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DESIGN OF DATA COMMUNICATION OVER POWER LINE

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) technology meets the drawback that the electric wires might radiate electromagnetic waves at high frequencies. The power-lines are designed to distribute power in an efficient way hence it is not adapted for communication. The high-speed data transmission power lines require appropriate digital communication techniques that efficiently use the available frequency band. Orthogonal Frequency Division Multiplexing (OFDM) as a type of multicarrier modulation, has become one of the preferred communication schemes to achieve reliable high-rate data transmission.

Index terms – Channel Model, Coupling methods, Orthogonal Frequency Division Multiplexing (OFDM), Powerline Transmission.

1. INTRODUCTION

One of the most important features of present data communication is its orientation on broadband services. To meet this requirement several media and solutions can be opted viz. utilizing the existing telephone lines through digital subscriber lines (DSL) or cable distributions via cable modems (CATV), using wireless technologies (WLL, WLAN) or utilizing electrical power lines (PLC). Electrical utility industry is in the process of deregulation and restructuring with the major economic objectives. Power transmission lines are used for multifunctional purposes, besides the electrical power transmission. Multimedia applications, HDTV etc. are some of the important functions met over power line, interested to electric utilities. These applications use the existing infrastructure of electric utility and consumers available even in the remote areas. Further, electricity is being supplied via a permanent connection, the data service offered over the electrical infrastructure is also permanently connected (no need to dial up the connection), making it ideal for the increasing number of online services. Power utilities will thus be able to market a basic Internet connection service at a flat-rate monthly subscription, like some cable operators. By providing electricity consumers to access the Internet through their existing electrical lines and domestic cables, this technology possesses potential mass-market scale, without investing cabling[1]. Electrical power lines are usually classified into the high (>l00 kV), medium (1-100 kV) and low (<1 kV) voltage networks, with respectively increasing communications difficulties. In this paper, the utility of high voltage power lines for broadband services are studied. The use of existing high-voltage power lines, typically operating at or above 66 kV, for transmitting data and voice is interesting because it provides electric utilities with an alternative to traditional communication networks.

The lines used for delivery of broadband services are same as those used for transmission of electricity. The development of newer, faster digital processors and sophisticated modulation schemes allowed to send high speed data through existing electric cables along with electrical power frequency currents. All power line ssing a communication systems operate by impre modulated carrier signal propagate over transmission lines. Amulti-carrier technique Orthogonal Frequency Division Multiplexing (OFDM) is considered as an alternative solution for data communication over power line[6].

2. POWER- LINE COMMUNICATION

Communication over power-line is based on electrical signals, carrying information, propagating over the power-line. The application for the power line communication would be a system where the wiring would impose the main expenses and a radio based system would not be feasible or too expensive. These prerequisites for power line communication system would be met by high voltage or medium voltage power lines because power cables are up to several tens/hundreds of kilometers and approaching even remote and rural areas.

Power system comprises of:

i)Power generation unit
ii)Transmission lines
iii)Distribution system

Transmission and distribution lines are designed for transmission of power from generating station to end user only. However, transmission lines, 66kV and above are presently employed for audio communication between the operators at two end of the transmission lines viz. substation operators, carrier protection schemes and telemetry signal. These signals are modulated before sending on transmission lines in the frequency range of 100 KHz – 500 KHz for overhead transmission lines and 10 KHz – 100 KHz for underground cables. Such conventional modulated communication system over power line functions satisfactory during normal operation of power system. However, during transient condition when a fault occurs on the transmission lines, power frequency harmonics up to 100 KHz frequency are generated and distributed to the communication system.

Some methodology describes that the communication shall not be disturbed during transient and emergencies for the safe operation of power system. Since the power wiring system was originally intended for transmission of AC power, the power wire circuits have only a limited ability to carry higher frequencies. Power lines are unshielded and will act as antennas for the signals they carry and have the potential to interfere with shortwave radio communications. For such a case, a novel method using OFDM for data communication over power-line is presented. OFDM modulation allows to mitigate interference with radio services by removing specific frequencies used.

A. Channel model

Figure (1.1) below shows a digital communication system using the power-line as a communication channel. The transmitter is shown to the left and the receiver to the right. Important parameters of the communication system are the output impedance, *Zt*, of the transmitter and the input impedance, *Zl*, of the receiver.

