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Reliability Analysis of Power Line Communication System for Smart Grid Realization

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ABSTRACT
This Article inspects the use of Power Line Communication (PLC) for Smart Grid (SG) realization. Smart Grid permits for a two-way communication of data, which aids in real time data collection, monitoring, examination, control, to recover overall efficacy of transmission of electricity, reduce energy consumption price, etc. Power Line Communication, a communication technology that allows the transmission of data over existing power lines is proposed for SG realization. Though, due to power lines being mainly used for transmission of electricity, it is not appropriate for data transmission as it is liable to noise, attenuation. In this article, the clipping technique is projected as a way to diminish effects of noise and attenuation in PLC. PLC delivers reliable communication and control and also is cost effective as the present power line infrastructure is used.

Keywords: *Power line communication, smart grid, noise, attenuation, clipping, equalizer*

INTRODUCTION

Smart Grids (SGs), a big technological innovation, have the potential to reduce climate change through a variety of operation and energy measures including the integration of renewable energy resources. The aim of smart grid is to use innovative, information-based technologies to increase power grid efficacy, reliability, flexibility and also diminish the need to build added infrastructure. Communication for SG is a very important aspect and a method that seems a better option to achieve this is Power Line Communication [1].

Power Line Communication which can also be referred to Powerline Digital Subscriber Line (PDSL) is a communication technology that enables transmission of data on a conductor also used for electric power transmission. Power Line Communication technology is widely used over sinusoidal and continuous electrical networks and data rates up to several hundred megabits per second are guaranteed [3]. PLC systems are limited due to varying impedance, high attenuation and noise. Thus, there is need for better PLC systems, to overcome these limitations. PLC provides the natural upgrade from simple electricity to hybrid and bidirectional electricity and data communication solutions. PLC technologies can either be Narrow-band PLC or Broadband PLC [1]. Smart Grid uses two-way communications in order to provide improved monitoring, control and better optimization for transmission of electricity, and this reduces energy losses, peak demand, and energy costs. In this paper, we investigate what PLC communication is, its advantages, some of its limitations, how these limitations can be solved and its applications.

RELATED WORKS ON POWER LINE COMMUNICATION SYSTEM

PLC is one of many communication technologies that can be implemented for

SG realization. PLC provides communication and control capabilities, using the existing power line network. The usage of PLC for SG shows to be price in effect, safe and reliable, as it is executed by adding a modulated carrier signal to the power cables [4].

PLC can be differentiated by the operation voltages of power lines. High-Voltage (HV) lines with voltages in range of 110kV to 380kV are used for nationwide (Wide Area Network-WAN) power transmission via overhead lines. Medium-Voltage (MV) lines have voltages in range of 10kV to 30kV which are connected to HV lines through a primary transformer sub-station and are used for power distribution in cities, large industrial regions (Neighbourhood Area Network-NAN). Low-Voltage (LV) lines have voltages in range of 110V to 400V and are connected to MV lines through secondary transformers sub-station, with the Home Area Network (HAN) implemented on LV lines. MV lines are coupled with a PLC repeater to establish a high data rate communication to reduce the effect of heavy attenuation on LV lines. One main advantage of PLC is the full control over the physical medium [1].

PLC technology can be divided into two; Broadband PLC and Narrowband PLC.

1. Broadband Power Line Communication (BPLC)
   BPLC operates in the high frequency range of 1.8-250 MHz and has data rates up to hundreds of megabits per second, used to provide broadband internet access [Galli, Scaglione and Wang, 2011].
2. Narrowband Power Line Communication (NBPLC)
   NBPLC operates in the low frequency range from 3 kHz to 500 kHz. NBPLC supports indoor and outdoor communications with LV and MV power lines. NBPLC are capable of data rates up to 500 kilobits per second. NBPLC is more safe, trustworthy and cost-effective and it is more favoured for home automation and smart metering [5].

PLC systems operate by imposing a modulated carrier, an Orthogonal Frequency Division Multiplexing (OFDM) signal, on the wiring system. This is due to the fact that the existing power line system is made solely for transmission of AC power at frequencies of 50 or 60 Hz, making power lines having a limited ability to support higher frequencies [9].

