# Smart Grid Enabled and Enhanced by Broadband Powerline

Strategic value and inherent technical characteristics of Broadband Powerline

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***Abstract*—For Smart Grid applications, Broadband Powerline presents inherent Unique Selling Points compared to other technologies. Many have promoted various technologies for Smart Grids. In Europe, new generation of Narrowband Powerline seem to gain ground. However, a growing number of utility and industrial companies, concerned about the limits of such widespread technologies, have tested and implemented Broadband Powerline- some with the help of bmp as strategy consultancy. The maturity coupled with the performance of this technology allows to forecast Broadband Powerline as one of the key technologies for Smart Grid, which will enable utility companies to overcome numerous challenges posed by the next generation energy distribution grid. Through this paper, we will describe the technologies forming the Powerline communications and especially, the place of Broadband Powerline among the Smart Grid technologies and its advantages.**

***Keywords-Broadband Powerline; Smart Grid; Smart Metering; comparative performance of AMR technologies; USPs.***

## I. INTRODUCTION

Traditional grid used by Utility companies is facing new challenges concerning the efficiency and flexibility of its applications. The development of Automatic Meter Reading (AMR) with Narrowband Powerline Technologies or other technologies was a first step. However, the needs of real time and permanent connectivity for all grid applications suggest the use of a technology offering higher performances and offering long term viability. Broadband Powerline appears as a technology meeting these needs and offering a global solution.

Through this paper, we will first focus on the overall market of Powerline Communications. Secondly, we will offer an overview of the Broadband Powerline technology, and then its advantages as unique selling points. Finally, we will describe some representative cases concerning Broadband Powerline and assess its competitive position.

## II. BROADBAND POWERLINE WITHIN THE LANDSCAPE OF POWERLINE

Using the electrical network to build a two-way communication Internet infrastructure, Broadband over Power Line technology (BPL) is currently taking a leading position [1] for the energy providers which want to upgrade their networks into "Smart Grids".

BPL transmits signals over the distribution networks in the 1 MHz-34 MHz (and beyond) via Orthogonal Frequency Division Multiplexing modulation (OFDM) [2]. This multi-channel modulation allows transmitting the signal over various frequencies, taking maximum advantage of the available frequency bandwidth.

Recent similar developments are being undertaken focusing on the CENELEC A band (under 148 kHz), but even here BPL presents significant and valuable advantages over such Narrowband Powerline technologies.

Used as part of the largest ongoing European projects, such as Linky by ERDF in France or Telegestore in Italy by Enel [3], the narrowband Powerline technology is a suitable solution for basic applications such as meter reading or remote billing. Supported by many international players, we are witnessing the emergence of several industrial standards, seeking to become European or even global references, such as PRIME [4] (led by Iberdrola), G3-Powerline [5] (led by ERDF) or Meters & More [6] (led by Enel). Some leading companies in PLC technology, such as Echelon [7] or Siemens [8], are following this trend and announced their willingness to open their protocols to all manufacturers.

TABLE I. PERFORMANCE OF NARROWBAND PLC

| Narrow-band PLC | Performance [9] | | | |
|---|---|---|---|---|
| | ***Modulation*** | ***Data rates*** | ***Reliability of data transmis-sion*** | ***Distance LV/LV*** |
| 1st Generation | FSK, S-FSK, BPSK, DCSK, DBPSK, DQPSK | Until 5 Kbps | 97% on a 3 days period | 700 m - 1,5 km |
| 3rd Generation | OFDM | Prime: 19,2 -128 Kbps G3 up to 300 Kbps | >95% overnight readings | Prime: 4 km G3: 6 km |

The market is characterized by a quick evolution of the narrowband Powerline performances. As referred in Table I, the technologies using simple carrier modulations (FSK [10], S-FSK [11], BPSK [12], DCSK [13]) show today a commercial maturity and are industrialized by industry heavyweights such as Echelon [14], Enel or Yitran [15]. However, the low data rates – not exceeding 5kbps – allowed by this 1st generation constrain the implementation of future new applications.

