POWER LINE COMMUNICATION (PLC) OVERVIEW

Alexandru-Ionut CHIUŢA[1], Cristina STANCU[2]

Abstract *Power line Communications (PLC) – communications over the electricity distribution grid – has become an interesting topic in recent years. Although this technology has been in use for special applications for several decades, such as street lighting, the communication is made exclusively in the narrowband range and transmission rates are low.*
In several European countries there exists an intensive interest to introduce Power Line Communication (PLC) network into operation for different purposes. These purposes represent different levels of traffic within the PLC network from a very weak level, when using the PLC network for some operational tasks of power distribution network up to very intensive traffic when using the PLC network for public access to Internet.

Keywords: PLC, modulation

1. Introduction

One of the most important features of present data communication is its orientation on broadband services.At this time, the fast Internet access seems to be the most popular service but also other services, such as VoIP, Conferencing or Teleworking ,are gradually expanding. To provide this services it can be chosen from several solutions,such as using the existing telephone lines through digital subscriber lines (xDSL) or cable distributions via cable modems (CATV), installing new optic fibres (PON), using wireless technologies (WLL, WLAN) or utilizing electrical power lines (PDSL, PLC).
The electrical power distribution grid offers a big potential for fast and reliable communication services. PLC technology is far behind recent leading access methods (fiber optics, CATV,WLAN) regarding transmission rates, services and deployments, but has a critical advantage: power lines can be found in essentially all buildings and residences, which cannot be said about other access methods.
In order to implement a PLC solution we must understand the critical properties of powerline channels,which are mainly influenced by cable losses and a high degree of branching.Also we must take into consideration the fact that the existing power lines have not been designed for transmitting signals with a high frequency component.

[1]Title: Prof., PhD ,Eng., Senior Researcher ,Faculty of Power Engineering, Politechnic University, Bucharest, Romania, Developing creativity Center AOSR.(chiuta@gmail.com)
[2]Student, Faculty of Power Engineering, Polytechnic University, Bucharest, Romania, (cristina.stancu86@gmail.com).

2. PLC Technology

PLC is a technology that facilitates the broadband data transfer over the existing power line infrastructure (medium and low voltage) in order to provide services like: Internet acces, VoIP and teleworking.

This technology consists in superimposing a high frequency signal (from 1.6MHz to 30 MHz) over the normal low voltage signal with a standardized frequency of 50-60Hz. See Figure 1 – The PLC signal.

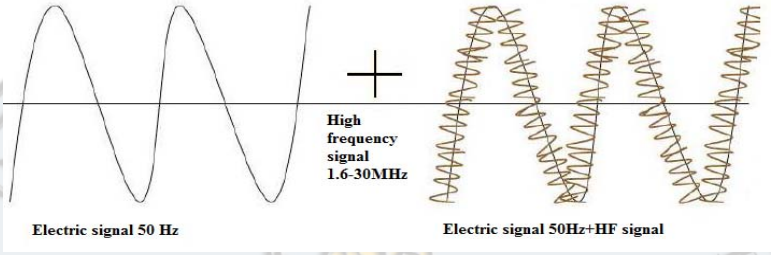

Fig.1 The PLC signal

For the PLC System Architecture see Figure 2 [2].

