

Do You Know Where Your Fault Currents are Flowing?

Robert Fuhr, P.E., Senior Member IEEE & Jessica McCue

PowerStudies, Inc. is an electrical engineering consulting firm that provides a variety of power system studies and services to corporations and facilities across the United States. One of the services provided is the investigation of problems in electrical systems. Below, Robert describes one of the more peculiar situations he's come across in his career as an electrical engineer.

PowerStudies, Inc. was hired to investigate a very strange power outage problem that was happening to a group of three buildings in Issaquah, WA. The campus was fed by the local utility company, Puget Sound Energy (PSE), out of their Pickering Substation. This substation has several feeder circuits that feed not only the campus, but other parts of Issaquah as well.



Two of the buildings contain two 1,500 kVA transformers that step down the voltage from 12,470 to 480 Volts. The third building has only one transformer. The campus is fed by a main S&C Vista Switch. The Vista Switch has a solid state electronic trip unit set to trip on phase and ground faults.

The problem first arose approximately nine years ago. A line-to-ground fault occurred on an adjacent PSE Pickering Substation feeder, not on the circuit feeding the campus. This fault tripped the PSE adjacent feeder breaker (which is correct) but also caused the campus Vista Switch to trip, blacking out the buildings. Obviously, this should not have happened.

CSS1 Way 3:

Event Report (No date and time stamp)

Amperes

1	2	3	G
602	596	664	1835

Settings for CSS1 controller Way 3 are as follows:

	Phase	Ground
TCC Curve Type	Tap	Off
Min. Pickup (amperes)	200	N/A
Time-Dial Multiplier	N/A	N/A
Inst. Pickup (KA)	6	N/A
Definite-Time Delay (ms)	96	N/A

Load Current (Amperes)	1	2	3	G
	56	51	43	25

Vista Switch Printout Fall of 2012

The problem then occurred again a year later. Not knowing exactly what to do, the decision was made by others to turn off the ground fault function. For several years, the problem disappeared and the Vista Switches did not trip. Everybody involved in the project assumed that the problem had been solved. Then in the fall of 2012, a line to ground fault again occurred on an adjacent Pickering Substation feeder. The Vista Trip Switch tripped out again; this time due to phase overcurrent. I was brought in again to investigate the problem.

I met with the owner, utility representatives, and the owner's contractor, Valley Electric, to discuss the problem. After a long discussion, a common theme emerged from the four outages that the building had experienced. Each mysterious Vista Switch trip occurred when a line to ground fault happened on an adjacent PSE Pickering feeder

The Vista Switch was closed and an investigation was launched. PSE technicians downloaded the event file from the Vista Switch trip unit. It showed that the trip unit tripped out on ground overcurrent. Initially, it was thought that the ground settings were set too low.

PowerStudies, Inc. was hired to verify that the protective device settings were correct. I reviewed the settings, plotted the devices on Time Current Curves, and determined that the settings were correct and was not the cause of the trip. The other investigators theorized that the Vista Trip units may be defective, sensitive to voltage sags, and decided to replace them. Valley Electric obtained new trip units and replaced the suspect units.

circuit. This caused the Vista Switch to trip on ground overcurrent (until it was turned off by others), then phase overcurrent.

So the question for me was “Why?” Why would a ground fault in another location of PSE’s system cause the Vista Switch to trip on phase overcurrent?

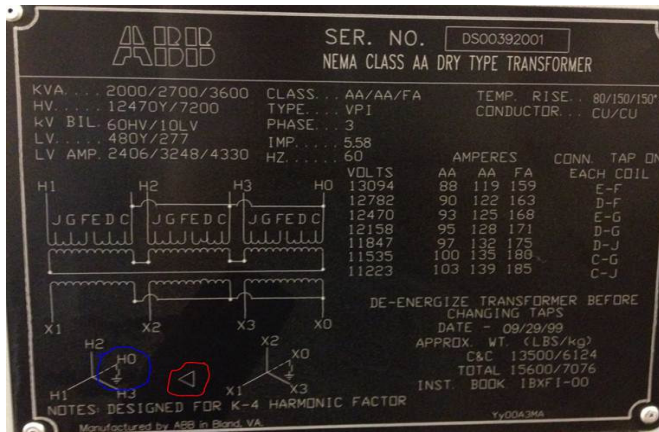
After a lot of research, I came across a very well written article titled, “A Review of System Grounding Methods and Zero Sequence Current Sources” by Gerald Johnson (Basler Electric), Mark Schroeder (Dominion VA Power) and Gerald Dale (Power System Relay Services). This article explains how ground fault currents can be distributed inadvertently when different types of faults occur. Page 7 of the article shows these different winding configurations and the flow of line-to-ground (zero sequence) currents for different winding configurations.

