Phantom Voltage Readings on Power Monitoring Devices (PMDs)

This document explains the phenomenon known as phantom voltage and how it affects certain Schneider Electric power monitoring devices.

In this document

Schneider Electric
35 rue Joseph Monier
92500 Rueil-Malmaison, France
www.schneider-electric.com

Safety information

Important information

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this manual or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

The addition of either symbol to a “Danger” or “Warning” safety label indicates that an electrical hazard exists which will result in personal injury if the instructions are not followed.

This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

⚠ DANGER

DANGER indicates a hazardous situation which, if not avoided, **will result in** death or serious injury.

⚠ WARNING

WARNING indicates a hazardous situation which, if not avoided, **could result in** death or serious injury.

⚠ CAUTION

CAUTION indicates a hazardous situation which, if not avoided, **could result in** minor or moderate injury.

NOTICE

NOTICE is used to address practices not related to physical injury.

Please note

Electrical equipment should be installed, operated, serviced and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

A qualified person is one who has skills and knowledge related to the construction, installation, and operation of electrical equipment and has received safety training to recognize and avoid the hazards involved.

Introduction

In some situations, voltage readings may be present on the power monitor's high impedance voltage inputs without any electrical connection to a voltage source. These harmless "phantom" (also known as "ghost" or "stray") voltage readings are usually caused by the capacitive coupling of voltages through the auxiliary (control) power supply of a PMD, and are exposed on the high input impedance of the measuring instrument. This phenomenon is usually observed on ungrounded PMDs (i.e. on "protective class II" devices without functional ground (earth) connections).

The phantom voltage is a physical phenomenon involving voltage coupling through very small values of capacitance, and therefore it cannot supply enough current to energize a load or cause harmful physiological effects to a person coming in contact with such phantom voltage.

Phantom voltage readings may be observed in correct meter installations; however, in order to avoid electrical shock, care must be taken to ensure that the observed voltage reading is in fact a phantom voltage, and is not a hazardous voltage back feeding from another circuit, or resulting from an improper installation, cable fault or a PMD failure.

"In order to help minimize the likelihood of reaching a wrong conclusion from this phenomenon, the National Eletrical Manufacturer's Association (NEMA) recommends the use of a Listed low impedance multimeter in place of a high impedance multimeter or other high impedance measuring device for testing on open conductors where there is no hard electrical connection. Without a low impedance measuring device, a high voltage reading is an inconclusive indication of possible faults in the cable. "[1].

It can be difficult to distinguish a back-fed voltage from a phantom voltage. If a phantom voltage is connected to earth (ground), the voltage will dissipate because is not supported by a source capable of delivering any significant current. A back-fed voltage, even though it does have a generation source feeding it, will likely have more current available and will arc when connected to earth (ground). [3]

Fluke 117 or Fluke 289 are examples of digital multimeters with low impedance measurement mode, "Volt –LoZ" mode, which will eliminate the phantom voltage reading. At the beginning of the measurement, the digital multimeter input impedance is low, on the order of few kΩ, which will dissipate any phantom voltage readings. When a "hard", non-phantom voltage is detected, the digital multimeter will automatically increase its input impedance to a much higher value and provide a correct voltage reading. [2]

To verify the correct PMD installation, please refer to the appropriate Schneider Electric PMD installation guide.

Grounded meters vs. ungrounded meters

The “protective class I” PMDs have a dedicated Protective Earth (PE) terminal, which must be properly bonded to the protective earth (ground) conductor in the installation in order to ensure that the meter is electrically safe. A Protective Earth (ground) terminal is marked with this symbol (IEC 60417-5019):

User accessible parts of such devices can be considered Protective Extra Low Voltage (PELV) circuits. The IEC 61140 defines a PELV system as an electrical system in which the voltage cannot exceed safe voltage levels under normal conditions, and under single-fault conditions, except earth faults in other circuits.