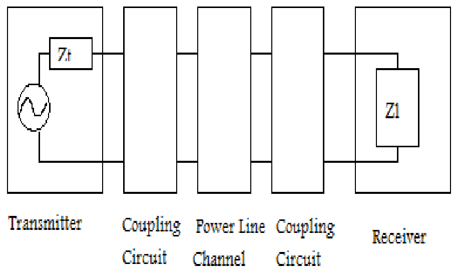

Figure 1.1 A digital communication system for the power-line channel

A coupling circuit is used to connect the communication system to the power-line. The purpose of the coupling circuits is two-fold: Firstly, it prevents the damaging 50 Hz signal, used for power distribution, to enter the equipment. Secondly, it certifies that the major part of the received/transmitted signal is within the frequency band used for communication. This increases the dynamic range of the receiver and makes sure the transmitter introduces no interfering signals on the channel.

3. COUPLING METHODS

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 equipments are coupled to the transmission line through coupling capacitor or capacitive voltage transformer (CVT) .In order that the communication signal is transmitted in the desired direction, a wave trap is connected towards the substation bus side.There are tw o schemes for coupling the equipment to the transmission line:

i)Phase to Ground coupling
ii)Phase to Phase coupling

A) Phase to Ground coupling

In phase to ground coupling as shown in figure (1.2), communication equipments 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 simple to design. However reliability of such system is poor especially during transmission and emergency hour.

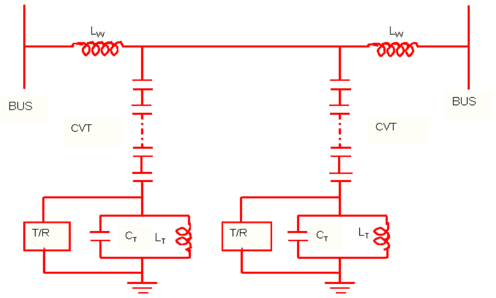

Figure 1.2 Phase to ground coupling

B) Phase to Phase coupling

In phase to phase coupling, the conductors of the two phases are used for coupling the communication equipments as shown in figure (1.3). Here the 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.

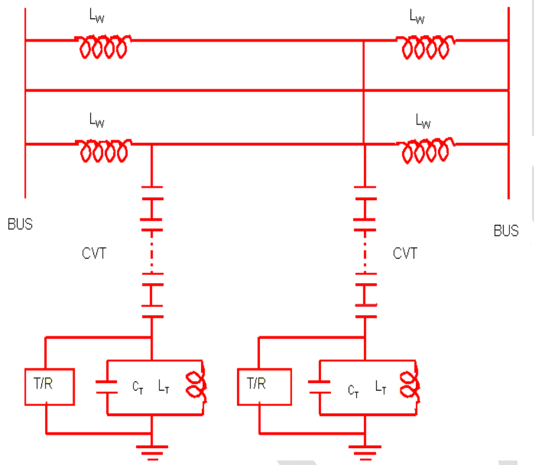

Figure 1.3 Phase to phase coupling

4. INTERFACING COMMUNICATION EQUIPMENT WITH POWER-LINE

Broad-band coupling for power-line carrier system was developed some 20 years ago but it is only in the past few years that it has any appreciable use. Several things have contributed to the revived interest in its application. Coupling equipment is an essential part of a broadband channel. Broad-band coupling may be defined simply as the use of filter circuits in lieu of conventional resonant type tuning units to obtain broader channel bandwidth .High voltage power lines are constructed with such strength that they are in general superior to any communication circuit except underground cable. Experience has demonstrated that power lines withstand storms, sleet, and floods long after all circuits are carried away. In view of the vital necessity of communication to a power company, it is very much natural that the power line should be used as a communication circuit because of its mechanical superiority.

The method of utilizing a power line as a telephone line is to superimpose high frequency currents on the power conductors. These currents are transmitted over the line as ordinary alternating currents. They are produced and received by equipment similar to the usual space radio apparatus. In considering the power line as a communication circuit it is immediately apparent that such a circuit differs from the usual telephone line. The principle difference is that the line is operated at high voltage. This gives rise to more or less noise due to spitting insulators and similar effects. In addition the line is not a simple circuit connecting the transmitter and receiver. In practice a power line is usually part of an extensive high voltage network with loops, taps and spurs. Such a network is not a constant and stable system from communication point of view because of more or less continuous changes due to switching. In general every time a switch is opened or closed in any part of the system, it makes a change in the communication circuit. These factors are now generally recognized. In some cases it was found that the natural changes in line characteristics due to switching were so great that a satisfactory communication circuit could not be obtained.

