HOW VOLTAGE INDICATORS WORK
APPLICATION NOTE

This document relates to the following PESD® family of voltage indicators:
R-3W2, R-3W, R-3W-SR, R-3MT-VI, R-3F2-LXX, R-3D2-XX

Introduction

Keeping personnel away from live voltage is foundational to electrical safety. Electrical safety demands a precise answer to the question, “Is voltage present?”. Voltage indicator Permanent Electrical Safety Devices® (PESDs) go a long way in providing the very first answer to this question, while a portable test instrument provides personnel with a second, redundant answer.

The ability to look at an electrical panel with a voltage indicator installed provides visibility of voltage from outside the enclosure without exposing personnel to the hazard. Not surprisingly, those using PESDs® on their equipment have found this concept embraced by safety, electrical, and maintenance people at all levels of influence.

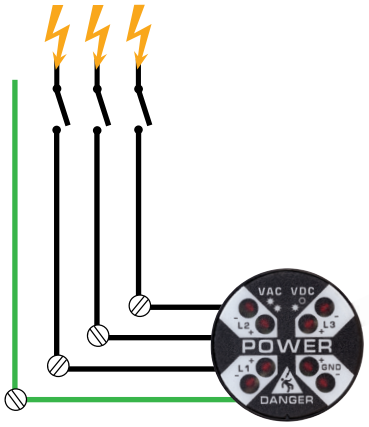

Figure 1: Typical Wiring Diagram.

Understanding how voltage indicators function helps clarify many application questions that arise when applying this device into any type of power system. Most examples will use a 480 VAC 3-Phase system *(Fig. 1)*.

Voltage Indicator Functionality

A voltage indicator uses a high impedance voltage detection circuit per phase to sense and illuminate AC/DC voltage. The illumination of the LEDs occurs only when current passes through two of these voltage detection circuits. Envision four voltage detection circuits (L1, L2, L3, GND) “meeting” each other in the center of the voltage indicator. The amount of the current that flows through the voltage detection circuit depends upon the phase and ground voltages, which allows for multiple current paths passing through at least four LEDs. Each voltage detection circuit has two LEDs; one LED illuminates when the AC sine wave is positive and the other LED illuminates when the AC sine wave is negative *(Fig. 2)*. For an LED to illuminate, current must pass through two of the voltage detection circuits, which causes four LEDs to illuminate. “Voltage when illuminated” means that if only one of the four LEDs illuminates, it still provides voltage indication to the worker. For DC systems only, one LED per voltage detection circuit will illuminate. When balanced voltages exist on each phase, the current flowing through each phase circuit is also equal *(Fig. 3)*.

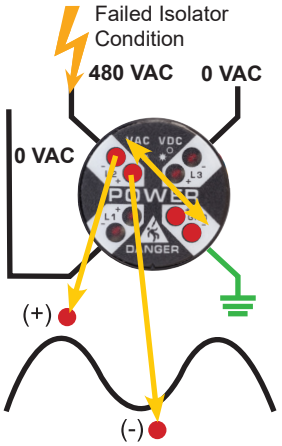

Figure 2: Two LEDs illuminate on the top and bottom of the sine wave. One LED per leg illuminates for DC.

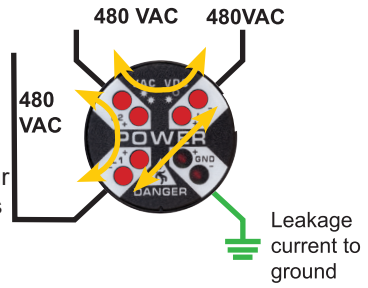

Figure 3: Balanced voltage; No illumination on GND LEDs.

Because these currents are shared equally between the phases, in this case no current flows to ground and therefore the GND LEDs are not illuminated. This is the normal operating mode for most voltage indicator installations, and for large voltage indicator installations (50+ units), this means that the accumulation of ground currents will not adversely affect ground fault detection systems. With the LEDs off, the nominal leakage current of 60µA has a negligible impact on the overall ground current to the electrical system.

When a voltage imbalance between phases exists, the GND LEDs will illuminate *(Fig. 4)*. Under this condition, the current flow to ground is proportional to the percent of voltage imbalance as calculated below:
V1: Voltage L1
V2: Voltage L2
V3: Voltage L3

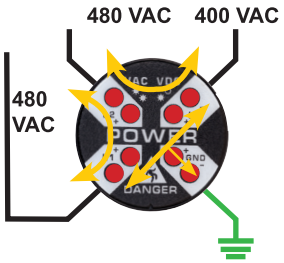

Figure 4: Unbalanced Voltage.

