

PowerLogic Solutions

Volume 3, Issue 1

In this issue, we discuss ground fault monitoring with the PowerLogic Circuit Monitor.

Beyond Blondel

—Monitoring all phases on a three-wire circuit

The Problem

An automotive manufacturer was in the start-up phase of a new production plant. The electrical system serving the new equipment was a 480V three-wire, ungrounded (delta) circuit. All of the new production equipment—air compressors, motors, conveyors, lights—was operating fine. During final commissioning of the electrical system, however, electricians measured unusual voltages.

Their readings showed that phase-to-phase voltages were about 480V on all three phases. Phase-to-ground readings, however, measured 130V,

550V, and 690V on the three conductors.

(Normal voltages to ground on a 480V ungrounded system are approximately 277V.) Detection devices at the main switchgear showed there was a *ground fault* (see sidebar on page 4) somewhere in the new plant, but an exhaustive investigation proved fruitless. Electricians added to the puzzle by discovering that the strange phase-to-ground voltage readings returned to normal when the ground fault detection system was removed from service. Even though plant equipment was operating properly, plant personnel were concerned that the high voltages to ground would cause insulation failures and catastrophic electrical faults.

This issue of *PowerLogic Solutions* describes *ground fault monitoring and neutral instability*, and recommends a way to measure ground faults on ungrounded systems with the PowerLogic Circuit Monitor from Square D Company.



Figure 1. In addition to its primary power monitoring functions, the PowerLogic® Circuit Monitor can be used for ground fault detection.

The PowerLogic Circuit Monitor is designed to perform metering functions; **it is not a protective relay designed to provide circuit protection**. Think of the circuit monitor as device used for ground fault **detection**, not **protection**. Alarm/relay functions are included with the circuit monitor to provide alarm annunciation and, in cases like this application, to be used in conjunction with existing ground fault protection systems.

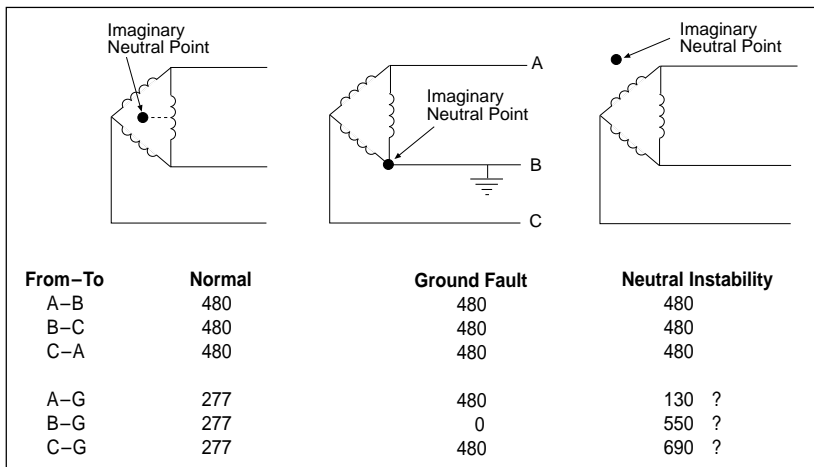


SQUARE D
GROUPE SCHNEIDER

Key Concepts and Terms

Neutral Instability. Neutral instability, a form of ferroresonance, is a rare problem. It occurs on three-phase ungrounded circuits that are equipped with ground fault monitoring through voltage transformers (VTs, previously called potential transformers, or PTs) connected phase to ground. The term itself seems to be a misnomer because a three-phase, three-wire circuit has no neutral conductor. *Neutral* in neutral instability refers to the single imaginary point in a delta (three-phase, three-wire) circuit at which all three phases measure equal voltages. This point in a delta circuit is typically at

Figure 2. Typical voltage readings from an ungrounded circuit under normal, ground fault, and neutral instability conditions.



Monitoring of Ungrounded Circuits

Power monitoring of three-phase, three-wire ac circuits is typically accomplished with two voltage inputs and two current inputs to the circuit monitor. This method of monitoring uses *Blondel's Theorem*, which states that a circuit can be monitored accurately with one less voltage/current sensing channel than there are current-carrying conductors. A three-phase, three-wire circuit, therefore, requires two voltage sensing inputs and two current sensing inputs. A three-phase, four-wire circuit requires three VTs and three current transformers (CTs).

