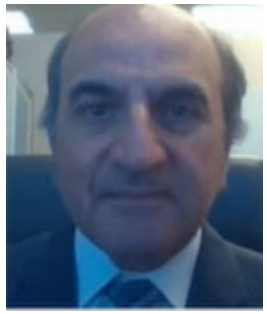
GARD

Unparalleled Protection

Technical Webinar Series 2021

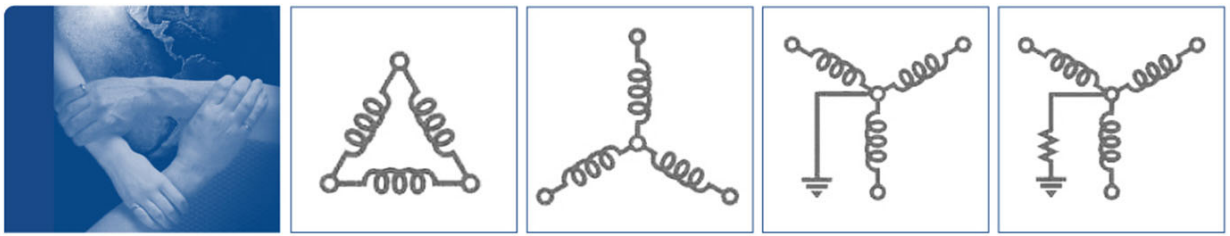
"Absence of Voltage Testing"



Presented by: **Sergio Panetta**

Vice President of Engineering, I-Gard Corporation

> www.i-gard.com



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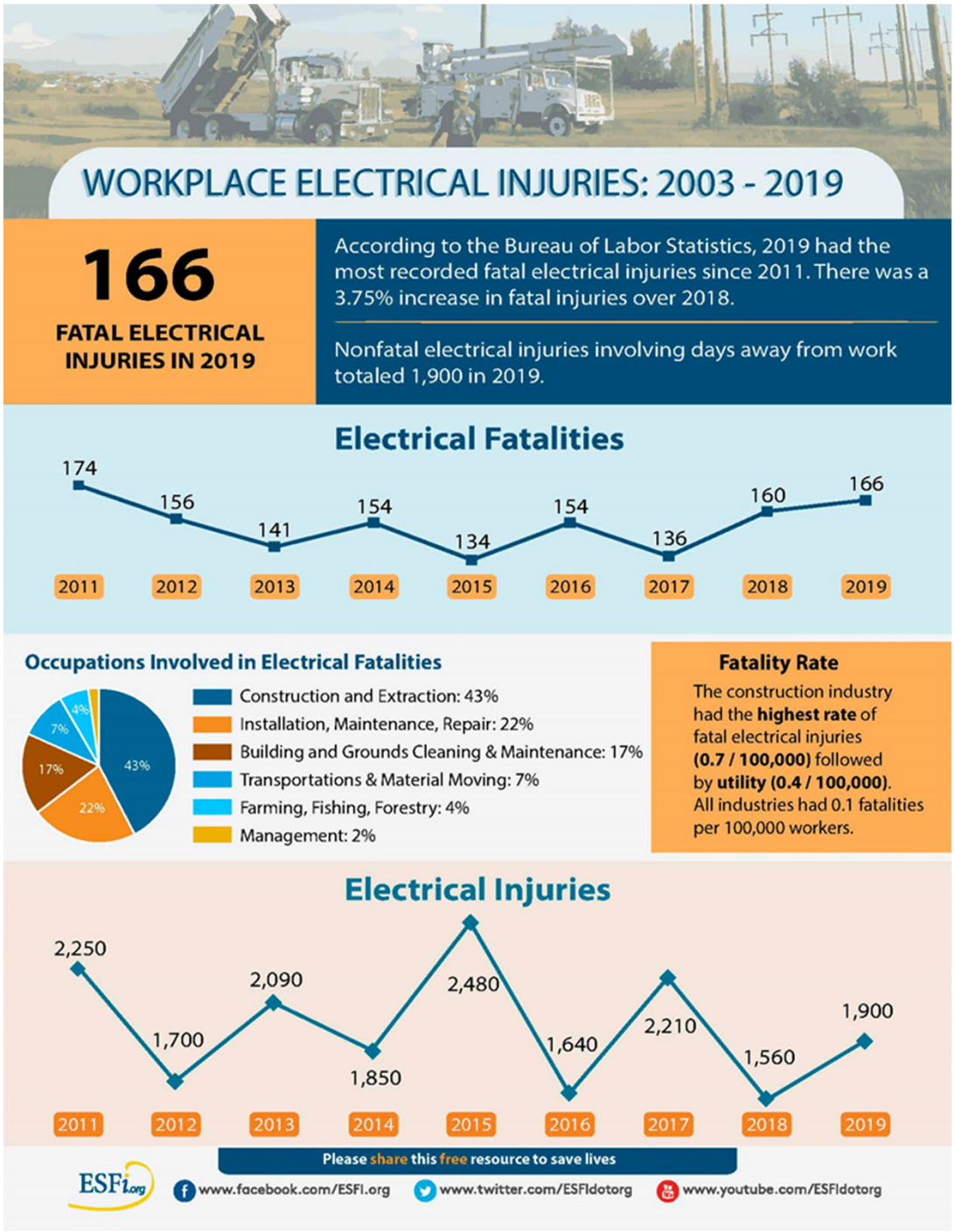
De-energizing equipment, following prescribed lockout / tagout procedures and verifying the absence of voltage are key components to establishing an electrically safe work condition.

