AN OVERVIEW ON POWER LINE COMMUNICATION BASED ON OFDM WITH DIFFERENT AFFECTING FACTORS

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ABSTRACT

In this paper we discuss the Power line communication, digital communication and Power line communication channel. Channel model and coupling schemes are also discussed in this paper. There are different effects occurs during the transmission of information through PLC, like signal attenuation, signal noise, signal distortion. Power line noise is known to affect the performance of broadband power-line communications significantly.There are several noise in PLC at medium and low voltage can be found, such as- colored background noise, periodic synchronous impulsive noise caused by switching operation of power supplies, periodic impulsive noise mainly caused by the devices, and asynchronous impulsive noise. Performance of High Voltage Power Line is also disturbed by corona noise and impulse noise. Coupling is required to separate Power and information signals, because of power signal is at high voltage range and communication signal is at low voltage.

Keywords: Power line Communication, Receiver and Transmitter,Orthogonal Frequency Division Multiplexing (OFDM), Noises and Attenuation, Coupling Schemes.

I. INTRODUCTION

Nowadays power line communications has become an important subject of research work. PLC appears to be a promising alternative to conventional technologies such as digital subscriber line (DSL) particularly in rural or underdeveloped areas where the conventional telephone line is still not available to a large population at the global level. PLC is an attractive alternative choice for traditional networks due to its ability to offer broadband internet facility, television cable, telephone service and home automation. The demand for multimedia communications provides a good prospect for PLC as a better transmission technique. However power line communication transmission is affected from many problems such as interference, several noise, delays in attenuation, presence of echoes, frequency selective fading due to multipath etc [1]. So it is necessary to employ a suitable modulation scheme such as orthogonal frequency division multiplexing (OFDM) to counter its unwanted effects on signal transmission. This OFDM is a spectrally efficient multicarrier modulation technique for high speed data transmission over multipath fading channels. It distributes data over a large number of sub-carriers spaced apart at precise frequencies, such that they are orthogonal to each other.

Recently, there has been a growing interest towards the possibility of exploiting existing power lines as effective transmission means. Both Low-voltage (LV) and medium voltage (MV) power line/, below 1 kV and from 1 - 36 kV, respectively, are advantageous because they a potentially convenient and inexpensive communication medium for control signaling and data communication. High-voltage (HV) power lines are, operating at or above 64 kV and can also be used for communication purposes.

Power utilities will thus be able to market a basic Internet connection service at a flat-rate monthly subscription, like some cable operators/providers.By providing both electricity consumers to access the Internet through their existing electrical lines and domestic cables, this technology possesses potential mass-market scale, without having to invest cabling.

II. POWER LINE COMMUNICATION SYSTEM

The power-line communications (PLC) has been applied as a data transfer method in both public electricity distribution networks and indoor distribution networks. Profile of these applications has been different. Devices that are developed for domestic use are mainly designed for the purpose of controlling electric devices at home. For example, the current and most common functions are: street light control system, fire alarm and heating control system. The systems and devices used by distribution companies are mainly meant for automatic meter reading (AMR) and energy consumption monitoring and load management applications. During the last years the conception of providing broadband Internet access through a low voltage distribution network has best discussion. The characteristics of power-line channels and the applicability of different digital modulation techniques have been widely researched. Due to technical and regular problems, the idea that providing Internet services through the distribution network was at least partly buried. Despite of this drawback, the power-line channel is still an appropriate channel for to control devices and transfer data that do not require a wide bandwidth or critical data transfer. An example for this kind of application is data transfer related to the condition monitoring of industrial low voltage electric motors.The power line communication given below in Figure 1. Shows transmitter, Receiver part and power line channel.