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More recently, yet still in development, a new generation using a multi-carriers modulation (OFDM) has been introduced on the markets, enabling higher data rates (from a dozen up to 128 kbps) and using the CENELEC A frequency band. As shown in Figure 1, this technology also increases the robustness of the signal, allowing crossing the transformers in order to communicate over the low and medium voltage lines, which is a clear advantage for electrical network including remote parts of rural areas. Definitely, more suited to the future, this new generation of OFDM-based products emerges, enabling for instance, the use of IPv6.

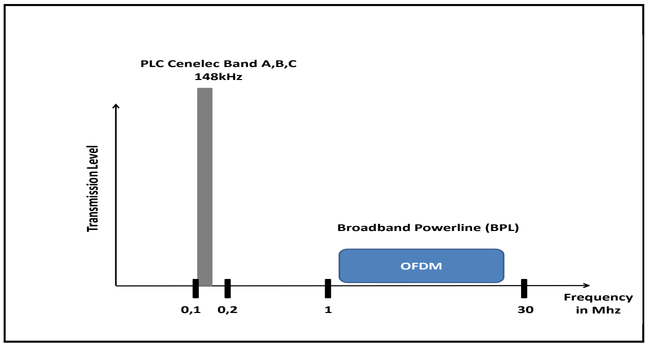


Figure 1. PLC and BPL basics [16]

To implement the most suitable Smart Grid network regarding the needs of each energy supplier, the key question is to clearly identify the limits of this architecture enabled by narrowband Powerline. In order to ensure the sustainability of the network, it is primordial to take into account the possible evolution of these needs, in addition to the required applications to date. These might entail the implementation of alternative technologies allowing other data rates, and permanent connectivity throughout the energy distribution network.

However, BPL reaches significantly more speed, as, in most of the cases, injecting 200 Mbps on the low voltage enables to benefit from Mbps up to the meter, and enhances the connectivity in enabling real time applications.

Performances of BPL depend on the distance to cover, the electricity environment (type of cable, cables' isolation methods, and type of secondary substation), skills of installer/integrators and the effective noise levels. Until recently, 200/300 Mbps was the maximum gross bandwidth reached by companies; however, current bandwidth can reach 400/500 Mbps or even 1 Gbps but higher speeds being addressed for the inhome market.

BPL current performances are unequalled on the medium and low voltage lines. On one hand, low voltage lines offer 200 Mbps speed over 250-300m without repeater and physical data rates under 1 Mbps over a long range transmission. As seen in the recent CEZ pilot [17] on Figure 2, where more than 1,000 meters have been connected through BPL, all meters have been read, with speeds up to 30 times higher than narrowband PLC having been tested in the same project in 2011. On the other side, BPL on medium-voltage underground lines is performing extremely well, allowing up to several tens of Mbps physical throughput. Such performances have been achieved with a number of tests and projects such as in Morocco with ONEE- Office National de l'Electricité et de l'Eau- [9] as early as 2008, or more recently in several deployments as backhaul or smart metering data as seen with Iberdrola in Spain [9].

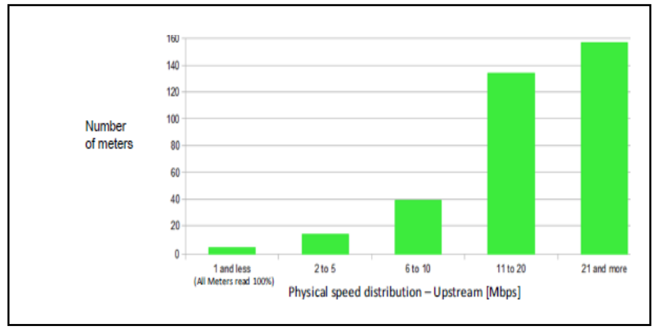


Figure 2. Physical speed distribution on a secondary substation sample equipped with BPL at CEZ as in October 2011 [17]

Today, BPL on overhead medium voltage lines are in some cases seen to allow 2 Mbps speed over 4 km and at least 200 kbps over 6 to 8 km.

## III. Revival of Broadband Powerline

After years of unrealized hopes, BPL activities are now intensifying though the growing interest shown by industrial and utility companies, or venture capitalists.

