Extollo Communications

Home Electrical Wiring

and

Cross Phase Coupling Overview

Introduction

One of the questions often asked is: "Will Powerline adapters communicate with each other if they are on different electrical phases". The answer is yes.

Many Powerline Communications (PLC) products developed prior to the HomePlug AV and the ITU-T G.hn standards had a coverage problem. A Powerline adapter placed in a particular power outlet in the home often could only communicate with a subset of the other power outlets in the home and not every other outlet in the home.

This is referred to as a cross-phase coupling problem. The cross-phase coupling problem raised questions about the nature of home electrical wiring and the reliability of power lines as a communications medium.

This Tech Note explains the basics of typical home electrical wiring, the cross-phase coupling problem, and how HomePlug & G.hn solved the problem.

Electrical Wiring In The Typical North American Home

To improve efficiency, electrical power is distributed through cities and neighborhoods at high voltages of typically 6 to 16 thousand volts (kV). Near the home, a utility step-down transformer reduces the voltage down to 240 V. The leads from the two 240 V windings of the distribution transformer are called Line1 and Line2. The 240 V power is a push-pull potential force that is divided evenly between Line1 and Line2. The utility distribution transformer is typically deployed on a gray pole-mount can or green pad mount box and supplies, on average, four homes per transformer. The schematic of a typical transformer is shown in Figure 1 below.

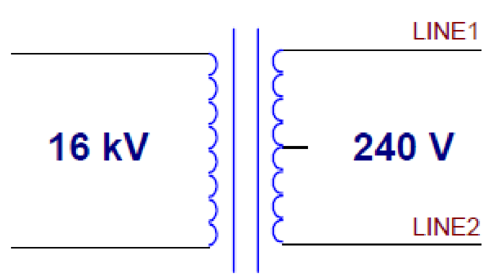

Figure 1. Transformer for a typical North American home

To provide the 110 V power available in most of the 2 and 3 prong electrical outlets in the typical home, the "phase is split;" a center tap is added to the 240 V side of the transformer. This center tap is called Neutral and is tied to ground in the electrical service panel in the home. Center tapping a transformer is like sitting on the center of a see-saw, the Line1 and Line2 potentials push up and down on either side of you and the center stays steady. The result is that there is 120 V of potential between Line1 and Neutral and between Neutral and Line2.

Inside the electrical service panel in the home, branches of electrical outlets are attached through circuit breakers to one of the two available 120 V phases, as shown in Figure 2 below. As each circuit breaker is added to the panel, the mechanical connection alternates between attaching the branch to the 120 V between Line1 and Neutral or the 120 V between Neutral and Line2. This configuration allows devices with high power consumption requirements, such as electric stoves and air conditioners, to take advantage of the higher 240 V available by connecting between Line1 and Line2.

When you look at a normal 120-volt outlet in North America, there are two vertical slots and then a round hole centered below them. The left slot is slightly larger than the right. The left slot is called "neutral," the right slot is called "hot" and the hole below them is called "ground." If an appliance is working properly, all electricity that the appliance uses will flow from hot to neutral.