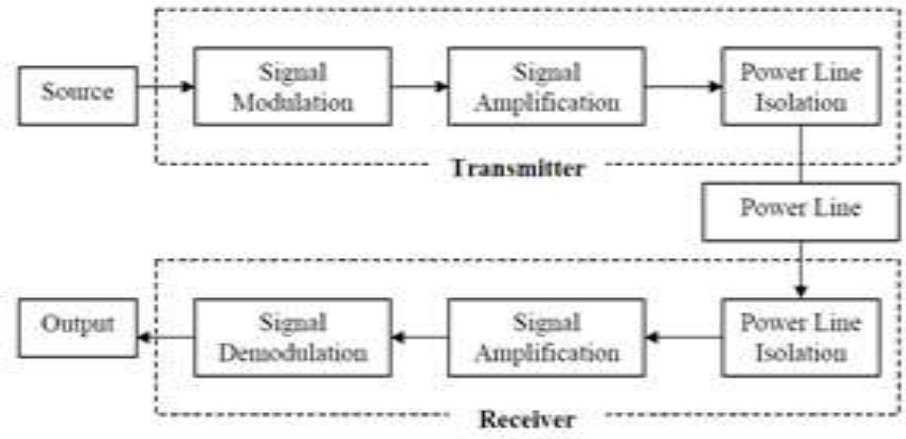

Figure 1. Power Line Communication System

Generally, a distribution network may be considered to be an unfavorable environment for communications. Power-lines are designed for the distribution of the electrical power. They are ideal for the distribution of high voltages at low frequencies. The data transmission generally uses high frequencies at low voltages, respectively. The power-line channel has a varying impedance, high attenuation and considerable noise. These properties easily cause small data transfer rates or big error percentages. For data transmission over any medium, it is necessary to determine the characteristics of the communications channel. When considering a communications channel, the interesting parameters are:

• Input impedance
• Signal attenuation
• Phase distortion
• Noise content

In the beginning of this chapter, the research carried out for public and domestic low voltage distribution networks is discussed. Next, the typical components belonging to industrial distribution networks are analyzed, measured and modelled with respect to power-line communications at the frequencies up to 30 MHz.

III. OFDM MODEL

Orthogonal Frequency Division Multiplexing (OFDM) is nothing but a specialized FDM technique [2]. In OFDM, all the carrier signals are orthogonal to each other, that means inter-carrier guard bands are not required and cross-talk between the sub-channels is eliminated. OFDM can be combined with multiple access using time and frequency or coding separation of the consumer. In the OFDMA, frequency-division multiple access is achieved by assigning different OFDM sub-channels for different users.

Let$\{s_{n,k}^{N-1}$with $E|s_{n,k}|^2 = \sigma^2$ be the complex symbols to be transmitted at the nth OF DM block, then the OF DM- modulated signal can be represented by

$$s_n(t) = \sum_{k=0}^{N-1} s_{n,k} e^{j2\pi k \Delta f t}, \qquad 0 \le t \le T_s$$

…………………………[1]

Where T_S,Δf, and N are the symbol duration, the sub channel space, and the number of sub channels ofOFDMsignals,respectively.ForthereceivertodemodulatetheOFDMsignal,the symbol duration should be long enough such that $T_s\Delta f$ = 1,which is also called the orthogonal condition since it makes$e^{-j2\pi k\Delta ft}$ orthogonal to each other for different k. With the or thogonal condition, the transmitted symbols $s_{n,k}$ can be detected at the receiver

$$s_{n,k} = \frac{1}{T_s} \int_0^{T_s} s_n(t) e^{-j2\pi k \Delta f t} dt$$

……………………………………..[2]

If there is no channel distortion.The sampled version of the baseband OFDM signal $s(t)$ can be expressed as

$$s_n\left(m\frac{T_s}{N}\right) = \sum_{k=0}^{N-1} s_{n,k} e^{j2\pi k \Delta f m \frac{T_s}{N}} = \sum_{k=0}^{N-1} s_{n,k} e^{j\frac{2\pi m k}{N}}$$

……………………….……….[3]

Which is actually the inverse discrete Fourier transform (IDFT) of the transmitted symbols $\{s_{n,k}\}_{k=0}^{N-1}$ and can efficiently be calculated by fast Fourier transform (FFT). It can easily be seenthat demodulation at the receiver can be performed using DFT instead of the integral in (2).

