Safer Lock-out Tag-out with Permanent Electrical Safety Devices

Electrically Safe Work Conditions Based Upon NFPA 70E and OSHA

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Abstract – Article 120.1 of the NFPA 70E establishes the procedure for creating an electrically safe work condition. Since this was written, the day-to-day practice of electrical safety has changed and goes beyond the precise language of Article 120.1(1-6). This is due to the increased usage of permanent electrical safety devices (PESDs) in Lock-out/Tag-out procedures (LOTO). The relatively new concept of permanent electrical safety devices actually improves the workers' ability to safely isolate electrical energy beyond that which was originally conceived when Article 120 was written. PESDs go beyond the high standard, yet they still adhere to the core principles found in Article 120.1. With PESDs incorporated into safety procedures, installed correctly into electrical enclosures, and validated before and after each use, workers can transition the once-risky endeavor of verifying voltage into a less precarious undertaking that never exposes them to voltage. Since every electrical incident has one required ingredient – voltage - electrical safety is radically improved by eliminating exposure to voltage while still validating zero energy from outside the panel.

Index Terms - Voltage detectors, voltage portals, non-contact voltage detector, NCVD, power warning alerts, permanent electrical safety devices, voltage detector validation procedures, verification, voltmeters

Introduction - To employees all safety – especially electrical safety – is personal. Little else matters to them unless electrically safe work conditions can be created and maintained through their work environment. Article 120.1 of the NFPA 70E was, as its title suggests, penned with the important purpose of establishing the "gold standard" for creating an electrically safe work condition. Since then, however, innovation in the realm of electrical safety has surpassed the precise language of Article 120.1(1-6) because it fails to speak directly to the value permanent electrical safety devices have in achieving an electrically safe work environment. The relatively new concept of permanent electrical safety devices (PESDs) actually improves the workers' ability to safely isolate electrical energy beyond that which was originally conceived when Article 120 was written.

The forward-thinking concept of PESDs goes beyond the high standard of safety for which competent companies strive, yet it still adheres to the core principles found in Article 120.1. With PESDs incorporated into safety procedures, installed correctly into electrical enclosures, and validated before and after each use, workers can transition the once-risky endeavor of verifying voltage into a less precarious undertaking that never exposes them to voltage. Let's face it; every electrical incident has one required ingredient – voltage. Electrical safety is radically improved by eliminating exposure to voltage while still validating zero energy from outside the panel.

Time-Tested Practices: The Foundation for Safety Improvements - The standard shoulder belt you (hopefully) use each time you are in a vehicle is an improvement on a simple lap belt found in many vehicles of the past. American car manufacturers offered seat belts only as options until Saab introduced them in 1958 as a standard safety element – an act that changed the landscape of passenger safety in vehicles. Later, driver- and passenger-side air bags offered breakthrough safety advances beyond the then-simplistic seatbelt only to later be enhanced by side-impact air bags. Each of these safety innovations relies upon each other for peak functionality and surpassed conventional safety protocols of 1958. Air bags provide little protection if drivers are not wearing seatbelts; shoulder belts without lap belts are ineffective, and side air bags alone are insufficient. These safety reformations, when used in conjunction with each other, raised the expectations of safety for all users and ultimately manufacturers began offering them as standard equipment. Similarly, PESDs are revolutionizing electrical safety and should be used in conjunction with existing safety practices.

Definitions and Resources[1]

Non-Contact Voltage Detector (NCVD) - A battery operated voltage detector that senses voltage without actually touching an energized conductor.

Voltage Portal - Extends a voltage source to the outside of an electrical enclosure in an encapsulated non-conductive housing designed for a NCVD to sense voltage if placed into the voltage portal (Fig. 1).

Voltage Indicator - A hardwired LED indicator permanently wired to the phase(s) and ground that illuminates when a 40VAC/30VDC or greater voltage deferential exists between two lone inputs. Typical 3-phase/4-wire voltage indicator requirements include (Fig. 2):

- Powered from the line voltage (no batteries)
- Applies to any power system by operating on a wide voltage range (40-750VAC/30-1000VDC)
- Cat IV rated for high surge immunity
- UL Certified to UL 61010-1 as per NFPA 70E 120.1(5) FPN
- Written Procedures and Training: Using PESDs in an electrical safety program requires written Lock-out/Tag-out (LOTO) procedures. Employees need to be trained and have access to these procedures.[2]

Validating a Voltage Detector - Creating an electrically safe work condition depends upon a process that ensures 100% accuracy from voltage detectors. To help ensure this, the NFPA 70E says, “Before and after each test, determine that the voltage detector is operating satisfactorily,” (NFPA 70E 120.1(5). Validation means that electricians first check their voltage detector to an independent voltage source (i.e. a nearby 120VAC outlet). Next, they check for zero voltage on the primary source.