One type that caught my eye was the Wye-grounded/Delta/Wye-grounded transformer. This winding configuration can act as a low impedance path for line-to-ground currents on a system creating a path for the zero sequence currents to flow. This allows the line-to-ground fault current to split and take an alternate path back to the Pickering Substation. The line-to-ground fault currents will flow to ground at the fault location and then flow up the ground connection of the primary side of the three winding transformer. The currents are redistributed (almost evenly) on to the phases.

Could this be the problem? The use of three winding transformers in commercial buildings is extremely rare. In fact, I have never seen this in my 33 years of experience in the industry. They are usually used at utility power plants to save money and space. To test the theory, I modeled the system in SKM and proved that this type of three winding transformer can indeed re-distribute line to ground fault currents back onto the phases.

Table 1. Transformer Connections and Zero Sequence Current

Transformation Primary (Pri.) Secondary (Sec.)	Passes Zero Seq. Current?	Provides a Source for Zero Seq. Current?
Y Y	No	No
Y Y _g	No	No
Y _g Y	No	No
Y _g Y _g	Yes	No
Δ Δ	No	No
Δ Y _g	No	Yes (to Sec. only)
Y _g Δ	No	Yes (to Pri. only)
Y Δ Y	No	No
Y Δ Y _g	No	Yes (to Sec. only)
Y _g Δ Y _g	Yes	Yes (to Pri. and Sec.)
Y _g Δ	Yes	No
Y _g Δ Y _g	Yes	Yes (to Pri. and Sec.)



A field visit to the site and buildings confirmed my suspicion that the transformer was a Wye-grounded/Delta/Wye-grounded unit. Again, the article helped me to determine the solution to the problem by removing the primary to ground neutral link. This changed the transformer winding configuration to a Wye-Ungrounded/Delta/Wye-grounded unit. With the link removed, the ground fault current can no longer flow up through the neutral link back to the phases.

In the fall of 2013, the Vista Switch was opened and the three buildings were de-energized. The Valley Electric electricians grounded each transformer primary, tested for the absence of voltage, and removed the primary to neutral link. Now that the cause has been determined and solution implemented, the mystery trips afflicting the campus buildings will not occur.



The moral of this story? Always know where your ground fault currents are flowing and verify the transformer winding configurations on your distribution system.

PowerStudies, Inc. can provide this service for your facility. Feel free to call us, fax us, or e-mail us. We would be happy to talk to you about your facility and solve your mystery power problems.

Telephone: (253)639-8535
 Fax: (253)639-8685
 E-mail: quotes@powerstudies.com
 Web: www.PowerStudies.com

About the Author

Robert Fuhr graduated with a B.S.E.E. from the University of Wisconsin in 1980. Before graduating, Mr. Fuhr worked for Madison Gas and Electric in Madison, WI and Tennessee Valley Authority in Knoxville, TN. After graduation, he worked for General Electric Company from 1980 to 1986 as a Field Engineer, performing commissioning and start up tests on many different types of power distribution equipment. Mr. Fuhr worked as a Senior Facilities Engineer at the University of Washington from 1986-1989. There he re-commissioned the electrical power distribution system for University Hospital.

In 1986, Mr. Fuhr established PowerStudies, Inc., a consulting firm that specializes in power systems studies, power quality services, and commissioning services. He also teaches classes in protective relaying, electrical systems, safety, power factor correction, harmonics and filter design. Mr. Fuhr is a Professional Engineer registered in 19 states, including Washington, Oregon, California, and Alaska.

Mr. Fuhr has been actively involved in Institute of Electrical and Electronic Engineers (IEEE) and the Industrial Applications Society (IAS) since 1986. He served as an officer for IAS from 1988 to 1992 and was the 1991-92 Chairperson of IAS and was a Member-at-large for the Seattle Section of IEEE from 1992-93. Mr. Fuhr is an IEEE Senior Member, a member of the Building Commissioning Association, and a member of the Electric League of the Pacific Northwest.