Blondel's theorem is based on simple electrical circuit principles. These principles prove that the vector sum of voltages or currents for the current-carrying conductors is always zero. Thus, the voltage or current on an unmetered conductor can be accurately calculated from the voltages and currents on the metered phases,

ground potential, except during a ground fault or neutral instability. (See figure 2.)

for all power system parameters.

Neutral instability is caused by the interaction of the charging capacitance of an ungrounded circuit and the nonlinear inductance of VTs connected to ground. When conditions of capacitance and inductance are right, neutral instability occurs. It can occur on a system which has operated normally for some time. It can be caused by a ground fault detection or monitoring design which has not caused problems on other three-wire circuits.

However, some customers want to monitor *all three phases* of a three-wire circuit. It isn't that they don't trust Blondel, but they are interested in ground fault monitoring. During a ground fault, the grounded system becomes a current-carrying conductor and Blondel's theorem is violated to a small degree. For most applications, this only causes a small error in power readings: ground fault currents are typically low (fewer than 10 amps on a 480V system) compared to phase currents. However, to prevent ground faults from remaining on the system for long periods, they should be identified and repaired quickly.

The common characteristic of systems with neutral instability problems is that these systems have VTs connected phase to ground somewhere on the circuit. Ungrounded systems normally do not have loads connected phase to ground; all loads, single-phase or three-phase, are connected phase to phase. In some ground fault detection schemes, all three phases must be monitored with respect to ground. When the detection system includes VTs connected phase to ground, neutral instability can occur.

What other reasons are there to monitor all three phases of a three-wire system? One customer wanted to track voltages with respect to ground during utility faults. This customer reported losing several induction motors during utility faults, each due to line-to-chassis failures. He suspected that line-to-ground voltage swells were initiating the failures.



PowerLogic Solutions is produced by Square D Company's Power Management Operation. Each issue presents a problem that might occur in a typical power system, and offers guidance on how to solve it.

Solution: Ground Fault Monitoring With the Circuit Monitor

As stated earlier, the circuit monitor accurately meters electricity parameters, but should not be used to replace overcurrent devices or ground-fault protection systems. However, the circuit monitor can be used to monitor and alarm when ground faults occur.

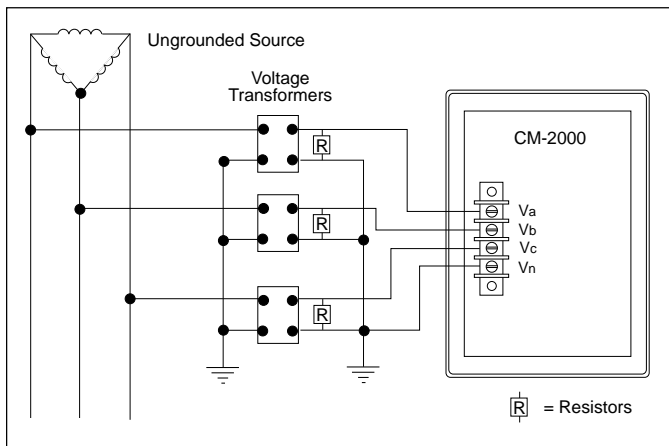


Figure 3. Voltage transformers, connected to ground on an ungrounded system, require resistors to reduce neutral instability concerns.

Ground fault monitoring can be accomplished as shown in figure 3. The resistors in the circuit serve to stabilize the voltage transformers connected to ground and eliminate the VTs as a source of neutral instability.

The resistors in figure 4 can be off-the-shelf heating elements, sized to meet the requirements. The resistors provide damping load to reduce the adverse effects of neutral instability. To ensure metering accuracy, the voltage transformers should be *instrument* transformers (Square D model 460R voltage transformers, for example), not control power transformers. Control power transformers can introduce 5% metering error, plus several degrees of phase shift.

Transformers and resistors must be properly sized to ensure metering accuracy and neutral stability. Contact PowerLogic Technical Support for more details on your specific application.

Circuit monitors should be configured for system 40, as if monitoring a four-wire circuit.

Line-to-ground readings will actually be represented as line-to-neutral values. Since line-to-ground voltages drop to zero on the grounded phase and increase to line-to-line values on the ungrounded phases, over- or undervoltage triggers. Circuit monitor alarms can easily be set to indicate ground fault conditions.

Conclusions

The unusual phase-to-ground voltage readings at the new plant were being caused by neutral instability on a 480V ungrounded system. The instability was introduced by the voltage transformers serving the ground fault detection system. These transformers were connected phase to ground on the ungrounded circuit, without regard for possible neutral instability problems.