BPL has long seemed to be unsuccessful, with cases such as IBEC [18], which after having announced a partnership with IBM in order to connect undeserved US American areas via BPL technology, suddenly ceased its activities at the beginning of 2012. Major companies such as Endesa and Itochu, which in 2005 decided to invest in DS2 [19], have disinvested later on, or Earthlink & Consolidated Energy, which, after investing in Ambient [20], has seen the company stopping its broadband Powerline activities meanwhile.

But, the maturity and newest developments of the BPL technology have led various players to re-consider their position towards this specific market.

The first positive factor was the achieved standardization in the field of BPL. Indeed 2010 was the year when two major standards for the BPL industry were reached.

The IEEE 1901 standard is based on the industrial norms Homeplug [21] and HD PLC [22].

The technology specified by IEEE 1901 aims at using transmission frequencies of less than 100 MHz, and allows data rates rating from 100 Mbps. It is also used by all classes of BPL devices, such as BPL devices used for the first-mile/last-mile connection, and broadband services as well as BPL devices used in buildings for LANs, Smart Energy applications, transportation platforms (vehicle) applications, and other data distribution (<100m between devices). Though the standard does not provide interoperability with the two technologies it is based on, it allows benefiting from the coexistence between these technologies supported by two different MAC layer protocols.

The ITU G.hn [23] standard, based on DS2/Marvell technology norm using OFDM access method, has first focused on the inhome market and can be supported by any wire (coaxial cable, electrical wire and telephone line). Its technology offers a data rate speed up to 1 Gbps but though being non-interoperable with IEEE 1901 based products, it has secured co-existence with these thanks to the Inter System Protocol (ISP), which coordinates the usage of the frequencies among the various domains of BPL implementation.

Such a context has been securing the environment for BPL and has enabled the emerging of new players, such as, just to name a few: Broadcom [24], Mstar [25], Qualcomm Atheros [26], which are chipset providers using IEEE 1901 standard or Lantiq [27], Marvell [28], Metanoia [29] using the G.hn standard. Sigma Designs [30] is one of the main chipset providers using both standards.

Furthermore, heavyweights have adopted BPL as part of their portfolio or strategy.

Alstom Grid [31] has partnered with a DS2 integrator to include BPL as a SCADA solution for medium voltage, integrating digital information together: telephony, video images, and grid data over 20 kV networks. Several deployments have been conducted by Alstom: in France, Brazil, India, etc.

In 2012, Siemens Financial Services Venture Capital has become shareholder of PPC [32] to strengthen their portfolio in BPL communications.

Alcatel-Lucent has been studying the opportunities, which might be realized by this technology, but up to now, it has not come out with a specific product or strategy.

Itron cooperates with PPC for integrating BPL in their modems. Other modem suppliers have also undertaken some first developments with BPL: Landis & Gyr [33], IUSA [34], ZPA [35] and Mikroelektronika [36]. In 2009, Elster [37] announced its collaboration with Defidev [38] for the first meter prototype with BPL and radio being integrated.

ETDE (groupe Bouygues) [39] is using BPL technologies for smart street lightning in various French cities.

Utility companies as well have chosen BPL for various segments: Iberdrola has decided to implement BPL on its medium voltage lines for gathering the AMR data, British Gas which invested in PPC company in 2012 to strengthen its presence in the European smart grid market will start a pilot project with BPL on various smart grid applications for new opportunities.

In addition, numerous utility companies all over the world are testing the technology for their own needs, in Europe (CEZ, EnBW, EDF, etc.), in Asia (Meralco, RESB, TPC, etc.) in Africa (CEET in Togo ONEE in Morocco, etc.), or in Latin America (Light, etc.).

The interest for BPL has been intensified due to the potentials of the technology for supporting new applications within Smart Grid.

## IV. UNIQUE SELLING POINTS OF BPL FOR SMART GRID INFRASTRUCTURE

Implemented on the low and medium voltage networks, BPL allows a real time and permanent connectivity and thus, continuous monitoring of the entire electrical grid. The technology works without creating interferences with the energy distribution activities and allows energy utilities to achieve immediate operational gains, such as:

In the short term:

- Technical and non-technical losses on low and medium voltage are identified and restrained.
- Manual meter readings are no longer required, replaced by remote metering enabling immediate and reliable readings.
- Invoices are automatically generated, preventing any entry error and reducing invoicing delay.
- Low and medium voltage network and substations remote monitoring allows improved network operations (preventive and reactive maintenance, etc.) and optimised investment decisions.