Despite awareness campaigns, increases in safety programs including designating May as Electrical Safety Month, the rate of electrical injuries and fatalities is almost unchanged over the past 10 years.

Something needs to change.



NFPA 70E, Article 120.5

120.5 Process for Establishing and Verifying an Electrically Safe Work Condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

(1)Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.

(2) After properly interrupting the load current, open the disconnecting device(s) for each source.

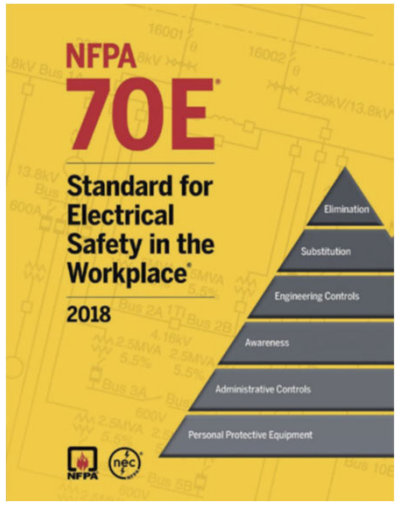
(3) Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that draw out-type circuit breakers are withdrawn to the test or fully disconnected position.

(4) Release stored electrical energy.

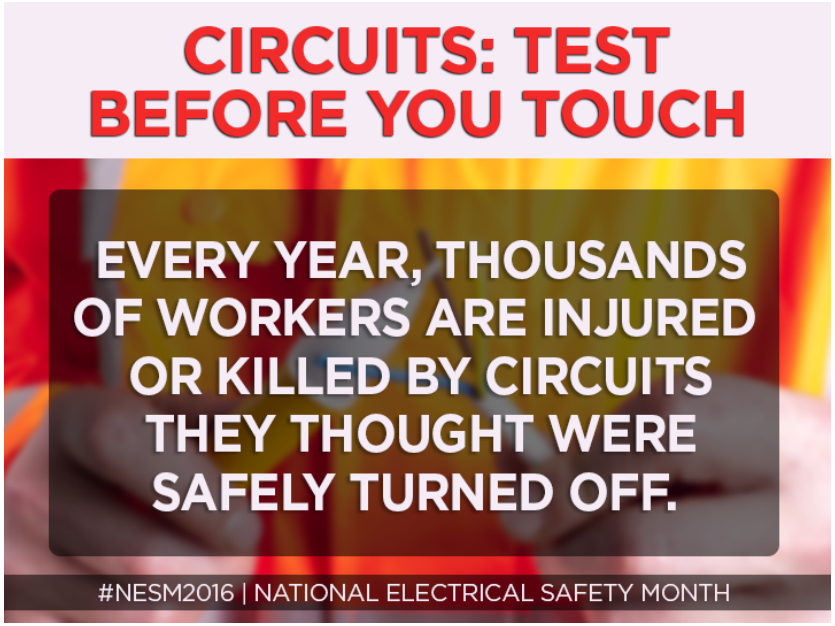
(5) Block or relieve stored nonelectrical energy in devices to the extent the circuit parts cannot be unintentionally energized by such devices.