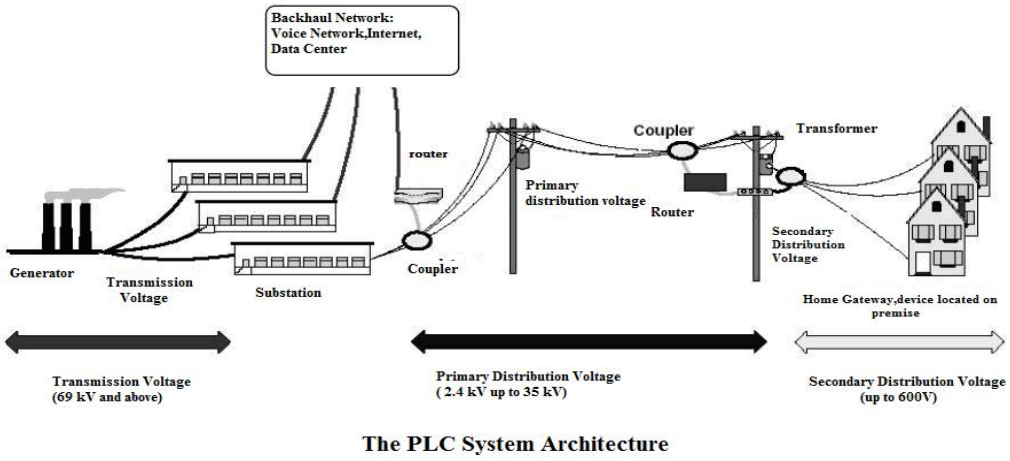

Fig.2 PLC System Architecture

In Europe the mains network is typically divided into three sections with different voltage levels: The high voltage (Transmission Voltage), medium voltage (Primary Distribution Voltage) and the low voltage (Secondary Distribution Voltage) section. From a communication point of view not all parts of the mains distribution network are of equal interest. Especially the low voltage distribution

grid is of great interest as the "last-mile" to the customer. The low voltage "local loop access network" between the substation and the customer premises are often operated in a star shaped structure.

The substation supplies the bus bar; the PLC-signal will also be applied to the bus bar. The physical connection from the substation to the backbone network can be realized by conventional communication links as fibre optics, radio relay links or broadband cables. Numerous - typically between three and ten - cables branch off the bus bar, which lead to the customer premises. Every cable supplies between tens and hundreds of households. Generally, these cables are laid into earth, only in some rural areas overhead lines can be found. The access networks ends at the house connection boxes turning into the in-house network. [1]

Data receivers can be located in any of the buildings. Such a scenario exhibits a strong level of branching (that means a great number of reflections), hence strong cross-coupling effects between wires in a cable and also a nonstationary topology caused by plugging different household appliances into the network. These are the reasons of many problems that the PLC channel suffers from.

The most important ones are:

• Frequency-varying and time-varying attenuation of the medium.

• Dependence of the PLC model on locations, network topologies and terminated loads.

• High interference due to noisy loads.

• High, non-white background noise.

• Various forms of impulse noise.

• Issues of electromagnetic compatibility (EMC) that limit the available transmitted powers.

3. General Aspects of signal propagation

3.1 Low pass Characteristic caused by cable losses

Cables of the mains network are usually laid into earth; they are built for energy transfer with little losses, but are not optimal for data transfer. Multiple measurements showed that these cables have a strong low pass characteristic depending on the type of cable, the length of the cable and the frequencies of the signal [2].

The low pass characteristic is caused by dielectric losses in the insulation of the cable. This also explains why overhead lines do not show this low pass characteristic. In-house cables show few low pass characteristic, caused by short distances.

The low pass characteristic of access networks limits the maximum distance to be overcome by PLC and on the other hand, it limits the maximum usable frequency. For better result we have to split up the available frequency range, in lower frequencies (below 10 MHz),which are used for access network, and higher frequencies between 10 MHz and 30 MHz, which are used for in-house networks.

Also, it must be taken into consideration that for long distances in access networks PLC often only is possible with a reduced data rate or sometimes is not possible at all. The attenuation effects functionality of PLC-systems as, because of EMC-compatibility, transmitter power cannot be increased infinitely. If attenuation exceeds a certain value, the signal cannot be received at all.

3.2. Signal propagation over the power line

The low voltage “local loop access network” between the substation and the customer premises are often operated in a star shaped structure. From a communication point of view they have a similar structure as mobile radio networks consisting of cells and base stations.

The” local loop access network” does not consist of point-to-point connections between substations and customer premises but represents a line bus with the distributor cables and the house service cables. A typical access network link between a substation and a customer (See Figure 3) consists of the distributor cable or a series connection of distributor cables with the characteristic impedance Z_{Li} and the branching house connection cables with the characteristic impedance $Z_{L,H}$.

The house service cable ends at a house connection box. The in-house cabling follows, which is modeled by termination impedance $Z_H(f)$. Each of the transitions at the connections between cables along the propagation path represents changes of impedance and causes reflections.