The “protective class II” PMDs do not have such PE terminal and they need not be connected to the protective earth (ground) conductor. Instead, the “protective class II” PMDs rely on double or reinforced insulation to provide protection against electric shock. Devices with this type of protection are marked with this symbol (IEC 60417-5172):

User accessible parts of such devices can be considered Separated (or Safety) Extra Low Voltage (SELV) circuits. IEC 61140 defines a SELV system as an electrical system in which the voltage cannot exceed safe voltage levels under normal conditions, and under single-fault conditions, including earth faults in other circuits.

Both types of construction provide sufficient protection against electric shock and are considered equally safe.

The “protective class II” PMDs may be equipped with a functional earth (ground) terminal, but this terminal must be properly isolated, using double or reinforced insulation, from any hazardous live voltages within the device. Functional earth terminals are marked with these symbols (IEC 60417-5017, IEC 60417-5018):

While the safety of “protective class II” PMDs does not depend on the presence of functional earth (ground) connection, such connections may help to eliminate phantom voltage readings on the PMD high impedance voltage inputs.

On the other hand, the presence of a functional earth (ground) connection may decrease the insulation resistance afforded by the PMD, which may not be acceptable in some installations.

The functional or protective earth (ground) connection can lower the immunity of PMDs to common mode electromagnetic disturbances, or to earth (ground) potential differences that may develop between the local PMD earth (ground) connection and the remote end of the communication cables.

For “protective class II” PMDs the connection (bonding) to a low impedance protective earthing (grounding) system in the installation is not required in order to guarantee meter electrical safety.

Meters with non-isolated neutral voltage terminal

According to international electrical safety standards such as IEC61010-1, IEC62052-31, IEC60255-27 and IEC61557-12, the neutral conductor shall be considered as hazardous live, the same as the “hot” phase conductors.

Some PMDs may be constructed with a non-isolated neutral voltage terminal. In this type of design, the neutral voltage is directly connected to the meter internal reference plane, without protective impedance or any other type of isolation. These types of PMDs do not exhibit phantom voltage readings as long as there is no significant voltage present on the neutral conductor, but can be more susceptible to electromagnetic disturbances that may be present on the neutral conductor.

The construction with non-isolated neutral can be easily applied only to simple PMDs without any user accessible conductive parts or communication ports, or to PMDs rated for voltages below 300V. With higher voltages and more complex designs with multiple communication ports and other accessible conductive parts, it is easier and much more economical to use construction with an isolated neutral voltage input (terminal).

Only some older Schneider Electric PMDs have non-isolated neutral voltage terminals.

All newer Schneider Electric PMDs have isolated (impedance-protected) neutral voltage terminals.

Analysis

In order to provide a better understanding of the origin and meaning of the phantom voltages on the PMD terminals, we have conducted SPICE circuit simulations and provided an explanation of the root cause and conditions in which phantom voltages may be observed on PMD inputs.