In the medium term:

- Quality of service is improved thanks to error prevention, innovative offers and tariffs meet specific needs of clients.
- Gathering information in real time allows optimised network operation and highly reactive maintenance services.
- Customer service can offer a highly efficient support, improved with real-time network information transmitted through the Broadband Powerline infrastructure, and thus, enabled to answer to any incident or demand accurately.

In contrast to the generated benefits, Broadband Powerline induces limited additional operational costs, essentially related to the IP (Internet) management tools and the equipment maintenance. Further, the achieved commercial maturity of the technology has allowed manufacturers to develop a wide range of dedicated products for applications related to energy distribution.

The flexibility of BPL communications and their ability to complement with any other telecommunication technology enable the use of existing infrastructures such as optical fiber deployed on High (or even Medium) Voltage networks or wireless technologies, and thus, to interface with any usual management system already deployed. Therefore, the investments required by the deployments are clearly defined and controlled.

The energy provider is able to activate its infrastructure and to remotely manage each of its BPL devices, the meter and other connected devices (sensors, alarms, cameras, etc.) as soon as first infrastructures have been implemented. Thus, Return on Investment of Broadband Powerline businesses is immediately enabled and attractive and grows along with the increase of the Powerline coverage.

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Broadband Powerline deployment might be divided in phases and cells, namely by group of LV equipments behind a transformer or a HV/MV line. The CAPEX can be spread across the first years of the project, in order to smooth out the required investments specific LV or MV groups. Such flexibility and incremental deployment permit previous analysis to identify the best potentials for operating savings.

The analysis of Broadband Powerline projects deployed until today has brought proof of the rapid profitability reached by the implementation of a Smart Grid network through this technology. This is being achieved through the incremental savings made available by Broadband Powerline, the control of the correlated investments and the limited operating costs. Coverage of the dense areas ensures a return on investment within a few years and easily balances out the lower profitability of more rural areas, to eventually reach a profitability worth up to five times initial investments.

These advantages are not the only benefits brought by Broadband Powerline, as this technology allows:

- A widening spectrum of possible applications thanks to the versatile nature of Broadband Powerline
- Possibility of upgrading the delivered speeds according to future needs and emerging new applications
- An efficient and simplified coverage of acentric, less dense areas

## V. HIGHLIGHTS ON SOME REPRESENTATIVE BPL CASE STUDIES- RETURN ON EXPERIENCE

Representative projects implementing BPL have been set up within Smart Grid and show the viability and performance of BPL compared to other technologies.

The most quoted as an example for AMR is the Advanced Metering Management Pilot Project, illustrated in Figure 3, and conducted by CEZ which has enabled to analyse and compare various powerline solutions for Smart Grid technology's installation.

Alongside various narrowband PLC solutions, such as:

- Landys&Gyr using PLC modem from local PLC vendor Modemtec,
- ZPA Smart energy which is a local company using a first generation PLC solution / licence from Renesas [40],
- ADD Grup Moldova [41]
- Echelon
- as well as a few GPRS from ZPA and a few RF from EHM,

all being deployed at 28 000 meter locations and in almost 1,000 distribution substations, 5000 BPL meters have been deployed with Corinex' technology in 2 regions Vrchlabí and Pardubice in underground cables. Over 100 BPL couplers have been installed on medium voltage technology, as well as several dozen repeaters.

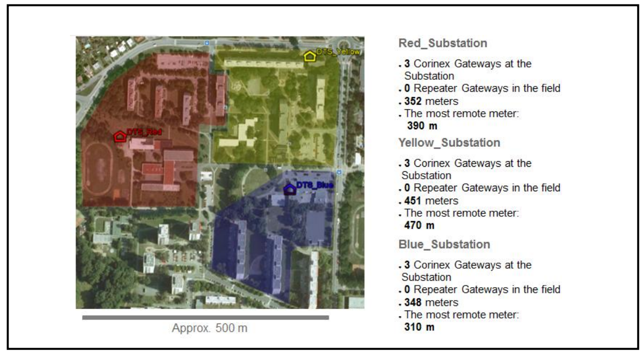


Figure 3. Pardubice BPL test with CEZ in Q1 2012 [17]

General issues appeared along the project deployment such as network optimization, LV nodes identification with high level crosstalks, to name only few of them. But on the whole, the project implementation was mastered and allows drawing significant conclusions about the various technologies' performance.