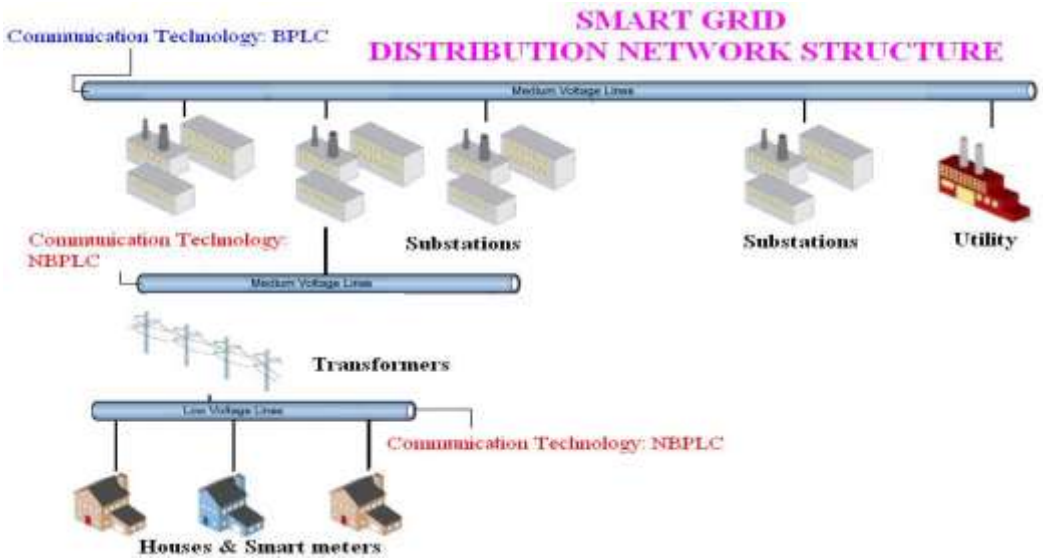

Fig.1:-*Smart Grid Distribution Network Architecture With PLC. [6]*

Currently, PLC delivers advantages for SG applications, and also has some challenges, which prerequisite to be considered to have appropriate working PLC model.

ADVANTAGES OF PLC IN SMART GRID

PLC delivers certain advantages for smart grid applications and some of the advantages are [7]

- A wide area is covered due to the existing power line infrastructure, thereby providing mobility for SG applications.
- It is relatively cheap as there is no need for additional cabling.
- PLC systems are flexible and can also cover long range communication.
- PLC systems deliver a steady communication system for SG applications.
- Installation of PLC systems is easy for indoor executions.

LIMITATIONS OF PLC FOR SMART GRID

Power lines are designed for power transmission and therefore there are difficulties in transmitting data over power lines. While PLC delivers a cost effective solution for SG application, it has certain challenges that requests to be considered for SG applications. Certain of these concerns comprise [2]:

- Noise: PLC is intended for transmission for electricity and thus might not be appropriate for transmission for data. Noise produced by electrical devices on the grid effects the PLC system.
- Varying impedance: this is caused due to variety of devices connected to the power grid.
- Channel attenuation,
- PLC lacks interoperability with various types of devices,
- Electromagnetic interference

METHODOLOGY

As mentioned in section 2.2, the use of PLC for smart grid has limitations, as power lines are originally intended for electricity transmission. In this paper, methods are proposed to solve these limitations.

Clipping Technique

The OFDM signal is more susceptible to noise, which can seriously affect the performance of OFDM system. To solve the problem of noise in PLC system, a method called *Clipping* can be used. Clipping is a technique in which the amplitude of the received signal is cut off over the threshold level without its phase change. A clipping block is added to the front-end of the OFDM receiver before demodulating [2].

$$y_n = \begin{cases} r_n & |r_n| \le T_c \\ T_c e^{j\arg(r_n)} & |r_n| > T_c \end{cases}, \quad n = 0,1,\cdots,N-1,$$

where T_c denote clipping threshold.

Turbo Equalizer

A process projected to solve channel attenuation is the Turbo Equalizer method. The turbo equalizer method works by jointly performing maximum *a posteriori* (MAP) detection or near-MAP detection for the inter-symbol interference channel (inner code) and soft-decoding the channel code (outer code) through an iterative process [10].

