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Power Line Communication Systems

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Abstract— This article constitutes an overview of the research, application, and regulatory activities on power line communications. Transmission issues on the power line are investigated 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 broadband and narrowband 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 onto 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 Broadband over Power Lines (BPL) are systems for carrying data on a conductor also used 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 into three broad categories: dc current supply used 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 megabits per second are guaranteed. Those PLC modems cannot operate on PWM networks who present, by nature, a broad spectral occupancy. Thus, this seminar proposes an overview 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 powerline carrier modem
.

Data rates over a power line communication system vary widely. Low-frequency (about 100-200 KHz) 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.

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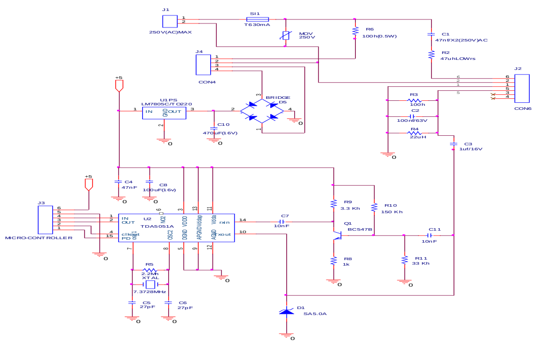

Figure 2.1 Circuit Diagram

III. 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 5 tones. HF-DTPLC changes its data transfer rate (DTR) from 40kbps to 400kbps automatically selecting appropriate modulation and tones for data transmission under diverse and changeable power line conditions. [6]

IV. HOME NETWORKING

Power line communications can also be used in a home to interconnect 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 powerline adapter sets at most electronics retailers and use those to establish a wired connection using the existing electrical wiring in the home. The powerline adapters plug into a wall outlet (or into an extension cord or power strip, but not into 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 outlet to give instant networking and Internet access to an Ethernet-equipped Blu-ray player, a game console (PS3, Xbox 360, 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 powerline networking standard for these powerline adapter products is from the HomePlug Powerline Alliance. HomePlug AV is the most current of the HomePlug specifications (HomePlug 1.0, HomePlug AV and the new HomePlug Green PHY for smart grid comprise the set of published specifications) and it has been adopted by the IEEE P1901 group as a baseline technology for their standard, due to be published and ratified in September or October of 2010. Home Plug estimates that over 45 million HomePlug devices have been deployed worldwide. Other companies and organizations back different specifications for power line home networking and these include the Universal Powerline Association, the HD-PLC Alliance and the ITU-T's G.hn specification.[7][8]

V. BROADBAND OVER POWERLINES

Broadband over power lines (BPL), also known as power-line Internet or power-band, is the use of PLC technology to provide broadband Internet access through ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" into any outlet in an equipped building to have high-speed Internet access. International Broadband 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 throughput and inability 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 bandwidth 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 serve rural communities. [2]

PLC modems transmit in medium and high frequency (1.6 to 80 MHz electric carrier). The asymmetric speed in the modem is generally from 256 kbit/s to 2.7 Mbit/s. In the repeater situated in the meter room the speed is up to 45 Mbit/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 135 Mbit/s. To connect to the Internet, utilities can use optical fiber backbone 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 into the line. Energy-saving devices often introduce noisy harmonics into the line. The system must be designed to deal with these

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natural signaling disruptions and work around them. For these reasons BPL can be thought of as a halfway 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).

Broadband 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 reduce 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 single house or a small number of houses. In Europe, it is more common for a somewhat larger transformer to service 10 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 bandwidth to the transformer is limited, this can increase the speed at which each household can connect, due to fewer people sharing the same line. One possible solution is to use BPL as the backhaul for wireless communications, for instance by hanging Wi-Fi access points or cellphone 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 shortwave broadcasters 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 shortwave 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 HomePlug Powerline Alliance showed that for modems using this technique "in general that with moderate separation of the antenna from the structure containing the HomePlug 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).[2]

VI. MEDIUM FREQUENCY COMMUNICATION

Power line communications technology can use the household 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 into the household 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 household wiring and decoded at the receiver. These devices may be either plugged into 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.

Since 1999, a new power-line communication technology "universal powerline 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.[7]

VII. LOW-SPEED NARROW-BAND COMMUNICATION

Narrowband power line communications began soon after electrical power supply became widespread. 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 (240/415V) 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.[4] 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 a reliable system which is cheap enough to be widely installed and able to compete cost effectively with wireless solutions. But the narrowband powerline communications channel presents many technical challenges, a mathematical channel model and a survey of work is available.

Applications of mains communications 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

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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 optimisation, contract management, expense estimation and gas applications safety.

There are also many specialised 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 powerline 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 powerline carrier. DLC uses narrowband powerline communication frequency range of 9 to 500 kHz with data rate up to 576 kbit/s. DLC is suitable (even in very large networks) for multiple realtime 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: EN 50065 (CENELEC), IEC 61000-3 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 allows end-end communications from substation to the customer premises without repeaters.[8]

The latest DLC systems significantly improve upon and differ from other powerline communication segments. DLC is mainly useful for last-mile and backhaul instrastucture that can be integrated with corporate wide area networks (WANs) via TCP/IP, serial communication or leased-line modem to cater for multi-services realtime energy management systems.
More recently, narrowband PLC communications techniques have also started to include implementations of more sophisticated communication technologies like OFDM, that were till date used in broadband domain. PRIME is one such system that operates within CENELEC A band and uses OFDM as the technology at physical layer to provide data rates up to 128 kbit/s. The PRIME Alliance is an industrial consortium that is putting forth these open specifications of physical and MAC layers and allowing for utilities to pick solutions from different vendors.[7].

IX. FUTURE SCOPE

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

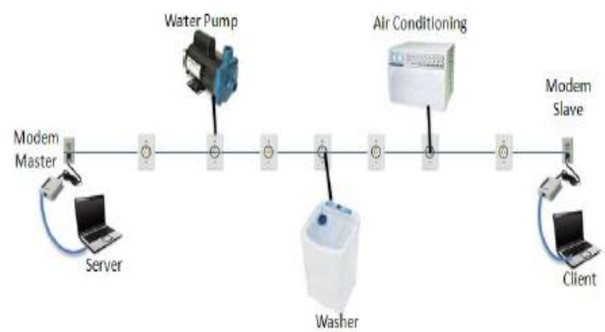

Figure 9.1 – HOME APPLIANCES CONTROL USING PLC

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 15 bps/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 models have been proposed. [2]

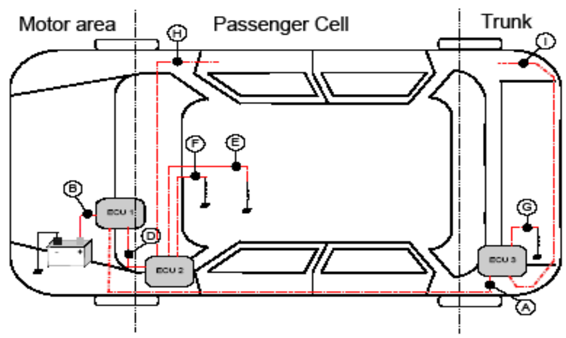

Figure 9.3 - PLC IN VEHICLE

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 Hompelug AV standard is being considered for broadcasting digital television. Many research projects are ongoing into these solutions and their applications, it is all to come, one should pay close attention to news about this technology

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