A Review on Power Line Communication Systems

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***Abstract*— This article constitutes an over view of the research, application, and regulatory activities on power line communications. Transmission issues on the power line are investigate and modeling approaches illustrated. Contemporary communication techniques and reliability issues are treated. Power lines constitute a rather hostile medium for data transmission. Varying impedance, considerable noise, and high attenuation are the main issues. The power line communication (PLC) is a new technology open to improvements in some key aspects. Some companies in the world provide broad band PLC devices and an increasing number of utility companies have already gone through field trials and commercial deployment of PLC services. Power-line communications over the low-voltage networks is gaining the attention of researchers in both broad band and narrow band application areas. The transmission characteristics of the power-line carrier are very significant in signal propagation. The power line modem uses the power line cable as communication medium. It is convenient as it eliminates the need to lay additional cables. The modem at the transmission end modulates the signal from data terminal through RS-232 interface on to the carrier signal in the power line. At the receiving end, the modem recovers the data from the power line carrier signal by demodulation and sends the data to data terminals through RS-232 interface.**

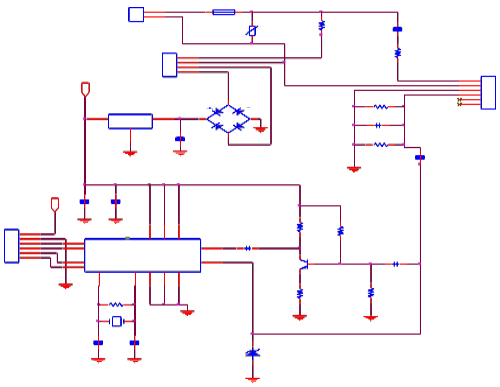
I. INTRODUCTION

Power line communication or power line carrier (PLC), also known as Power line Digital Subscriber Line (PDSL), mains communication, power line telecom (PLT),Power line networking (PLN) or Broad band over Power Lines (BPL) are systems for carrying data on a conductor for electric power transmission. Electrical power is transmitted over high voltage transmission lines, distributed over medium voltage, and used inside buildings at lower voltages. Power line communications can be applied at each stage. Most PLC technologies limit themselves to one set of wires (for example, premises wiring), but some can cross between Two levels (for example, both the distribution network and premises wiring).Typically the transformer prevents propagating the signal which allows multiple PLC technologies to be bridged to form very large networks. Generally power networks can be classified in to three broad categories: dc current supply use in industrial applications such as automotive; sinusoidal supply used for electrical distribution networks or domestic applications; and pulse width-modulated (PWM) networks used in the vast majority of applications involving converters and actuators.

Power- line communication (PLC) technology is widely used over sinusoidal and continuous electrical networks and data rates up to several hundred mega bits per second are guaranteed.Those PLC modems cannot operate on PWM networks who present, by nature, abroad spectral occupancy. Thus, this seminar proposes an over view of the PLC technology and its operating limits over a PWM network. Based on a detailed study of the inverter spectrum, new PLC modems dedicated for the PWM network are developed. The capacity of these modems in terms of transmission reliability and data rate is evaluated. This technology avoids using any additional cables between the actuator and the converter which can be advantageous in terms of price and overall dimension.

II. PLC

The PLC is nothing but the communication media in between the transmitter and the receiver which is known as power line channel or power line carrier modem.Data rates over a power line communication system vary widely. Low-frequency (about100-200KHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second; however, these circuits may be many miles long. Higher data rates generally imply shorter ranges; a local area network operating at millions of bits per second may only cover one floor of an office building, but eliminates installation of dedicated network cabling.



Ratified in September or October of 2010. Home Plug Estimates that over 45 million Home Plug devices have been deployed worldwide. Other companies and Organizations back different specifications for power line Home networking and these include the Universal Power line Association, the HD-PLC Alliance and the ITU-T's G.hn specification.

V. BROAD BAND OVER POWER LINES

I. High-Frequency Communication

High frequency communication may (re)use large portions of the radio spectrum for communication, or may use select (narrow) band(s), depending on the technology. HF-DTPLC modem modulates base band data with Differential Binary Phase Shift Keying (DBPSK) or Differential Quadrate Phase Shift Keying (DQPSK), and transmits the modulated data on maximum of 5tones. HF-DTPLC changes its data transfer rate(DTR) from 40kbps to 400kbps automatically selecting appropriate modulation and tones for data transmission under diverse and change able power line conditions.

