POWER-LINE CARRIER EQUIPMENTS LINE INTERFACE PROTECTION

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Abstract*: Power Line Carrier - PLC communication equipments where used by electricity companies to send data over high voltage power lines for almost thirty years. Recent developments in modulation and error correction algorithms made possible data rates of several mega bits per second, allowing this method to be used as an alternative for telephone and Internet home connection using the low voltage network. One of the most critical components of this transmission is the interface between the power line and the communication processor. Due to high voltages, impedance characteristics of power lines and, not at the last, due to extremely high amplitude and time-independent disturbances, the coupling network needs to be carefully designed to provide both the signal path and the safety required by the home-used equipment standards. Starting from standard configurations, this article presents some theoretical aspects of power line coupling network and propose a new protection circuit topology that complies with the most critical EMI condition documented in EN50065-1 and provides the largest available bandwidth for data transmission.*

Keywords*: communication, power, line, carrier, PLC, coupling, network, disturbance, protection.*

Introduction

The idea of sending power and data signals on the same pair of wires has the same age as the telegraph itself. There are two patents issued in the 20's to the American Telephone and Telegraph Company in the field of "Carrier Transmission Over Power Circuits". United States Patents numbers 1,607,668 and 1,672,940, show systems for transmitting and receiving communication signals over three phase AC power wiring. In the 80's, there where many articles showing new methods for power line communication using the military spread spectrum technology. The goal was to bypass the unpredictable characteristics of power lines by using small amplitude signals over a large frequency band. Commercial spread spectrum power line communication has been the focus of research and product development of many companies. After about two decades of development, spread spectrum technology has still not delivered on its promise to provide the products required for the proliferation of power line communication. Due to high voltage, impedance characteristics of power lines and high amplitude time-independent disturbances, most of the efforts where done to improve the mains coupling network. While some regulatory agencies introduced new levels of admitted perturbations, research efforts where made to improve both the separation between the mains and the low voltage circuitry and the bandwidth utilization. This article presents some standard methods of coupling and a new combined protection and coupling network.

Power Line Characteristics

There are three major characteristics of power lines communication:

- High noise
- High attenuation
- Signal distortion

The main reason is that power lines where designed to deliver power not data and all design effort where only done to minimize the circuit resistance between the power injection point and the loads.

The equivalent power line model is presented in Figure 1.

The main noise sources are:

- Dimmers (triac controlled lights - produce large impulses (20 to 50V) and 100Hz harmonic)
- Switching power supplies (computer sources - fundamentals at 20 kHz to 1MHz)
- Universal series wound motors (vacuum cleaners, kitchen appliances, drills - high repetition rate impulses, etc.)

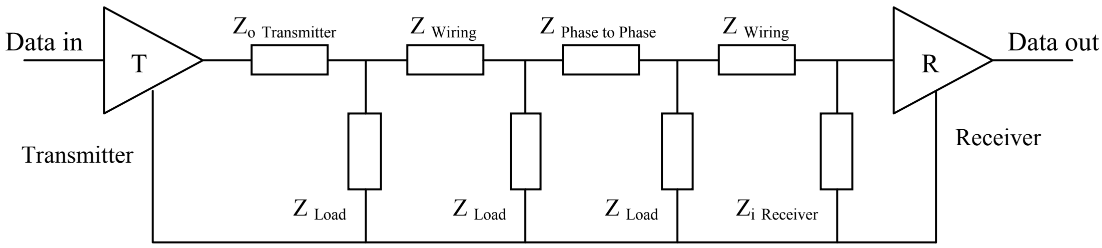

Figure 1. Equivalent circuit between the signal injection point and the receiver

The impedance at a point of a power line network varies with time as consumers on the network are alternately drawing and then not drawing power from the network at twice the AC line frequency. Another problem arises from the common view that wiring capacitance dominates signal propagation effects. While the wire capacitance is dominant for cases where the termination or load impedance is much greater than the characteristic impedance of the wire, power lines are frequently loaded with impedances significantly below the characteristic impedance of the wire. Common examples of loads which present very low network impedance at communication frequencies include capacitors used within computers and television sets sources used to meet electromagnetic emission regulations and resistive heating elements. The impedance of these devices is typically an order of magnitude or more below the characteristic impedance of power wiring. Some typical values are presented in Table 1. Most of the protection schemes presently used involve high voltage capacitors in parallel with power line. A typical connection diagram is shown in Figure 2.

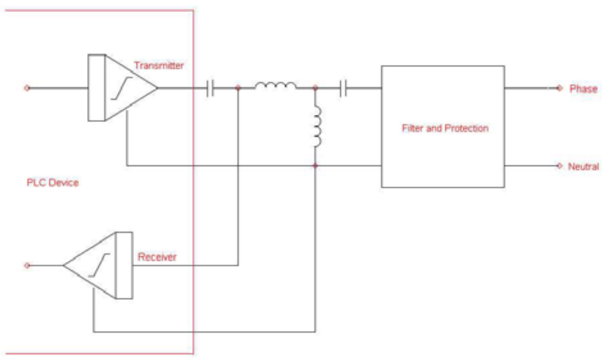

Figure 2. Common coupling circuit between the PLC device and the power-line

Load characteristics	Impedance @50Hz	Impedance @100kHz
1kW electric oven	14.42 ohms	14.42 ohms
2kW electric heater	28.81 ohms	28.81 ohms
0.1 μF EMC capacitor	31830 ohms	15.92 ohms

Table 1. Typical impedance interfering with data path

Fuses and a LC high-pass filter and in some cases a varistor, as shown in Figure 3, are the only protection provided for these devices. Without any protection on the high voltage path, high energy pulses are traveling through the filter and damaging the low voltage circuit or even the communication processor.