(6) Apply lockout/tagout devices in accordance with a documented and established procedure.

(7) Use an adequately rated portable test instrument to test each phase conductor or circuit part to test for the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.



Traditional Approach Test Before Touch”” (TBT).



Key Principles IEEE 2006 PCIC DuPont Presentation

- **Consider All Circuits Energized Until Tested**
- **Test EVERY Conductor To Be Touched**
- **PPE Is Required Until Test is Completed**
- **Test Instrument Must Be Verified**
- **Knowledge of Equipment Is Essential**
- **Test Circuit Again If Job Continuity Is Broken**
- **Testing Must Be Done At Each Location Where Conductors Are Going To Be Touched**

Traditional Approach Test Before Touch”” (TBT).

- Arrange Barriers Around Equipment to be Tested
- De-energize Electrical Equipment
- Apply Locks / Tags as per LOTO Instructions
- Select, inspect and put on PPE
- Select and Test the Tester on a Known Voltage Source
- Open Door to Electrical Equipment to Be Tested
- Test Equipment Phase-to-Phase and Phase-to-Ground
- Re-Test the Tester on a Known Voltage Source

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18.3% of facilities experienced a personal injury when using hand-held voltage test instruments.

36.7% reported near misses of personal injury.

11.7% of facilities experienced interruptions to plan operations due to voltage testing incidents.

IEEE Applications VOL 33, No 2.

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According to Step 7 of NFPA 70E 2018 Article 120.5:

Use an adequately rated portable test instrument to test each phase conductor or circuit part to verify it is de-energized. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exception No. 1: An adequately rated **permanently mounted test device** shall be permitted to be used to verify the absence of voltage of the conductors or circuit parts at the work location, provided it meets the following requirements:

(1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work;

(2) It is listed and labeled for the purpose of verifying absence of voltage;

(3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground;

(4) The test device is verified as operating satisfactorily on any known voltage source before and after verifying the absence of voltage.

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Permanently Mounted Test Devices
= Voltage Indicator =

Voltage indicators are permanently mounted and use LED-style indicators that illuminate when presence of voltage is detected.

They typically illuminate at approximately 40V to 1000V, depending on the device and manufacturer. These devices are an excellent way to provide a visual warning when voltage is present.

Voltage indicators should never be used to verify the absence of voltage. Equipment may be energized, even if the voltage indicator is not illuminated.

Lack of illumination can be caused by a failed LED, a bad installation, or a failed device.

Installation codes often require voltage indicators to be fused. If the fuse is open, the voltage indicator will not illuminate when voltage is present.

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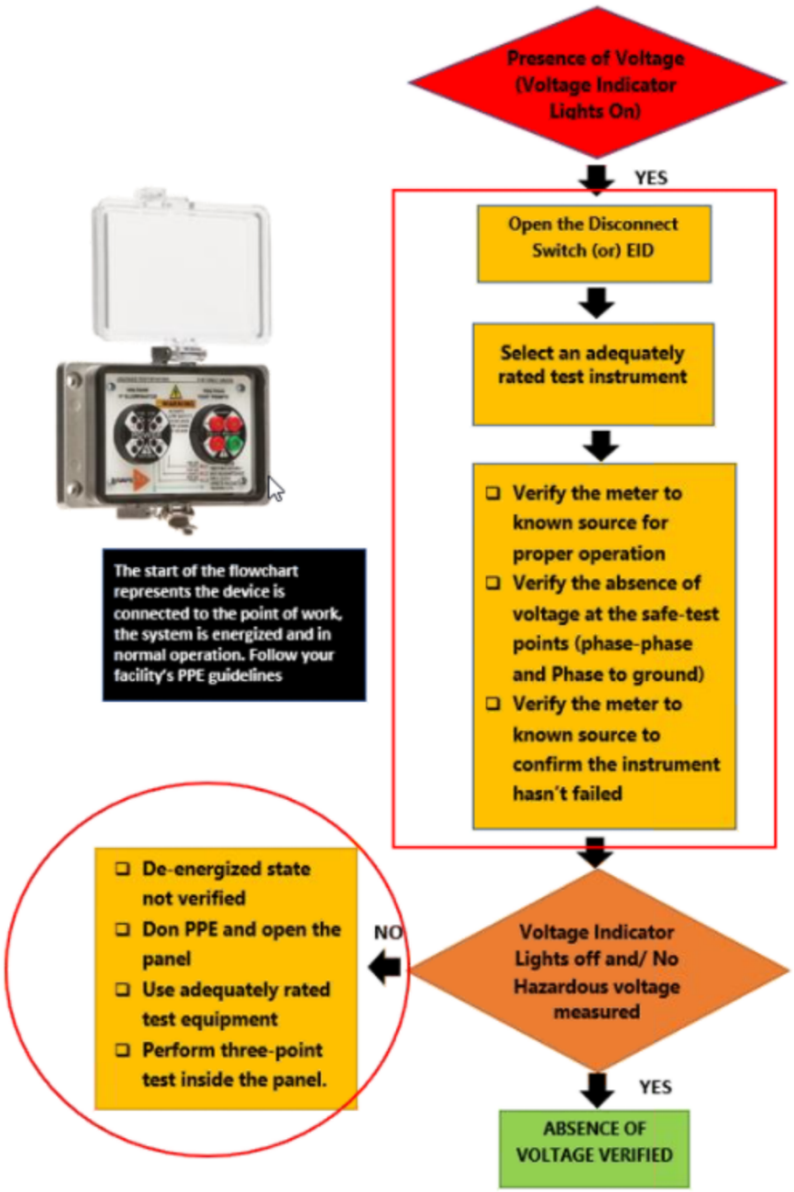
Permanently Mounted Test Devices
= Test Portals =