The Voltage Portal:

Extends voltage to the outside of an enclosure into an encapsulated non-conductive housing.

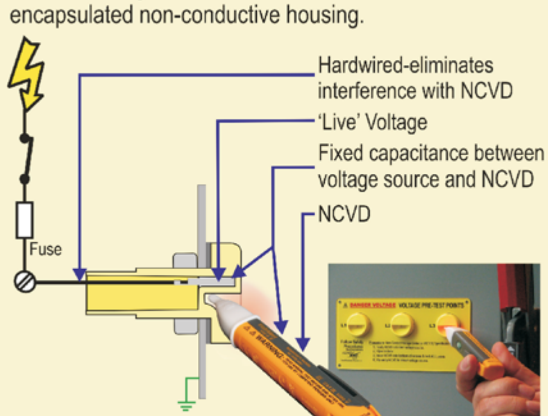

Fig. 1
Cut-away view of a typical voltage portal

Work begins only after the voltage detector is rechecked to the independent live voltage source. This straight-forward validation procedure works for a portable voltage detector because it can be physically moved between two voltage sources. Because of this, perhaps the authors of NFPA 70E only considered portable voltage detectors (i.e. voltmeters), not PESDs, when writing Article 120.1? Over the past several years, PESDs have become a way for Fortune 500 companies to increase safety and productivity simultaneously. Weyerhaeuser started using voltage indicators (a PESD) in 2004 and that quickly spread to other facilities. Warren Hopper, Manufacturing Services Manager Weyerhaeuser stated, “Use of the fixed voltage

The Voltage Indicator:

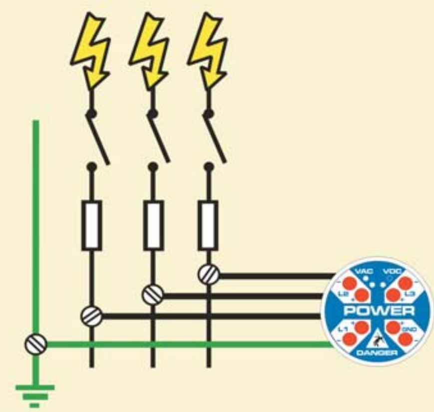

Fig. 2
Voltage indicator wiring diagram

indicators would allow us to avoid opening starter or disconnect compartment doors for approximately three quarters of all lockouts.”[3] The same principles absolutely apply to PESDs. However, because a PESD cannot be moved between two voltage sources, the technique for validation needs a slightly different approach.

So what actually needs to happen to validate a voltage detector? Testing for voltage simply requires a small amount of current to flow between the two voltage potentials. The voltage detector circuit determines a voltage potential by relating this current flow to actual voltage and providing the worker an appropriate indication (audible, visual or digital display).

Validating a Voltage Portal & NCVD Combination - A NCVD determines whether or not voltage exists in a conductor by creating a low current capacitive circuit between the conductor, the NCVD, the worker, and ground (Fig. 3). Therefore, when the NCVD is positioned close to a live conductor this completed circuit causes the NCVD to beep or flash telling the worker that voltage exists in the conductor. Because voltage portals mount permanently to the outside of enclosures, the worker has to stand in the same place when using his NCVD. This makes this capacitive circuit more reliable and more repeatable than it would be when workers use a NCVD in all other applications.[4] Since NCVDs are portable, they can also be checked to an independent voltage source as per NFPA 70E 120.1(5).

Minimum Requirement for a Voltage Indicator - A voltage indicator is hardwired to the 3-phase disconnect and earth ground (FIG 2). The circuit illuminates LEDs when AC/DC voltage exists between any two phase(s) and(or) ground. Since voltages above 50 volts are deemed unsafe by NFPA 70E,[5] it is imperative that the LEDs on a voltage indicator illuminate for all voltages above 50 volts. Perhaps, the most compelling characteristic of a voltage indicator is the wide operating characteristics (40-750AC/30-1000VDC). This feature separates it from other devices, like a pilot light, for example, that would quickly fail if the voltage exceeded its normal operating range (i.e. 120VAC +/- 10%).