II. HOME NETWORKING

Power line communications can also be used in a home to inter connect home computers (and networked peripherals), as well as any home entertainment devices (including TVs, Blu-ray players, game consoles and Internet video boxes such as Apple TV, Roku ,Kodak Theatre, etc.) that have an Ethernet port. Consumers can buy power line adapter sets at most electronics retailers and use those to establish a wired connection using the existing electrical wiring in the home. The power line adapters plug in to a wall out let (or in to an extension cord or power strip, but not in to any unit with surge suppression and filtering, as this may defeat the signal) and then are connected via CAT5 to the home's router. Then, a second (or third, fourth, fifth) adapter(s) can be plugged in at any other out let to give instant networking and Internet access to an Ethernet – equipped Blu- ray player, a game console (PS3,Xbox360,etc.) a laptop or an Internet TV (also called OTT for Over-the-Top video) box that can access and stream video content to the TV.

The most established and widely deployed power line networking standard for these power line adapter products is from the Home Plug Power line Alliance. Home Plug AV is the most current of the Home Plug specifications (Home Plug1.0, Home Plug AV and the new Home Plug Green PHY for smart grid comprise the set of published specifications) and it has been adopted by the IEEEP1901 group as a base line technology for their standard, due to be published and Broad band over power lines (BPL), also known as power- line Internet or power-band, is the use of PLC technology to provide broad band Internet access through ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" in to any out let in an equipped building to have high-speed Internet access. International Broad band Electric Communications or IBEC and other companies currently offer BPL service to several electric cooperatives.

BPL may offer benefits over regular cable or DSL connections: the extensive infrastructure already available appears to allow people in remote locations to access the Internet with relatively little equipment investment by the utility. Also, such ubiquitous availability would make it much easier for other electronics, such as televisions or sound systems, to hook up. Cost of running wires such as Ethernet in many buildings can be prohibitive; Relying on wireless has a number of predictable problems including security, limited maximum through put and in ability to power devices efficiently.

But variations in the physical characteristics of the electricity network and the current lack of IEEE standards mean that provisioning of the service is far from being a standard, repeatable process. And, the amount of band width a BPL system can provide compared to cable and wireless is in question. The prospect of BPL could motivate DSL and cable operators to more quickly several communities.

PLC modems transmit in medium and high frequency (1.6to 80MHz electric carrier). The asymmetric speed in the modem is generally from 256kbit/s to 2.7Mbit/s. In the repeater situated in the meter room the speed is up to 45Mbit/s and can be connected to 256 PLC modems. In the medium voltage stations, the speed from the head ends to the Internet is up to 135Mbit/s. To connect to the Internet, utilities can use optical fiber back bone or wireless link.

Deployment of BPL has illustrated a number of fundamental challenges, the primary one being that power lines are inherently a very noisy environment. Every time a device turns on or off, it introduces a pop or click in to the line. Energy-saving devices often introduce noisy harmonics in to the line. The system must be designed to deal with these. Natural signaling disruptions and work around them. For these reasons BPL can be thought of as a half way between wireless transmission (where likewise there is little control of the medium through which signals propagate) and wired transmission (but not requiring any new cables).

Broad band over power lines has developed faster in Europe than in the United States due to a historical difference in power system design philosophies. Power distribution uses step-down transformers to re duce the voltage for use by customers. But BPL signals cannot readily pass through transformers, as their high inductance makes them act as low-pass filters, blocking high-frequency signals. So, repeaters must be attached to the transformers. In the U.S., it is common for a small transformer hung from a utility pole to service a s ingle house or a small number of houses. In Europe, it is more common for a somewhat larger transformer to service10 or 100 houses.

For delivering power to customers, this difference in design makes little difference for power distribution. But

for delivering BPL over the power grid in a typical U.S. city requires an order of magnitude more repeaters than in a comparable European city. On the other hand, since band width to the transformer is limited, this can increase the speed at which each house hold can connect, due to fewer people sharing the same line. One possible solution is to use BPL as the back haul for wireless communications, for instance by hanging Wi-Fi access points or cell phone base stations on utility poles, thus allowing end-users within a certain range to connect with equipment they already have.