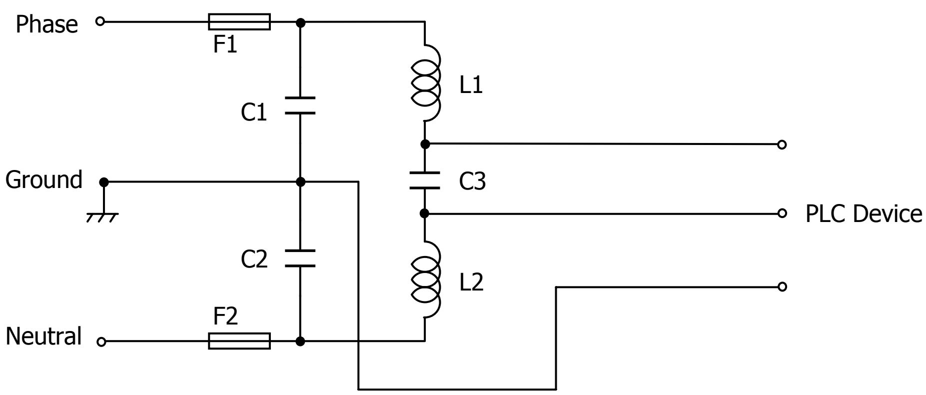

Figure 3. Standard structure of a power-line filter

Proposed Protection Filter

The proposed new protection scheme was tested in a real environment, without any damages for about 3 years (there where a lot of lightings are other high voltage disturbances during this period). For the best possible protection both low voltage and high voltage protection where combined. For the high voltage part, thermally protected metal-oxide varistor where used, in combination with plasma surge arrester. For the low voltage path two new configuration structures where tested, one using only silicon avalanche diode on the primary and the second with standard Zenner diodes combined with temperature dependant resistors as shown in Figure 4. Schemes where computer simulated, laboratory measured and real-life tested. The second scheme was the best in practice, surviving several times on very high voltages discharging.

On the proposed diagram F1 and F2 are fast acting fuses, carefully selected for the maximum current required by the device. The first protecting devices are SA1 and SA2, two plasma surge arresters. Because high voltage spikes appear only between one active and the ground, we use two such devices are mounted between the phase and neutral and the ground.

The first innovation in the scheme is the two thermal variable resistors with only 1 ohm in resistance at 20 degrees. Their resistance rises with temperature, arriving at almost 30 ohms at 80 degrees. Three classical protection elements are MOV1, MOV2 and MOV3 - metal oxide varistors. The combination of thermal variable resistors and metal oxide varistors give the best possible protection against lighting induced voltages.

The second innovation is the Zenner diodes in the transformer secondary. Measurements made over many configurations shows that many damages where produced by high voltages induced in the secondary, between the device chassis and the active wires (this was the cause in one experiment when the fusses where good but the communication processor where destroyed). In order not to interfere with the signal and to ensure efficient protection, proper diode breakdown voltages must be selected (in our experiments at 10Vpp voltage in the secondary we used 24V diodes).

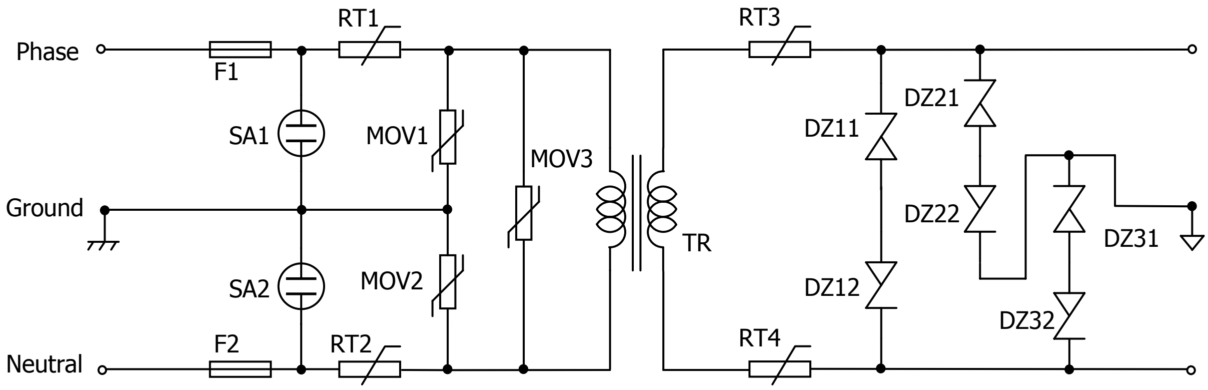

Figure 4. New power-line interface protection filter

Conclusions

Power-line communications are the big challenge for the years to come. Many efforts where done in the past five years to improve Due to unpredictable characteristics of the impedance and high voltage disturbances, interfacing between the mains and the small signal processor is the key to success..

References

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