Validating a Voltage Indicator - A hardwired voltage indicator brings up three interesting issues. First, it is impractical to verify the voltage indicator to another independent voltage source. Trying to accomplish this by adding a switch to toggle between the line voltage and the test voltage adds more components and complexity and leads to unreliability.[6] Second, since the voltage indicator's sole purpose is to indicate voltage, anything installed between the source voltage and the voltage indicator increases the chance of a false negative voltage reading - switches, relays and fuses included.[7] Third, because of the three phase circuit design, a voltage indicator accommodates multiple current paths between phase(s) and ground, thereby reducing the number of possible failure modes.[8] In one possible circuit design, before a single LED illuminates, the current must pass through at least four LED flashing circuits. "Voltage when illuminated" means if only one of the four LEDs illuminates, it still provides voltage indication to the worker.

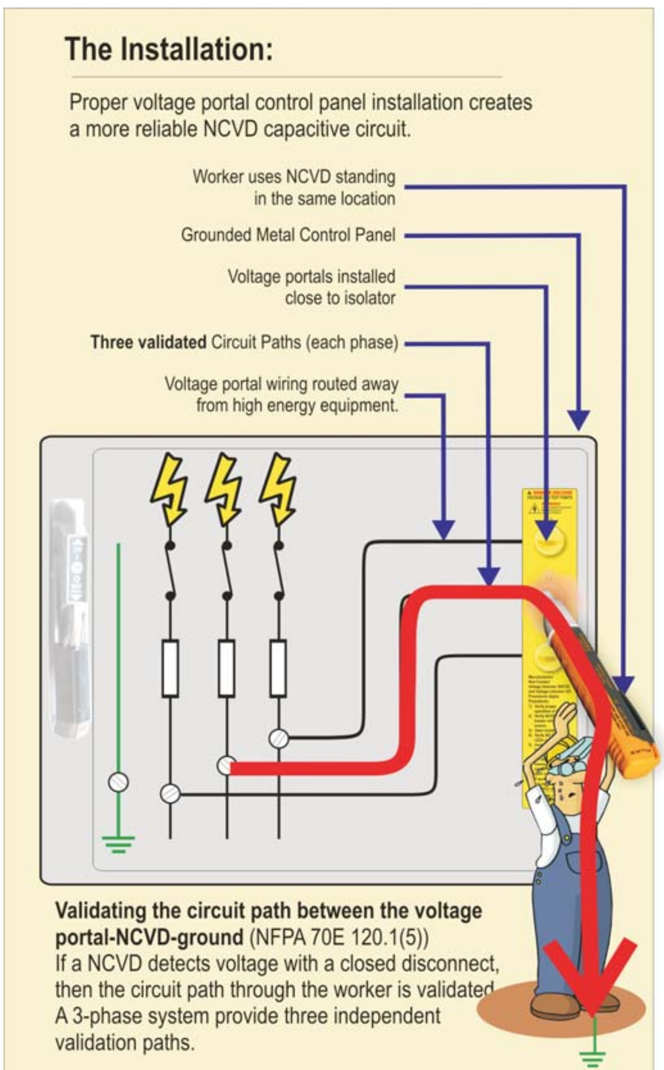

Fig. 3 Proper voltage portal installation improves reliability of NCVD operation

Multi-meters Compared to PESDs - Creating electrically safe work conditions relied soley upon the portable multi-meter before PESDs came along. This tool is not only used in electrical safety, but has features making it invaluable for other purposes such as electrical troubleshooting and diagnostics. Additionally, a PESD leaves no question or confusion when a worker uses it in creating an electrical safe work condition because it was designed, built, and installed for a single purpose - voltage indication for electrical safety. Understanding these differences helps determine an acceptable validation procedure for PESDs.

Voltage indicators and voltage portals have unique strengths and complementary characteristics, and when used together they meet the validation requirements of NFPA 70E 120.1. The traditional method of validating the voltage detector to an independent voltage source is met with the NCVD/voltage portal combination. On the other hand, it can be argued that a voltage indicator by itself cannot be validated by the traditional method. However, because permanently-mounted voltage detectors are designed to only detect voltage, the built-in advantages over a simple multi-meter needs to also be considered in validating this device (Fig. 5).

Written LOTO Procedures & Mechanical LOTO - A PESD only becomes a real safety device only after it is included as part of a written LOTO procedure. Without this, PESDs are nothing more than just another electrical component. The LOTO procedure must explain to the worker each step in the LOTO procedure that involves the PESD. At a minimum, workers will need to verify proper operation of the PESD before and after performing a LOTO procedure.