IV. ATTENUATION AND NOISES IN PLC

4.1 Signal Attenuation

The conductors and insulation materials of signaling and power cables are not ideal. Part of the power that the transmitter injects into the cable does not reach the receiver. The loss mechanisms are:

• Resistive losses of the conductors
• Dielectric losses of the insulation

• Radiation losses

• Coupling losses

The main loss mechanisms of low voltage power cables at signal frequencies used in power-line communications are the dielectric losses, resistive losses and coupling losses. The radiation losses are significant if the separation of the conductors is an appreciable fraction of the wavelength. With the cables researched and in the frequency band 100 kHz – 30 MHz this condition is not fulfilled. Transmission line discontinuities such as- mechanical connections, changes in cable type or load appliances, to joint cause coupling losses. The coupling losses depends on the topology of the distribution network, the signal frequency, characteristics of cabling and characteristics of devices connected to the distribution network. The resistive losses of the conductor are caused by the finite conductivity of conductors in PLC. At the high frequency, the current is forced to flow on the surface of the conductor due to the skin effect. The resistive losses increase as a function of frequency with relation of $r \sim f$.

Dielectric losses occur in the insulation material. The polarized molecules inside the insulation material turn synchronized to the frequency of the electric field. The friction between the molecules causes power losses at each time when the electric field changes polarity positive to negative and negative to positive. The resistivity of insulation material is finite. Existence of leakage currents in the insulation material causes also losses. The losses of the insulation material are expressed by the term loss tangent or dissipation factor tanδ:

$$\tan\delta = \frac{\varepsilon_i'' + \dfrac{\sigma_i}{\omega\,\varepsilon_0}}{\varepsilon_i'},$$

where ε_i' is the real part and the ε_i'' is the imaginary part of the relative complex permittivity of the insulation material and σ_i is the conductivity of the insulation material.

4.2 Signal Noise

Besides signal attenuation and phase distortion, noise is an important factor that influences on the success of digital communications over a power-line channel. The power-line channel does not represent an Additive White Gaussian noise (AWGN) environment like many other communication channels [6]. Instead, it can be regarded as a fading multipathchannel with quasi-stationary frequency response. The frequency response of the channel varies as a function of time. But, it can generally be considered to be constant during a transmitted symbol. Power-line noises can be classified into five categories[6]:

(a). Colored background noise: This noise has a relatively low power spectral density, which is frequency variant. The noise is caused by numerous weak noise sources. Power spectral density of this type of noise varies in terms of minutes or may be in hours.

(b). Narrow band noise: This noise consists of sinusoidal signals with modulated amplitudes. The sources of the noise are broadcast stations and the noise level varies within the daytime.

(c). Periodic impulsive noise that is asynchronous to the mains frequency: The impulses have a repetition rate generally from 50 kHz to 200 kHz. The noise is mostly caused by switching power supplies.

(d). Periodic noise that is synchronous to the mains frequency: The impulses have a repetition rate of 50 Hz or 100 Hz and are synchronous to the mains cycle of the signal. The duration of impulses is short, generally in the order of microseconds. This noise is caused by power supplies that operate synchronously with the mains cycle [3].

(e). Asynchronous impulsive noise: The noise is caused by switching transients in the distribution network. The impulses have a duration from some microseconds up to a few milliseconds. The power spectral density of this type of noise can have levels of more than50 dB above the background noise.

In order to develop modulation techniques, power-line communication systems and network planning and simulation tools, channel models are required. The channel models proposed for power-lines are mostly based on the multipath propagation of a signal [6]. These models assume that due to imperfect terminations the impulse injected from the transmitter into the channel reaches the receiver propagating directly and indirectly from the source to the destination. The main signal is followed by a number of echoes.

In other words, the multipath nature of the channel spreads energy send by the transmitter in the time-space. The presented models generally require the measurement of the transfer function or impulse response of the channel. They are formed by taking into account the most significant reflections and their amplitudes from the impulse response of the channel. The multipath channels and their characteristics are discussed in [7].