The second major issue is signal strength and operating frequency. The system is expected to use frequencies of 10 to 30 MHz, which has been used for many decades by amateur radio operators, as well as international short wave broad casters and a variety of communications systems (military, aeronautical, etc.). Power lines are unshielded and will act as antennas for the signals they carry, and have the potential to interfere with short wave radio communications. Modern BPL systems use OFDM modulation, which allows them to mitigate interference with radio services by removing specific frequencies used. A 2001 joint study by the American Radio Relay League (ARRL) and Home Plug Power line Alliance showed that for modems using this technique "In general that with moderate separation of the antenna from the structure containing the Home Plug signal that interference was barely perceptible at the notched frequencies "and interference only happened when the "antenna was physically close to the power lines"(however other frequencies still suffer from interference).

VI. MEDIUM FREQUENCY COMMUNICATION

Power line communications technology can use the house hold electrical power wiring as a transmission medium. This is a technique used in home automation for remote control of lighting and appliances without installation of additional control wiring.

Typically home-control power line communication devices operate by modulating in a carrier wave of between 20 and 200 KHz in to the house hold wiring at the transmitter. The carrier is modulated by digital signals. Each receiver in the system has an address and can be individually commanded by the signals transmitted over the house hold wiring and decoded at the receiver. These devices may be either plugged in to regular power outlets, or permanently wired in place. Since the carrier signal may propagate to nearby homes (or apartments)on the same distribution system, these control schemes have a "house address" that designates the owner.

Since1999, a new power-line communication technology "universal power line bus" has been developed, using pulse-position modulation (PPM). The physical layer method is a very different scheme than the modulated/demodulated RF techniques used by X-10. The promoters claim advantages in cost per node, and reliability.

VII. LOW -SPEED NARROW-BANDCOMMUNICATION

Narrow band power line communications began soon after electrical power supply became wide spread. Around the year 1922 the first carrier frequency systems began to operate over high-tension lines with frequencies of 15 to 500 kHz for telemetry purposes, and this continues. Consumer products such as baby alarms have been available at least since 1940.

In the 1930s, ripple carrier signalling was introduced on the medium (10-20 kV) and low voltage (240/415 V) distribution systems. For many years the search continued for a cheap bi-directional technology suitable for applications such as remote meter reading. For example, the Tokyo Electric Power Co ran experiments in the 1970s which reported successful bi-directional operation with several hundred units. Since the mid-1980s, there has been a surge of interest in using the potential of digital communications techniques and digital signal processing. The drive is to produce are liable system which is cheap enough to be widely installed and able to compete cost effectively with wireless solutions. But the narrow band power line communications channel presents many technical challenges, a mathematical channel model and a survey of work is available.

Applications of mains communication vary enormously, as would be expected of such a widely available medium. One natural application of narrow band power line communication is the control and telemetry of electrical equipment such as meters, switches, heaters and domestic appliances. A number of active developments are considering such applications from a systems point of view, such as demand side management. In this, domestic appliances would intelligently co-ordinate their use of resources, for example limiting peak loads.

Control and telemetry applications include both 'utility side' applications, which involves equipment belonging to the utility company (i.e. between the supply transformer substation up to the domestic meter), and 'consumer-side 'applications which involves equipment in the consumer's premises. Possible utility-side applications include automatic meter reading(AMR), dynamic tariff control, load management, load profile recording, credit control, pre-payment, remote connection, fraud detection and network management, and could be extended to include gas and water.

A project of EDF, France includes demand side management, street lighting control, remote metering and billing, customer specific tariff optimization, contract management, expense estimation and gas applications safety. There are also many specialized niche applications which use the mains supply within the home as a convenient data

link for telemetry. For example, in the UK and Europe a TV audience monitoring system uses power line communications as a convenient data path between devices that monitor TV viewing activity in different rooms in a home and a data concentrator which is connected to a telephone modem.