In the Pardubice BPL project, where no repeaters have been installed, a final average meter reading success rate of 99.705% was registered. Indeed, after the installation by CEZ (which has been done by the utility without assistance by Corinex), some 1.6% of the 1220 meters were not connecting first, but this was resolved quickly after reviewing.

Thus, BPL appeared as having superior connectivity and performance to any other PLC deployments.

Furthermore, CEZ states that the costs are comparable with narrow band solution in absolute terms, and hundreds times lower in price per Mbps.

Thus, though emerging as smart metering solution, BPL - among the numerous technologies tested or deployed for Smart Grid applications (Narrowband Powerline, Wireless, Radio, GPRS, etc.) - possess unique selling points to be pinpointed in the direct control of the energy distribution network, through a permanent and continuous connection (without concentrator for example), under truly controlled costs and allowing the possibility to increase data rates for future applications.

Another Smart Grid area is the utilization of BPL for MV lines, allowing SCADA applications, monitoring of the distribution substations and gathering the data flow from the meters. The appetence of various utilities and industrialists indicate a soon to come maturity for BPL. Many Utility companies are testing (EDF, EnBW, Stadtwerke Ratingen, Scottish Power, etc.); but already some have decided to implement this in a full deployment. Iberdrola in Spain is a good example as already 40% of the targeted MV substations are connected through BPL.

In France, one project has as well come to maturity with the SICAE de la Somme et du Cambraisis [42], which has deployed, jointly with Alstom Grid, innovative BPL technology for MV power grid applications such as telephony, video surveillance, remote meter reading, real-time data exchange with grid controls and active demand response management.

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The BPL platform has been successfully deployed over 65 km of underground and overhead lines with approximately 50 communication points on grid nodes for its French rural municipalities.

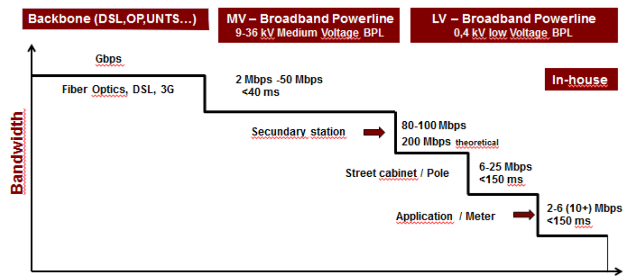


Figure 4. General overview of BPL performance [9]

Unequalled performance on underground and overhead MV lines has been attained in this project, showing that BPL has pushed further its first limits related to distance and sufficient bandwidth, especially related to overhead MV lines.

## VI. CONCLUSION

On the facts gathered from numerous projects and as highlighted by Figure 4, Broadband Powerline, enabling permanent, reliable and fast connectivity onto the entire electrical grid, is therefore considered as a future proof technology, particularly relevant for the implementation of the Smart Grid. However, it is foreseen that hybrid architectures will best meet the specific objectives and priorities of each energy provider, where as Broadband PLC/BPL can and is expected to play a central role.

Some expect the European market potential for BPL in Smart Grids to reach €25bn by 2020 in the Low Voltage segment (metering, e-Mobility, Home Gateway,etc.), while the MV (mainly network automation) is forecasted at €3.5bn. [43].

Though BPL will have to face specific challenges such as imposing an interoperable standard, while using BPL, one should as well consider the use of the excess of capacities which could be used to create high data rates Internet connections and make them available for various applications.

In this respect, one could think of Internet and telecom services, as well as the usage of BPL for smart street lightning networks and the set up of smart cities and buildings.

The deployment of BPL solutions has allowed companies such as Bouygues, ETDE to offer additional services basing on a platform developped first to monitor the street lightning system. Thus, excess capacities enable video-surveillance, traffic monitoring, and the creation of hot spot WIFI as seen in some French cities in the Parisian region.

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