VX: Largest difference either L1, L2 or L3 AV:
Average Voltage: (V1+V2+V3)/3 (480+480+400)/3=453
Percent Unbalance: (AV-VX)/AV (453-400)/453=11%

With an imbalance less than 1%, the GND LEDs remain off. Somewhere between 1% and 15% the GND LEDs start becoming visible (around 60µA) and become fully illuminated above 15%. Under a single phasing condition, the maximum current flow in the ground leg is 600µA at 480 VAC *(Fig 2)*. With a phase loss condition, the current flow in GND is approximately 193µA. An electrically noisy environment also causes the GND LEDs to illuminate by inducing voltages at various frequencies into the ground leg. The GND LEDs will almost always be on when

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voltage indicators are installed in close proximity to energized drives or high-powered solid-state devices.

High Resistance Ground (HRG) System

HRG systems limit the current flow from a ground fault somewhere in the electrical system through a grounding resistor connected to the transformer neutral. In many cases, the current flow in the ground system illuminates the GND LEDs *(Fig. 5)*. However, other factors also cause the GND LEDs to illuminate, so when a voltage indicator is installed on a HRG system, illuminated LEDs do not necessarily mean a ground fault exists in the system.

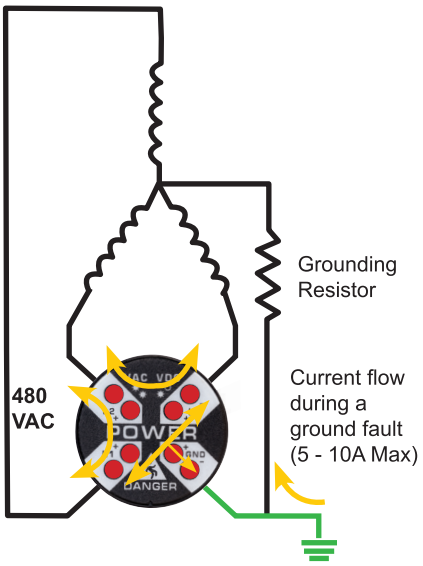

Figure 5: A high resitance ground system limits current due to a ground fault. The current flow in the ground conductor may or may not cause the GND LEDs to illuminate.

Ungrounded Systems

A voltage indicator has reduced functionality when installed into an ungrounded or floating power system. Because only a capacitive connection and no hardwired connection exists between ground and the incoming transformer, the voltage indicator will not be able to detect a single-phase isolator failure (*Fig. 6)*. There may be cases where enough capacitive coupling exists to provide a ground connection for the voltage indicator to function normally (see comments below for verifying the ground connection).

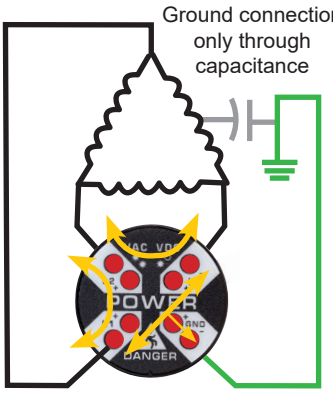

Figure 6: An ungrounded floating delta makes only a capacitively coupled ground connection to the voltage indicator and will not be able to detect a failed isolator (single-phase).

A Safe Ground Reference Point Required

LED illumination means that voltage exists. Voltage does not discriminate, so neither does a voltage indicator. A safe ground reference for the GND leg of the voltage indicator ensures that the LEDs illuminate in an isolator failure or single-phase condition occurs *(Fig. 2 & 7)*. Without a ground connection, there would be no path to complete the LED illumination circuit. If the GND LEDs do not illuminate after installation, pulling a fuse or disconnecting one voltage indicator lead wire should allow current flow to ground thereby testing the integrity of the ground connection.

About Voltage Indicator PESDs®

Voltage indicators are self-powered, UL listed, and permanently installed devices that visually alerts the presence of voltage with flashing or non-flashing, redundant LED indication lights. Typically hardwired to the load side of an electrical feeder or a disconnect switch, voltage indicators illuminate whenever hazardous voltage is present in any individual phase and can assist in verifying voltage presence in addition to OSHA's requirements in 29 CFR 1910.147.

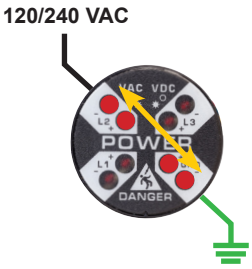

Figure 7: Single-phase voltage indicator application requires current flow to ground thereby always illuminating the GND LEDs.

In addition to our line of voltage indicators, the ChekVolt® PESD offers voltage presence indication and absence of voltage test points. This combination of technology offers all the benefits of the voltage indicators with the ability for a qualified person to complete an absence of voltage test using a properly rated portable test instrument; all without opening the enclosure.

For more information checkout our Frequently Asked Question section by visiting www.pesd.com or by scanning the QR Code to the right.

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