Due to branches and reflection points the signal not only propagates on the direct connection between transmitter and receiver, but also additional propagation paths have to be considered. Those usually have longer ways and cause time delayed echoes. The result is multi-path signal propagation with frequency selective fading. In some extreme cases a set of frequencies may be wiped out completely. Another result of multi-path signal propagation is an extension of the impulse response of the channel considerably influencing the functionality of PLC-systems with high data rates, as generally the duration of the impulse response of the channel is greater than the duration of the transmitted symbol.

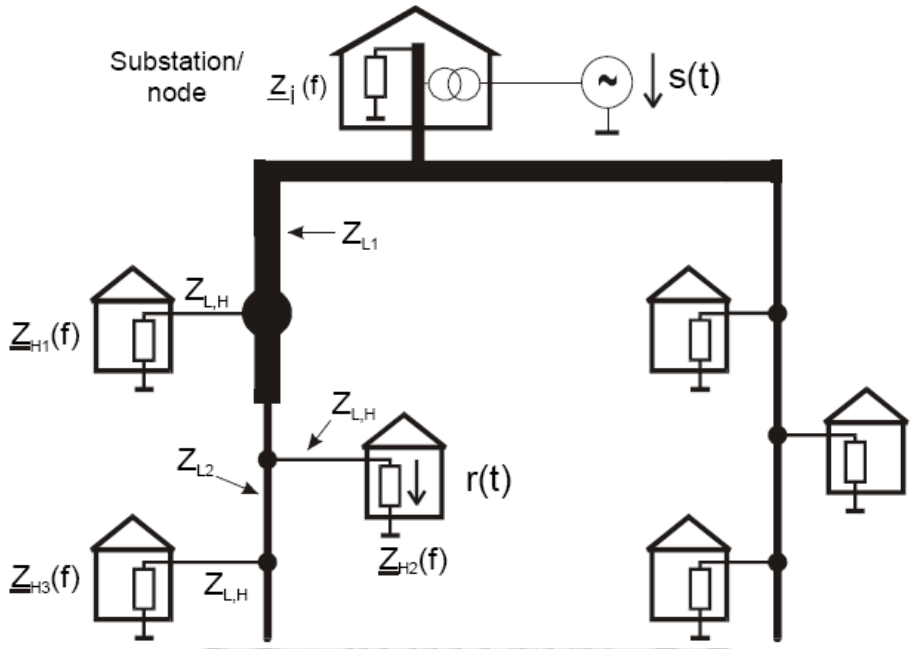

Fig.3 Signal propagation over the power line "loop"[2]

4. Modulation techniques for the PLC system

4.1 The spread spectrum technique

The basic idea of spread spectrum (SS) systems is the use of the code sequence that spreads narrowband signals over wider bandwidths [3]. This approach is suitable for the PLC environment because: it decreases narrowband interferences and selective attenuations.

If we want to use these features, we need a large bandwidth expansion that may severely limit the maximum data rate.

The use of the spread spectrum modulation technique leads to a multiple access technique [4] called the code-division multiple access (CDMA) that allows several users, possibly with different rate demands, to access the PLC channel simultaneously.

There are basically three methods how the variable-rate CDMA can be implemented:

1. Multimodulation, where different users use different modulation schemes;

2. Multicode, where the so-called virtual users are defined. These virtual users are transmitting at the same rate and are detected by different receivers. Each physical user can have assigned one or more virtual users according to its transmission rate;

3. Variable spreading means that high-rate users transmit shorter modulated signals with a reduced spreading length.

With the CDMA, an available bandwidth is open for each participant, so the access need not be coordinated.

On the other hand, if more participants become active, then higher mutual disturbances will arise. Therefore, a trade-off between the quality of service and the number of active customers is essential.

4.2 Multi-carrier modulation

The orthogonal frequency division multiplexing (OFDM) transmission scheme is suitable for frequency-selective channels because of its ability to cope with this feature by dividing the available bandwidth into N equally spaced narrowband subchannels [4]. A data stream is distributed to subcarriers

(each subcarrier is centered in one subchannel) and transmitted in parallel. To obtain a high spectral efficiency, the frequency responses of subcarriers are overlapping and orthogonal, hence the name OFDM.