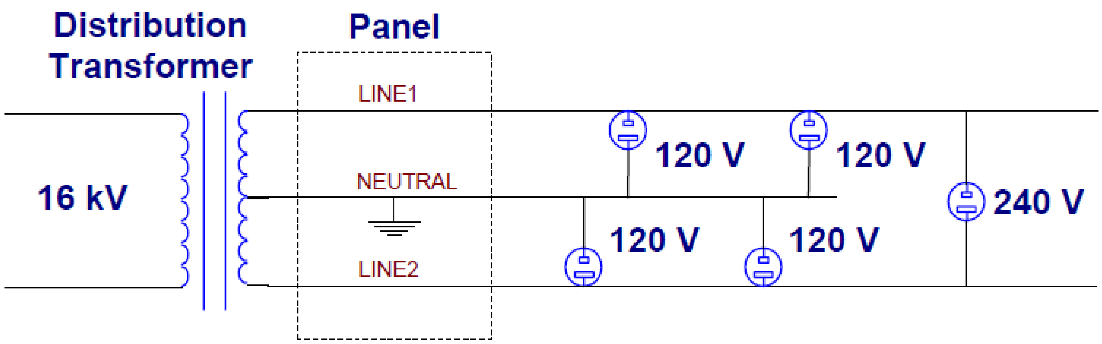

Figure 2. Electrical wiring in a typical North American home

The Cross-Phase Coupling Problem

In Figure 3 the outlets have been given individual names to aid in this discussion. Power lines attenuate signals. As the signal travels farther and farther down the power line it becomes smaller and smaller until the signal is no longer usable. Devices communicating on the same phase, such as a device from outlet L1A to a device on outlet L1B, the signal has a relatively short path, Line1, on which to travel. Even when two outlets are on different branches but on the same phase, Line1 provides a relatively short path. Attenuation is often measured in dB. The typical outlet to outlet path has an attenuation of between 30 to 50 dB. HomePlug AV2 and G.hn technologies have a dynamic range of 70-90 dB. Therefore the signal can be attenuated by 70-90 dB before it is lost.

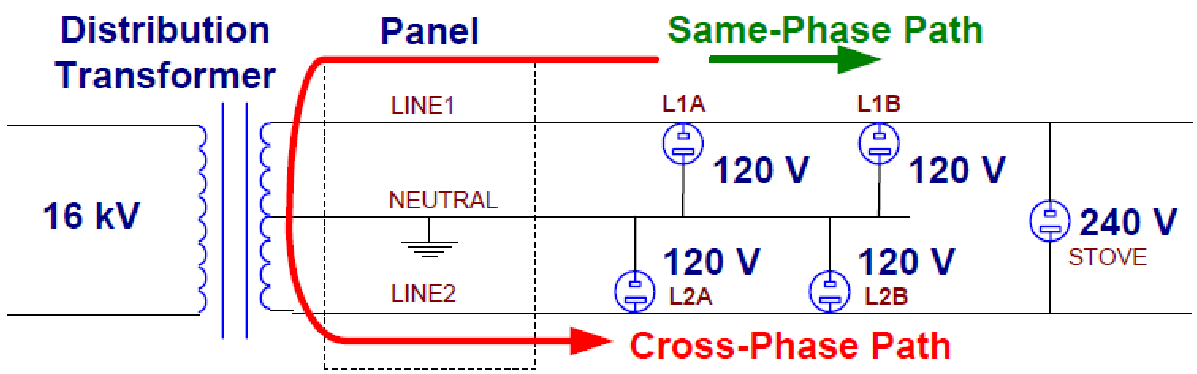

Figure 3. Electrical outlets in a typical North American home

The cross-phase coupling problem happens when a device in outlet L1A tries to communicate with a device in outlet L2A. The only path from Line1 to Line2 is the long wire (red line) from the panel to the utilities distribution transformer, through the highly attenuating distribution transformer, and back down the long wire from the utilities distribution transformer to the panel. In this scenario, the attenuation from Line1 in the electrical panel to Line2 in the electrical panel can be 35 dB or higher. Add 35 dB to cross the panel to the 50 dB required for an outlet to outlet connection and the total attenuation comes close to exceeding the 90 dB “link budget” provided by the dynamic range of HomePlug’s AV2 and G.hn technology.

The result is that older generation Powerline technologies achieve approximately 80% coverage. If you walk around a house and do a random outlet to outlet test checking for a connection, the technology will work in 4 out of 5 connections, or 80% of the time.

Solving the Cross-Phase Coupling Problem

Older generation powerline technologies use relatively low signaling frequencies, typically below 2 MHz. HomePlug AV2 and G.hn use much higher signaling frequencies, 2-86 MHz. At these frequencies, the Bus Bars in the electrical service panel start to look like a capacitor. The Bus Bars are two large copper bars that run down the center of the electrical service panel to which the circuit breakers physically attach. The electrical panel acts as a cross-phase coupler, as shown in Figure 5.