V. COUPLING IN PLC

Power transmission line operates at high voltage whereas communication equipment functions at volt to millivolts. It is therefore necessary to protect the communication equipment from high voltage transmission line. These equipment's are coupled to the transmission line through coupling capacitor or capacitive voltage transformer (CVT) [5].In order that the communication signal is transmitted in the desired direction, a wave trap is connected towards the substation bus side.There are two schemes for coupling the equipment to the transmission line:

5.1 Phase to Ground Coupling

In phase to ground coupling as shown in figure 2, communication equipment's are connected only with single conductor. Thus earth is used for the returning path. Here only ground mode is used for propagation of communication signal from transmitter to receiver. Phase to ground coupling is economical and easy in design [5]. But, reliability of such system is poor especially during transmission and emergency hour.

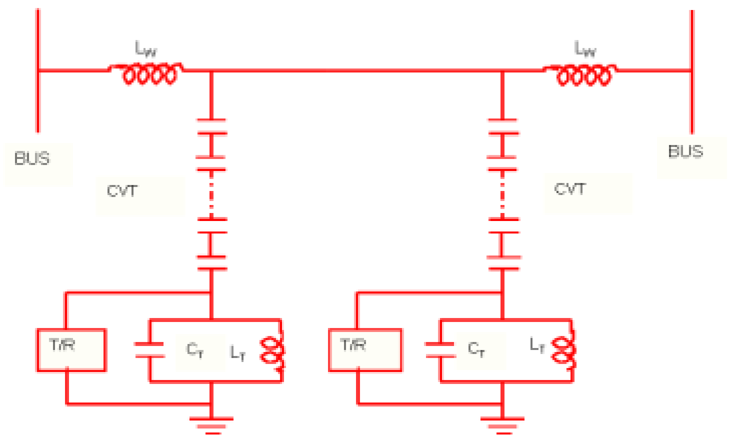

Figure2. Phase to Ground Coupling

5.1 Phase to Phase Coupling

In phase to phase coupling, the conductors of the two phases are used for coupling the communication equipment's as shown in figure 3. In this coupling, Signals are fed to transmission lines in differential mode and outer conductors of the phases are generally used for enhancing the reliability though the coupling equipment in the scheme is doubled. Thus, the cost of such coupling scheme is higher to phase to ground coupling.

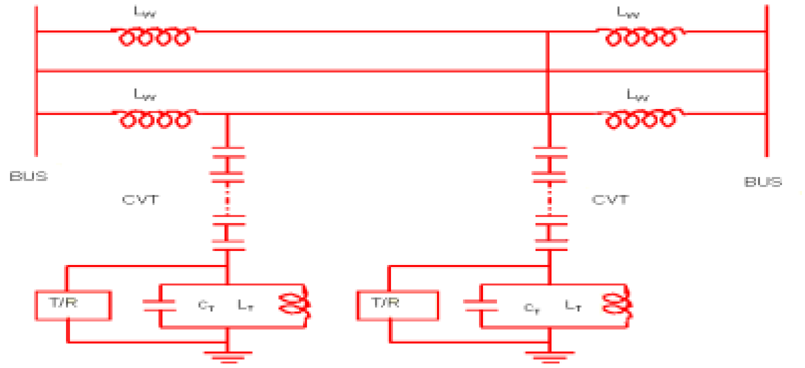

Figure3 Phase to Phase Coupling

VI. CONCLUSION

Power line communication can be considered as an attractive alternative to traditional networks as it offers broadband internet access, telephone service and cable television. However, in addition to AWGN, corona noise is found to be a major interfering noise in HV PLC in OFDM [8]. Here, the performance of OFDM can be affected by corona noise with the variation of the branch lengths in the multipath and different weather condition, and other noises such as colored background noise, asynchronous impulsive noise, and synchronous impulsive noise also affecting the Low Voltage PLC [9]. Here Coupling schemes are used to prevent the electronic devices with high voltage Power Line.

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