Square D recommended that the customer install resistors across the VTs in the ground fault detection system. The resistors provide damping in the LC (inductive-capacitive) circuit

formed by the transformer reactance and the system charging capacitance. Thus, the resistors change the circuit characteristics to the point that no neutral instability occurs.

Circuit monitors can *detect* ground faults when connected to a grounded instrument transformer circuit. But ***circuit monitors should never be used instead of a ground fault protection system.*** The detection circuit should be equipped

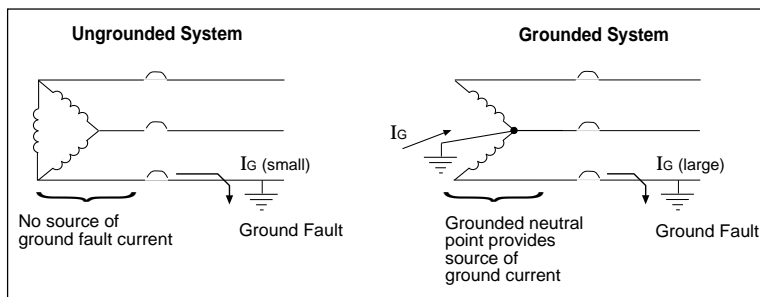


Figure 4. Ungrounded systems are used because inadvertent ground faults do not trip overcurrent devices and shut down critical processes.

with resistors to ensure neutral stability. Resistors must be sized according to the instrument transformer characteristics.

Circuit monitors detect ground fault conditions by monitoring for abnormally low or high voltages with respect to ground. Due to the low amount of ground current, current variations are insufficient to distinguish ground faults from changes in load current.

While the circuit monitor provides a ready means of ground fault detection, don't neglect its real power: monitoring a myriad of other system parameters and helping you drive cost reductions, productivity improvements, and power quality enhancements.

Square D Company's Power Management Services can assist you with ground fault detection and monitoring. In addition, we provide power quality consulting services to ensure that power disturbances don't disrupt your operation.

Test Your Power Quotient

Refer to volume 2, issues 1 and 2, in addition to this issue, for answers to the following questions. Answers are below.

True or False

1. Neutral instability refers to current unbalance on a 208/120 V wye circuit.
2. Total harmonic distortion is a term indicating the magnitude of harmonics present in a voltage or current signal.
3. High-resistance grounded systems have some characteristics of both ungrounded and grounded circuits.
4. Circuit Monitors should be used for protective ground fault relaying.

5. There is no difference between THD and thd readings.
6. By double-clicking on the title block in a four-cycle waveform capture, you can obtain a breakdown of the harmonic characteristics of a voltage or current signal.

Ground Faults

Ground faults occur when energized conductors come in contact with metallic parts normally at ground (zero voltage) potential. Common causes of ground faults are nicks in wire insulation, failure in the insulation in an electrical machine like a motor or heater, and contact made between grounded parts and exposed energized conductors.

When ground faults occur on a circuit served by a transformer with a grounded neutral point (grounded wye), high currents flow on the faulted phase. These currents are usually sufficient to trip circuit breakers or melt fuses. Even so, code requirements may call for a ground fault protection system if expected ground fault current exceeds a certain level.

Ground faults on ungrounded or high-resistance grounded transformers typically draw less than 10 amperes. Unlike faults between phases, or between phase and ground on a grounded source, these ground faults typically do not draw enough current to operate a circuit breaker or fuse. If not detected and repaired, they can remain on a circuit for considerable periods of time.

This ability to sustain a ground fault without tripping overcurrent devices is the primary reason ungrounded or high-resistance grounded systems are used. They serve critical processes that, when unexpectedly shut down, cause high economic or human losses.

Most engineers prefer grounded systems, especially for serving sensitive electronic equipment. As an alternative, they may consider a high-resistance grounded system for critical loads. High-resistance grounded systems offer some benefits of the grounded system, but do not shut down critical processes during a ground fault. IEEE Standard 1100, the recommended practice for powering and grounding sensitive equipment, recommends solidly grounded systems, especially when serving electronic loads.

Answers

1. False, three-phase ungrounded circuits in a ferrous resonant condition (page two, this issue).
2. True (page 3, volume 2, issue 2).
3. True (page 4, this issue).
4. False, they should be used for protection, not *pro*tection (page 1, this issue).
5. False, the values are different (page 3, volume 2, issue 2).
6. True (page 2, volume 2, issue 2).