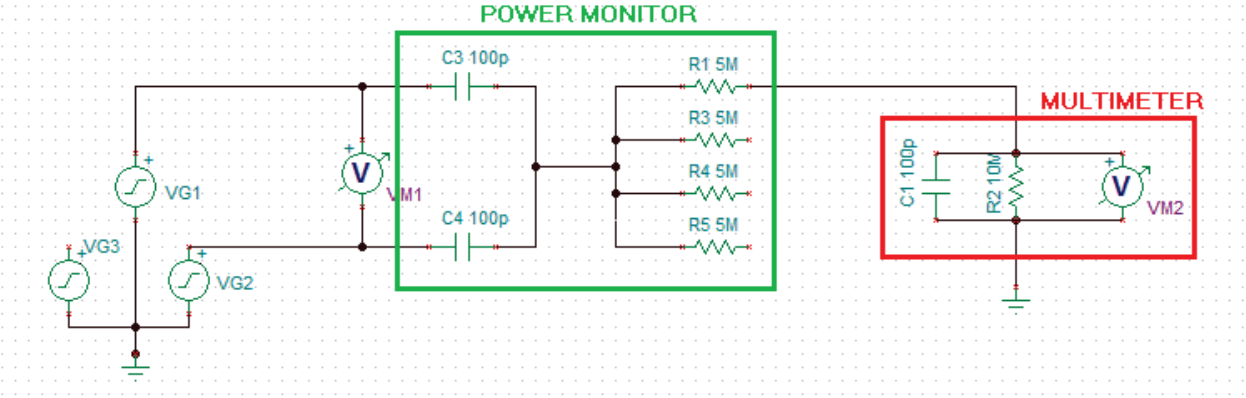
Use Case 1

A Power Monitor registers phantom voltage readings when control power is applied, but none of the voltage measurement inputs are connected to the phase voltages.

Conditions:

- Control (auxiliary) power terminals are connected.
- The voltage measurement terminals of the PMD are not connected.
- A protective class II PMD is ungrounded (i.e. there is no functional earth (ground), or if a functional earth (ground) terminal exists, it remains unconnected).
- The voltage on the PMD voltage measurement terminals is measured with respect to earth (ground) using a digital multimeter with high input impedance.

The simulation circuit below represents a PMD with 5MΩ voltage input impedance (a typical value for Power Logic devices). The control power is connected to a 230VAC, 50Hz source. The capacitance between the primary and secondary side of the power supply is modeled with a 100pF capacitor. The value of this capacitance can vary for different PMDs. A digital multimeter with high input impedance of min. 10MΩ and input capacitance of max. 100pF (typical values found in many digital multimeters) is connected between the PMD voltage input terminal (any phase) and earth (ground).



The results of the simulation show that the high impedance digital multimeter will measure approximately 27VAC under these conditions. In reality this voltage will vary for different PMDs between approximately 26VAC - 33VAC depending on the capacitive coupling across the power supply transformer, auxiliary supply voltage, frequency, etc. There will be no dangerous current flow between the high voltage control power source and the voltage input terminal where the measurement is performed. The protection against electric shock is afforded by the reinforced insulation in the power supply of the PMD, and protective impedances in the voltage measurement inputs.

Use Case 2

A Power Monitor registers phantom voltage readings when control power is applied and one of the voltage measurement inputs is not connected to the phase voltages. The remaining measurement inputs are connected.

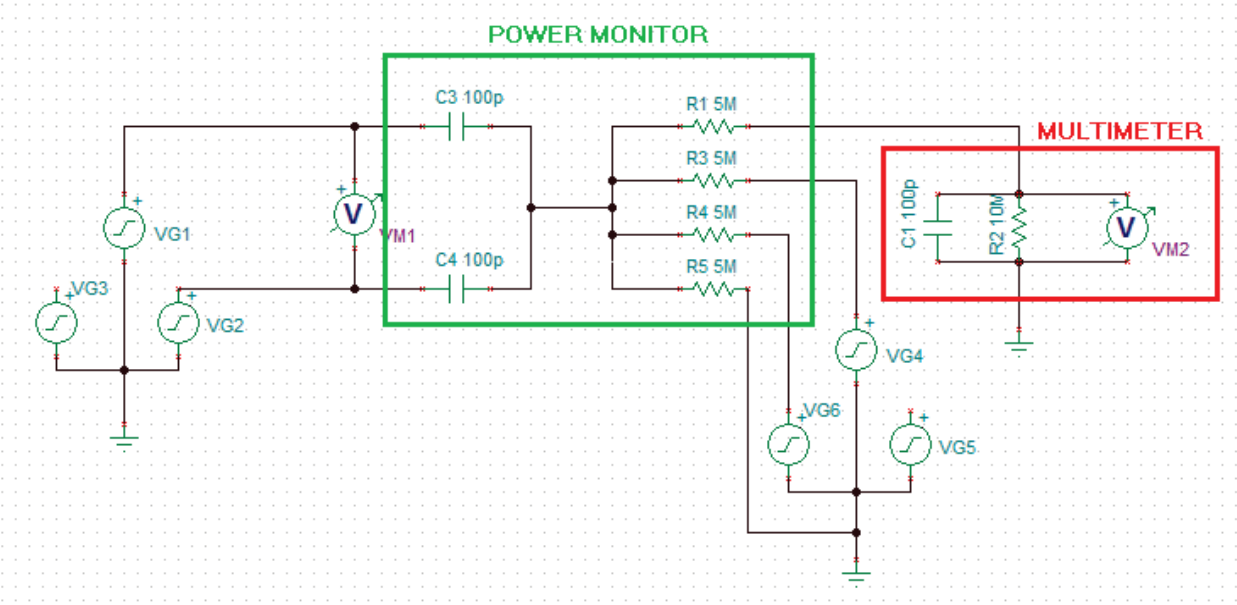
Conditions:

- Control (auxiliary) power terminals are connected.

- The voltage measurement terminals of the PMD are connected, except for one.
- A protective class II PMD is ungrounded (i.e. there is no functional earth (ground), or if a functional earth (ground) terminal exists, it remains unconnected).
- The voltage on the unconnected voltage measurement terminals is measured with respect to earth (ground) using a digital multimeter with high input impedance.

The simulation is similar to the previous one, but with additional voltage sources connected to model the measured phase voltages.

The digital multimeter will now read a higher phantom voltage as the voltages connected to the voltage measurement terminals will increase the potential of the internal meter reference plane with respect to earth. However there will be no flow of dangerous current through the unconnected voltage measurement terminal due to high impedances present in all voltage measurement terminals. According to the international safety standards these impedances have been qualified as protective impedances by independent safety testing laboratories.



The observed and simulated phantom voltages are the result of coupling of the control (auxiliary) power voltage through the internal capacitance in the power supply, and sometimes also coupling of the phase voltages through the high impedances of the voltage measurement inputs. When a digital multimeter is used to perform the measurement on the unconnected voltage input, the multimeter's high impedance forms a voltage divider with the internal impedances in the PMD, exposing phantom voltages. These phantom voltages are normal artifacts of the design and should not pose any safety concerns to the end user.

Once the voltage inputs of the PMD are connected to the external circuits, the phantom voltage readings should disappear, and the PMD should read zero voltage when these external circuits are not energized.

The phantom voltage reading on unconnected PMD voltage inputs may be eliminated by using low impedance measuring devices, such as digital multimeters with a low impedance input (e.g. Fluke 711 or Fluke 289).

Conclusion

In some installations protective class II PMDs without functional earth (ground) connections may exhibit phantom voltage readings on unconnected voltage inputs. These phantom voltages are normal artifacts of the design; they do not pose an electric shock hazard, and should not raise any safety concerns.

However, care must be taken to ensure that the observed voltage reading is in fact a phantom voltage, and is not a hazardous voltage. Digital multimeters (such as Fluke 117 or Fluke 289) with low impedance measurement mode (“Volt –LoZ” mode) should be used to eliminate the phantom voltage reading.

NFPA 70E safe electrical work practices should be observed: before working on the equipment the absence of power should always be verified with a properly rated voltage sensing device. A proper Lockout / Tagout procedures should be followed. According to NEMA recommendations, a low impedance measuring device should be used where phantom voltages may be present.

All PowerLogic power monitors comply with the requirements of the latest editions of the IEC/EN 61010-1, UL61010-1, and CAN/CSA C22.2 No. 61010-1 safety standards, and have been certified by independent, internationally recognized and accredited product safety testing laboratories.

Even if occasional phantom voltages are observed on the PMD’s high-impedance voltage inputs, they pose no risk to end user safety or proper PMD operation, when the PMD is installed according to the manufacturer’s instructions and according to the requirements of local electrical codes.

Sources

[1] NEMA Engineering Department Bulletin No. 88 October 1998, reviser Feb 2003, reaffirmed Dec 2011.

[2] Ghost voltages – phantom readings can lead to the wrong diagnosis, Fluke Application Note, 2003 Fluke Corporation.

[3] Electrical testing safety: Is it a backfed or induced voltage?, Jim White, Shermco Industries, Inc, Reliable Plant web site.