Efforts have been made to solve this problem by modifying the communication apparatus. Modification tending to reduce the number of frequencies per channel and introduction of special system of modulation has greatly increased the amount and complexity of the equipment. By its very nature power line communication equipment should be kept just as simple and reliable as possible. Instead of complicating the equipment it is proposed to correct the trouble at its source by stabilizing the power line. The method is to insert high frequencies resistances in to the power line at such points as are necessary to block off detrimental circuits and provide a clear circuit for the channel desired. Apparatus for this purpose has been developed which has proved very effective. This apparatus consists of an inductance coil very similar to those ordinary used for lighting arrester work together with the necessary tuning equipment. These tuned circuits do not absorb energy at the power frequencies nor in any way disturb the power system. In order to appreciate the problem presented by a power network some of the properties of transmission line at very high frequencies may be noted. A line of great length does not act like a large capacity or a large inductance but rather as a pure resistance of approximately 400 to 600 ohms for the average power line construction. The impedance of a short line open at the end varies over a wide range .A broad-band coupling system provides a carrier path not only at and near the resonant frequency of the trap, but also at frequencies considerably removed from trap resonance. Broad-band coupling offers advantages of versatility in multiple frequency coupling, and in special applications allows the use of groups requiring band-widths unattainable with resonant tuned circuits .

A) Power line carrier coupling equipment

The major power line carrier coupling components are shown in fig. (1.4). The inductance of the wave trap L_W with capacitance C_W and inductance of tuning coil L_T with capacitance C_T for two parallel tuning circuits, while the capacitance C_C of the coupling capacitor with the inductance L_C of the stack tuning coil form a series tuning circuit. All the tuned circuits have a common midband frequency f_0. Thus, the coupling equipment at one end forms a π section band-pass filter.

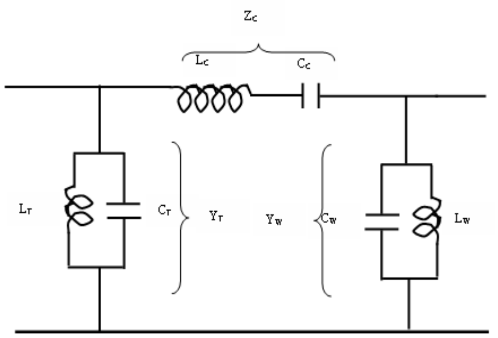

Figure 1.4 Simplified equivalent circuit of coupling equipment

Where,

L_T, L_W are the inductance of the tuning coil and wave trap respectively,

C_T , C_W are the capacitance of the tuning coil and wave trap respectively,

Y_T , Y_W are the admittance of the tuning coil and wave trap respectively, and

Z_C is the impedance of the coupling.

R_0 represents the matching termination which is equal to the source resistance

The optimum bandwidth at the half power points under maximally flat conditions can be calculated from

$$f = 4\pi f_0^2 C_C R_0$$

A mathematical model of a transmission line which takes into account the coupling equipment has been developed. In this, the system is terminated by its characteristic impedance to avoid excessive mismatches losses. Characteristic impedance is the inverse of characteristic admittance.

The propagation matrix has an important property that any function of ψ is a function of only the diagonal propagation matrix $\lambda^{1/2}$, and is defined as

$$\psi = Q\lambda^{1/2}Q^{-1}$$

Where,

ψ is the propagation matrix

Q is the eigen vector corresponding to the eigen value λ and

$$Y_0 = YQ\lambda^{-1/2}Q^{-1}$$

where Y_0 is the characteristic admittance.

Therefore, the characteristic impedance is given as:

$$Z_0 = Y_0^{-1}$$

5. CONCLUSION

This paper presents the data communication over the power- lines. The main advantage of this kind of communication system is the use of existing power-lines infrastructure, which simplifies the implementation. The paper starts with a general introduction to power-line communication, by studying some measurements of basic properties using MATLAB to understand the behavior of the power-line as a communication channel. Then these results combined with the modulation method to present a communication strategy for the power-line channel.

The approach in designing a communication system for the power-line channel is a simple implementation. The result is a flexible structure which can be upgraded and adapted to future needs. System level simulation of digital power line carrier communication is carried out by considering all the basic building blocks. Convolution code can be effectively used to reduce BER and hence improve the performance of power-line channel. The performance and throughput of the proposed system can further be improved using turbo or LDPC codes.

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