Due to a subchannels' narrowband property, the attenuation and group delay are constant within each channel.

A substantial advantage of the OFDM is its adaptability, since it is possible to choose the optimum modulation scheme individually for each subchannel. It is also possible to fade out the signal on some frequencies because of very bad conditions for transmission or regulatory restrictions [1].

5. Advantages, Disadvantages & possible uses of PLC technology

Advantages

- Can be implemented in remote rural areas and residential homes
- PLC has a fast data transmission rate
- The PLC Network is flexible
- Uses existing power line home wiring
- Easy to install
- PLC offers a peer to peer deployment using a single Modem-Master
- Implementing a PLC Project ,the companies expand their business portfolio
- Multiple services can be provided using a single system

Disadvantages

- Can have transmission blocks and interference
- The power line is designed exclusively for power distribution
- "Hostile" network environment - Power lines are often called hostile environments for networks because of the flux and change that can occur

such as power surges, lightning, and brown outs. A power surge usually slows data transmission, and a brown out will affect the network devices much like it affects other electrical appliances in your home. Lightning is viewed as noise by the system. Further, you risk permanent damage to your PC, printer, and other appliances connected to the power line network from lightning and power surges, since several power line networking technologies do not permit you to plug into a surge protector or power strip first**.**

- Tied to outlets
- No standard established

5.3 Possible uses of PLC technology

- Resource Sharing
  Home networking allows all users in the household to access the Internet and applications at the same time. In addition, files (not just data, but also audio and video depending on the speed of the network) can be swapped, and peripherals such as printers and scanners can be shared. There is no longer the need to have more than one Internet access point, printer, scanner, or in many cases, software packages.

- Communications
  Home networking allows easier and more efficient communication between users within the household and better communication management with outside communications. Phone, fax, and e-mail messages can be routed intelligently. Access to the Internet can be attained at multiple places in the home with the use of terminals and Webpads.

- Home Controls
  Home networking can allow controls within the house, such as temperature and lighting, to be managed though the network and even remotely through the Internet. The network can also be used for home security monitoring with network cameras.

- Home Scheduling
  A home network would allow families to keep one master schedule that could be updated from different access points within the house and remotely through the Internet.

- Entertainment/Information
  Home networks enable a plethora of options for sharing entertainment and information in the home. Networked multi-user games can be played as well as PC-hosted television games. Digital video networking will allow households to route video from DBS and DVDs to different set-top boxes, PCs, and other visual display devices in the home. Streaming media such as Internet radio can be sent to home stereos as well as PCs.

6. Conclusions

This paper analyses the basic features an overview of the real transmission environment of outdoor power distribution lines and presents possibilities for modelling of information signal transmission in this environment by means of the PLC technology.

Abbreviations

CATV Cable Television

CDMA Code Division Multiple Access

xDSL x Digital Subscriber Line

MCM Multi Carrier Modulation

OFDM Orthogonal Frequency Division Multiplexing

PLC Power Line Communication

HF High Frequency

R E F E R E N C E S

[1] IST Integrated Project No 507667 Opera, D4: "Theoretical postulation of PLC channel model" (http://www.ist-opera.org/drupal2/files/OP2_WP1_D4_v4.1.pdf);

[2] G. Chouinard, Power-line Communications (PLC) or Broadband-over-Power-line (BPL) (2) (2004);

[3] M.Gotz, M.Rapp, Characteristics and Their Effect on Communication System Design, IEEE Communications Magazine, April 2004, pp;

[4] R. Roka, S. Dlhan, Modelling Of Transmission Channels Over The Low–Voltage Power Distribution Network, (Journal of Electrical Engineering, VOL. 56, NO. 9-10), 2005, 19;

[5] Power line Communications Networking Comparison Tutorial http://plugtek.com/networking-comparison-tutorial.shtml;

[6] Power line communication http://en.wikipedia.org/wiki/Power_line_communication.