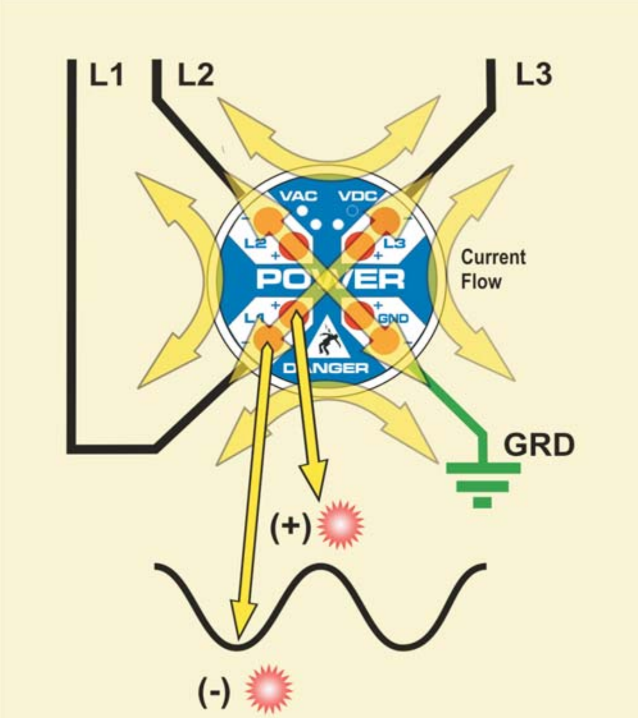

Fig. 4
Current flowing through four voltage detector circuits 'meet each other' in the center of the circuit.

Six current 'validation' current paths exist through a voltage indicator circuitry.

Current must pass through two voltage detection which illuminates four LEDs.

LEDs illuminate on the (+) and (-) part of the sine wave.

Interestingly, the mechanical maintenance workers receive a huge benefit with PESDs when these devices are used in mechanical LOTO procedures. Workers performing mechanical LOTO (work involving no contact with conductors or circuit parts) procedures must still isolate electrical energy. PESDs provide a means of checking voltage inside an electrical panel without exposure to that same voltage. Without these devices, a mechanic performing mechanical LOTO would be required to work in tandem with an electrician using a voltmeter to physically verify zero voltage inside an electrical panel before work begins. In this case, the electrician is exposed to voltage. With PESDs, the mechanic can single-handedly check for zero electrical energy without any exposure to voltage, thereby making the LOTO procedure safer and more productive.

This is exactly how a western Pennsylvania power plant increased both the safety and efficiency of their operators. Operators were able to perform more maintenance tasks during off-shift hours by installing voltage portals into each motor control center bucket, rewriting their LOTO procedure, and training the operators to use NCVD detectors with voltage portals. In the past, even a simple maintenance task like replacing a broken fan belt was side-barred until the first-shift electrician arrived to lock-out the electrical energy feeding the fan motor. In the end, both electricians and operators became more productive and still complied with OSHA LOTO requirements.[9]

Reduced Arc Flash Risk and Personal Protective Equipment - An electrical safety program is safer when workers can determine a zero electrical energy state without any voltage exposure to themselves. Verifying the proper operation of a meter and testing for absence of voltage before working on electrical conductors (test-before-touch) must remain a habitual practice for workers. The goal of PESDs is to ensure when workers test-before-touch they test only dead conductors. Therefore, after completing a hazard risk analysis (NFPA70E Annex F) on the installation and PESDs written into this procedure, users may conclude this task may be done without special PPE. Without PESDs, a failure of an isolator may go undetected until the electrician discovers live voltage after opening the panel. This exact scenario is a common cause of arc flash. A direct short circuit may result from one misstep by the electrician while checking voltage. Even worse yet, the electrician would take a direct hit in the face from the resulting arc flash. Because PESDs meet NFPA 70E 120.1 and the lessened risk of voltage exposure, some will conclude that the need for personal protection equipment (PPE) is reduced once the panel is open. Whether or not you agree with this, voltage detectors are a low-cost, redundant voltage verification tool that reduces arc flash risk, increases safety, and adds productivity for an installed cost of $150.

Conclusion - Safety is an evolution based on best work practices and innovation. High safety standards not only create safer workplaces, but also encourage safety innovations. Ultimately, safety standards must be rigid enough to garner the highest level of safety while still being flexible enough allowing for advances through innovation to be incorporated while still adhering to the principles of Article 120.1. Now, thinking outside the panel doesn't leave you boxed in.