SYSTEM MODEL

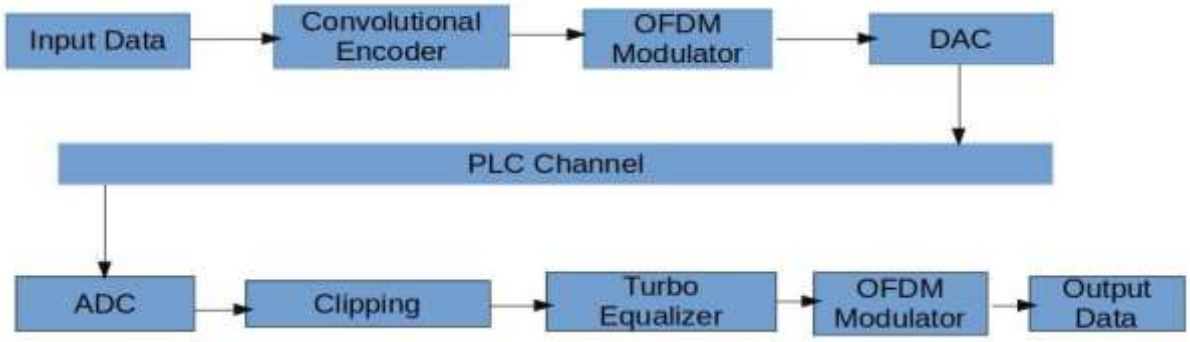

Fig.2: *PLC System Model.*

From Figure 2, above, a PLC system model can be defined. The input data is modulated by chanel coding at the convolutional encoder, which neutralize the effect of chanel fading. Then the signal passes through the OFDM modulator, with the input signal being imposed with a OFDM signal and then modulated to increase the frequency of the signal to be transmitted on the power line. As power lines are only capable of transmitting analog signals, the OFDM signal which is digital signal is converted to analog signal by the digital-to-analog converter to be transmitted via the power lines. The received signal is then converted back to digital by the analog-to-digital converter. This received signal has been affected by noise, attenuation. This noise and channel attenuation is reduced through the clipping and equalizer block. Then the received signal is then demodulated and the original data is recovered.

To ensure SG interoperability, IP support must have a role to play. To enhance the performance of PLC technology, convergent network architecture with integration with Ethernet-based networks has to be considered. This convergence can be achieved through a shared common layer, the Data Link or Physical Layer that enables interconnectivity. Also, the integration of Ethernet network using the TCP/IP protocol to form a convergent network can also be used to mitigate attenuation [8]. The G3-PLC adopted by the G3 alliance was born out of this convergent method.

PLC-BASED SG APPLICATIONS

The fundamental purpose of the Smart Grid is to provide a real time monitoring and control function for an improved efficiency of electricity transmission. The usage of PLC for SG has numerous applications. These applications will be addressed in the sub-sections below.

- Advanced Metering Infrastructure: PLC enables a two-way communication that can be utilized to exchange information between customer devices and control systems in an AMI. AMI can measure, analyse, and gather energy usage from meters via the use of PLC on a real time basis. Even though Ultra Narrowband PLC technology has low data rate, UNB-PLC is used for remote meter reading and can cover huge distances up to 150km [Yigit *et al.*, 2014].
- Demand Side Management (DSM): An application of DSM is Demand Response (DR). DR answers the demands of various energy requests. DR helps reduce peak demand and enable consumers monitor energy consumption. DR controls peak, power conditions, and increases power system efficiency by adopting a real time pricing scheme. The DR system

is implemented through the BB-PLC [7].

- In-home Environment: The Home Energy Management System (HEMS) offers advantages to the grid, such as reliability and reduction of peak demand due to the continuous monitoring and reporting of energy demands to the grid [7].
- Fault Detection: High-Voltage (HV) lines can be used to remotely detect faults such as short-circuited insulators or cable outbursts. Traffic losses, signalling errors can be prevented through remote fault detection by PLC [7].

CONCLUSION

PLC has been seen as a solution into the realization of Smart Grid. It is easy to build as it uses existing power line infrastructure. This paper highlights various advantages of PLC. Also, limitations of PLC such as noise disturbances were discussed. A method, Clipping Technique, was proposed to solve the noise issue in PLC. Many research projects are ongoing into PLC applications and solutions.

CONTRIBUTION TO KNOWLEDGE

While PLC has been touted has a good option for Smart Grid realization, its noise and channel attenuation challenges make it difficult to implement. This paper has proposed methods to solve these issues; Clipping and Turbo Equalizer.

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