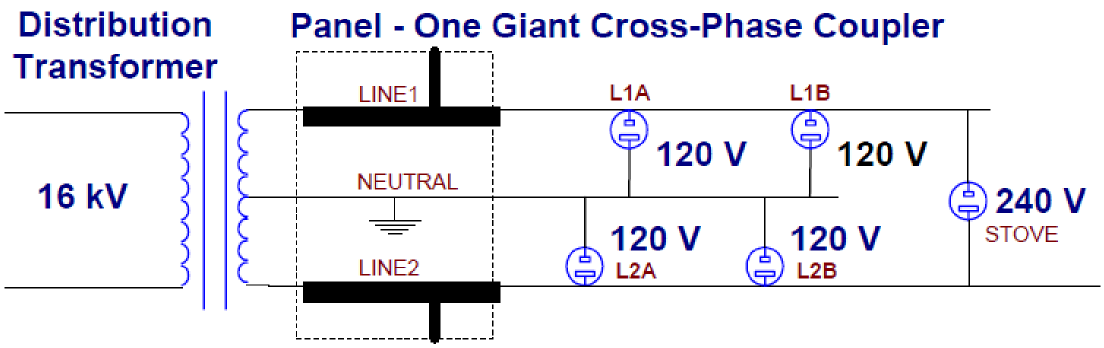

Figure 5. The electrical panel acts as a cross-phase coupler

The result is that HomePlug and G.hn signals couple, or "radiate" across the electrical service panel's circuit breaker Bus Bars with as little as 5 dB of loss. Therefore, the powerline signals of an adapter on Phase 1 can communicate with an adapter on Phase 2 through the Bus Bars in the electrical service panel as shown in Figure 6.

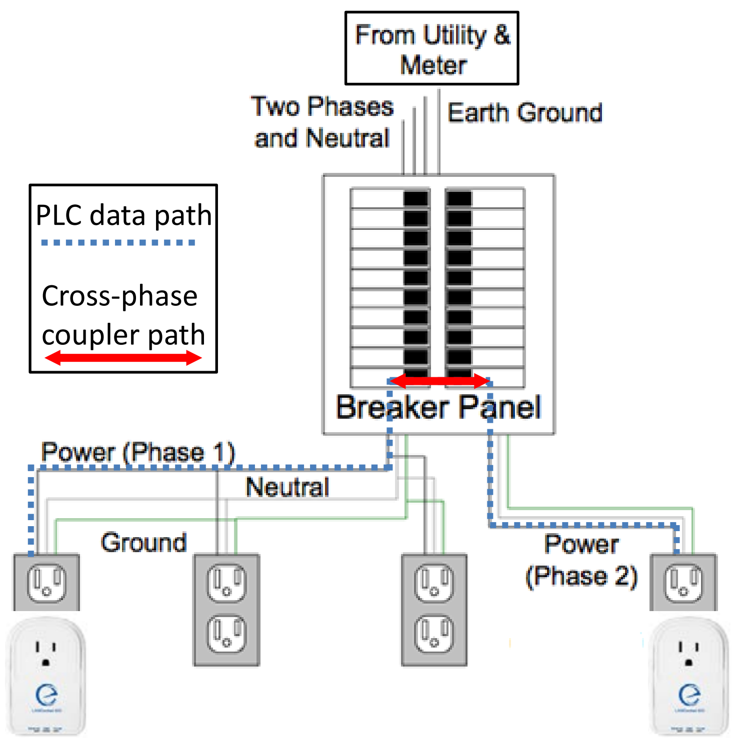

Figure 6. The cross-phase coupler path

Conclusion

HomePlug and G.hn technologies addresses all of the challenges present in communicating on the electrical power lines within the home. HomePlug's AV2 and the G.hn standards improves the rate-reach performance within the home, resulting in a 99% in home coverage.

Technical Details

Electrical currents travel in closed loops, not point-point connections as illustrated in the figures. For each of the paths described here, the loop is closed by a return path on the Neutral. However, this does not affect the explanation. Though it is equally valid to state that the signal travels on the neutral, the current loop concept will illuminate the same result: the return path of the loop may have to travel across phases.

Three-Phase Power

Some homes, particularly those in Multi-Dwelling Units and 240 V nations, may use three-phase power instead of split phase power. The result is that there may be a third line, Line3, entering the home. Though the details of the diagrams change, the end results do not.

References

Intellon's application note 26002637
National Electrical Code® (NEC)
IEEE National Electrical Safety Code® (NESC®)