About the Author - Phil Allen is the President and owner of

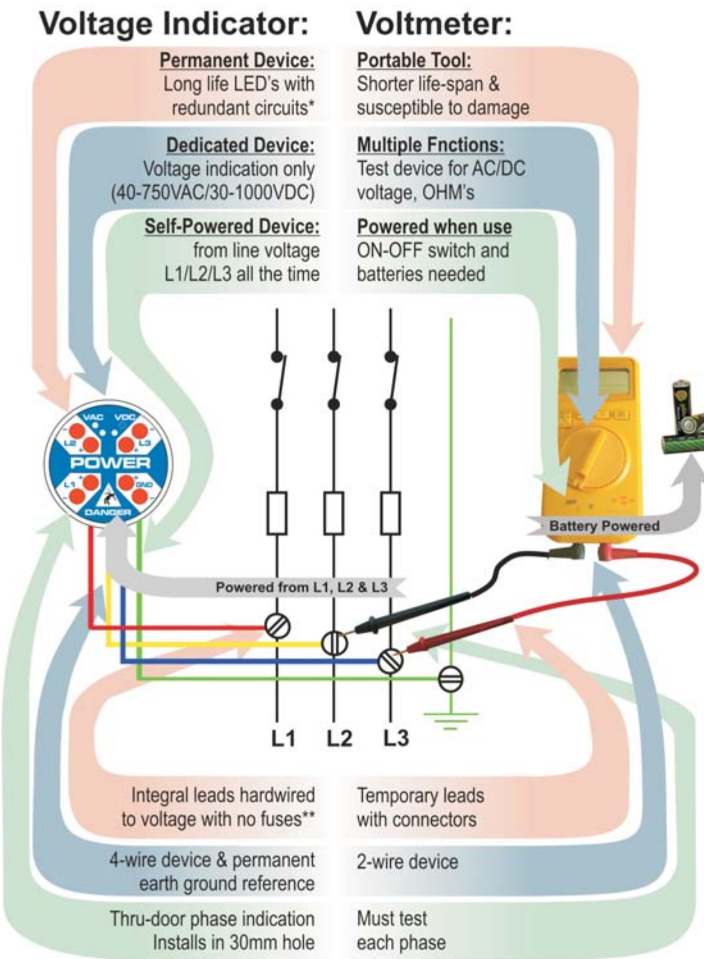

Fig. 5 Voltage indicator to voltmeter comparison.

Fig. 6 Installation of a voltages indicator and voltage portals on a typical 3-phase panel.

Grace Engineered Products, the leading innovator of permanent electrical safety devices. He holds two US Patents, a power receptacle design and a voltage detector test circuit. His passion is finding new and more efficient ways of bringing electrical safety to the forefront. Phil did his undergraduate work at California State University, San Luis Obispo and is a 1984 graduate with a BSIE.

Grace Engineered Products is a member of the Rockwell Encompass Partner program, and is best known for its GracePort® line of custom-made data port interfaces. In addition to the GracePort® line, the company provides a well-established line of products – ChekVolt® and VoltageVision® - that make pre-verifying electrical isolation through enclosure doors safe and easy. Their focus is on NFPA 70E guidelines and making companies electrically safe while also increasing their employee productivity.

Footnotes & References

(1) For more reference information please see http://graceport.com/thru_door.cfm
(2) OSHA 29 CFR 1910.147, 1910,333(b) NFPA 70E 120.2(B)(2), 120.2(C)(1)
(3) One Mill's Response to a Specific Type of Arc Flash Problem, Warren S. Hopper, PE, Senior Member, IEEE, Weyerhaeuser Company, Springfield, OR
(4) For more info, see Voltage Portals Improve Non-Contact Voltage Detectors paper http://www.graceport.com/assets/files/Application%20Notes/Application_VoltagePortals%20Improve%20NCVD.pdf
(5) NFPA 70E 110.6(D)(1)(b), 110.7(E)
(6) This is impractical because it requires a 600V fused three -pole double throw relay. The fusing, the relay wiring, and switching introduces 18 connections (failure points) between the voltage source and the voltage indicator.
(7) False-Negative: When voltage exists in a conductor and the voltage detector does not sense it.
(8) This design has four voltage detection circuits (L1, L2, L3, GRD) with two LED flashing circuits each. Therefore a current path between two phases passes through at least four LED flashing circuits. For more information, see: http://graceport.com/assets/files/Application%20Notes/How%20does%20it%20work%204page.pdf
(9) OSHA 1910.147