Ghosts in the Student Housing

by Poul Nørgaard (translated from Danish)

How a missing neutral wire caused such high magnetic fields that audio systems were affected.

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It was a warm and boring afternoon. I sat in my office, fighting with a report, when the phone rang. The person on the other end presented himself as the electrician for the local student co-op housing. He sounded a little unsure of himself, when he described some strange events in one of the co-op buildings.

The start of the story

First, the students noticed that their CRT computer screens started to show wavy lines. Then strange sounds were heard in some of the rooms, like a deep hum.

The electrician explained that when he was called in, he discovered that the hum came from some speakers. They turned off the audio equipment, but the speakers still hummed. They disconnected the cables to the speakers, so they stood in the middle of the room with no connection to anything, but they still hummed. This is when they started thinking of ghosts.

Time for EMC measurements

After we talked some more, I thought there was a natural explanation that did not involve any ghosts. We agreed that I should come for a visit to do some EMC measurements and look over the electrical installation.

After seeing and hearing the disturbances myself, I measured the magnetic field in the most affected room. I did this with a loop antenna and an oscilloscope, which showed a very strong 50 hertz magnetic field.

I had no doubt that the disturbances were caused by this very strong low-frequency magnetic field, which probably was created by stray currents in the building's electrical system. We therefore continued our measurements at the main power distribution panel in the basement.

The outgoing cable from the master panel was too thick for the clamp meter to reach around it, so it was not possible to measure the stray current. Instead, we measured the magnetic field directly on the cable to be 135 A/m (1700 milligauss, 170 microtesla).

We then went to the first sub-panel to measure the stray current there. On the three cables leaving the sub-panel, we measured a common mode net current of 23 amps, 16 amps and 18 amps respectively. This meant there was a combined net current of 57 amps, which is incredibly high and indicates that there is something major wrong with the electrical system.

The cause of the ghosts

After talking more with the electrician and the superintendent, it came to light that the main power distribution panel had recently been replaced and it might have been around that time that the disturbances started. Based on that, I concluded that the problem was probably inside the new master panel.

It would have been best to immediately shut down the electrical system for the whole co-op, and then inspect the master panel, but to minimize the impact on the students and their computers, we decided to wait until early the next morning.

We disconnected the power to the whole co-op the next morning at 6 a.m. The master panel was opened and it was quickly determined that the neutral latch was missing. This meant that the neutral wire was not connected inside the panel and that the co-op had no neutral at all.

The problem was found, the latch installed and the ghosts disappeared immediately.

What happened?

The electrical system has three phases, a neutral and a ground. The current normally runs forward through a phase, through the appliance, and then back through the neutral wire. But, how does the current run when the neutral wire is missing? What made the co-op's power system still work?

The explanation is that the co-op's electrical system is a four-conductor PEN system, with bonding at all the sub-panels. This is not a setup we normally recommend, but in this case it allowed the system to continue operating.

Since the current could not return through the neutral, it instead returned via the grounding wire. This was possible, since the neutral and ground were connected (bonded) in each of the sub-panels. The current then travelled through various ground connections around the building. Possibilities include the grounding of the electric water heaters to the steel water pipes, any extra grounding a student may have to a steel radiator in the hydronic heating system, the extra ground rod that existed, the ventilation system ducts or even the rebar in the wall or floor. Finally, it travelled through the soil back to the transformer.

All these incidental ground paths have together with the neutral wires kept the voltage at 236 VAC. Without these connections, the voltage would have exceeded 360 VAC, which would have damaged electrical equipment connected to the building power.

Translator's notes

This story took place in Denmark, which has a 50 hertz power cycle and uses three-phase PEN (Phase-Earth-Neutral) systems in their buildings. North America uses 60 hertz, and typically has two-phase PEN systems.

This case can also happen in North American installations. Even though bonding at subpanels is discouraged by the National Electric Code, it happens.

The story took place in the era just before flat computer screens, which are not so easily affected by magnetic fields as CRT type computer screens and televisions.

About the author

Poul Nørgaard is a SWAT specialist at the DELTA Test & Consultancy (madebydelta.dk) in Horsholm, Denmark.

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