Other applications

Please indicate bellow which other applications you think are possible and/or desirable:

THANK YOU FOR YOUR COOPERATION…

Notes:

BPLC = Broadband PowerLine Communications
NPLC = Narrowband PowerLine Communications

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