VIII. DISTRIBUTION LINE CARRIER(DLC)

DLC uses existing electrical distribution network in the medium voltage (MV) —i.e., 11 kV, Low Voltage (LV) as well as building voltages. It is very similar to the power line carrier. DLC uses narrow band power line communication frequency range of 9 to 500 kHz with data rate u p to 576kbit/s. DLC is suitable (even in very large networks) for multiple real time energy management applications. It can be implemented under REMPLI System as well as SCADA, AMR and Power Quality Monitoring System. DLC complies with the following standards: EN50065 (CENELEC), IEC61000-3 and FCC Part 15 Subpart B.

There are no interference issues with radio users or electromagnetic radiation. With external inductive or capacitive coupling, a distance more than 15 km can be achieved over a medium voltage network. On low voltage networks, a direct connection can be made since the DLC has a built –in capacitive coupler. This allow send-end communications from substation to the customer premises without repeaters.

The latest DLC systems significantly improve upon and differ from other power line communication segments. DLC is mainly useful for last-mile and backhaul in structural that can be integrated with corporate wide area networks (WANs) via TCP/IP, serial communication or leased-line modem to cater for multi-services real time energy management systems.

More recently, narrow band PLC communications techniques have also started to include implementations of more sophisticated communication technologies like OFDM, that were till date used in broad band domain. PRIME is one such system that operates with in CENELECA band and uses OFDM as the technology at physical layer to provided at a rates up to 128kbit/s. The PRIME Alliance is an industrial consortium that is putting forth these open specifications of physical and MAC layer sandal lowing for utilities to pick solutions from different vendors.

IX. FUTURES COPE

A PLC modem is also used in controlling of home appliances like water pump, air conditioning, washer, cooler etc.

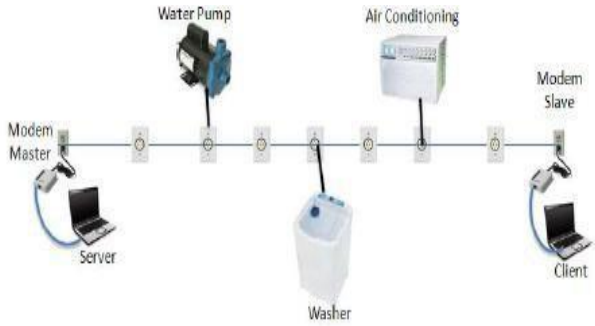


Figure 9.1– HOME APPLIANCES CONTROL USING PLC

It is also useful in low speed data communication networks. One natural application of narrow band power line communication is the control and telemetry of electrical equipment such as meters, switches, heaters and domestic appliances. A number of active developments are considering such applications from a systems point of view, such as demand side management.

Figure 9.2 - LSDCN USING PLC

The analysis presented here shows that channel efficiency can theoretically reach 15bps/Hz in the aforementioned scenario. A classification of the impulsive noise is also proposed as well as some statistical models for some of the main statistical variables. The most destructive noise was detected in the gasoline motor, where a high amplitude component appears with an inter-arrival time that depends on the motor regime. A large number of impulses have been captured in the vehicle power line. They have been processed to estimate the maximum amplitude, the width, and the inter- arrival time of the impulses. Then, simple statistical model shave been proposed.

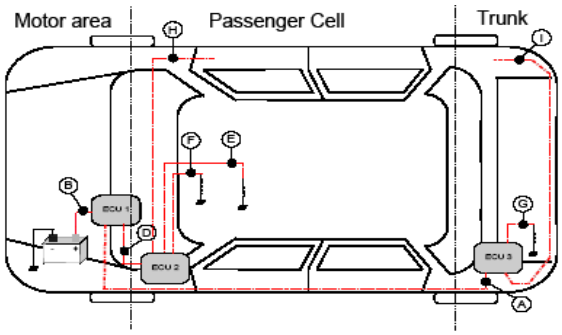


Figure 9.3 - PLC IN VEHICLE

X. CONCLUSION

PLC solutions may be seen as complementary or alternative solutions to traditional fixed line networks, wireless networks and VDSL networks. According to existing network architectures, buildings or technical constraints, either solution can be chosen, but one can also consider one solution to complement another! PLC bandwidths are set to increase, the Home plug AV standard is being considered for broad casting digital television. Many research projects are on going in to these solutions and their applications, it is all to come, one should pay close attention to news about this technology.