Test portals are permanently mounted devices that can be used with a portable tester, such as a digital multi-meter, to measure voltage.

These devices are an excellent tool for troubleshooting and determining the magnitude or value of any voltage that is present.

Test portals will test at the point in the circuit at which the test leads are installed

Permanently Mounted Test Devices



There was an promoted practice of using a combination voltage indicator and voltage test port for conducting absence of voltage testing as per the process noted in the graphic.

This approach is quicker than the traditional approach and reduces time required by more than 50%.

This approach tests for voltage without opening the electrical cabinet door thereby reducing the potential for exposure.

But does this approach meet the requirements for an Absence of Voltage Tester?

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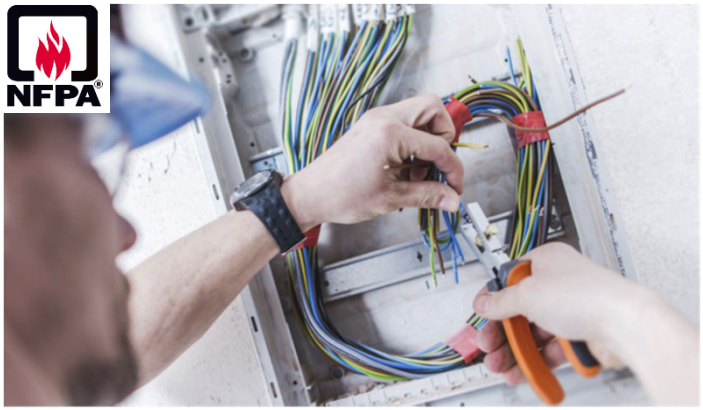
NFPA



FATAL ELECTRICAL INJURIES AT WORK, 2012 – 2016 FINDINGS

A total of 739 workers died from exposure to electricity, Or nearly 3 deaths every week over the five year period.

417 of these deaths were caused by direct exposure to electricity, such as touching a live wire.

80% of fatal injuries from direct exposure to electricity while workers were engaged in constructing, repairing, or cleaning activities.

The leading location for fatal injuries from direct exposure to electricity were industrial places and premises (36% of deaths).

WORKPLACE ELECTRICAL INJURIES: 2003 - 2019

166

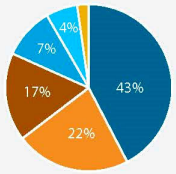
FATAL ELECTRICAL INJURIES IN 2019

According to the Bureau of Labor Statistics, 2019 had the most recorded fatal electrical injuries since 2011. There was a 3.75% increase in fatal injuries over 2018.

Nonfatal electrical injuries involving days away from work totaled 1,900 in 2019.

Electrical Fatalities

Occupations Involved in Electrical Fatalities



- Construction and Extraction: 43%
- Installation, Maintenance, Repair: 22%
- Building and Grounds Cleaning & Maintenance: 17%
- Transportations & Material Moving: 7%
- Farming, Fishing, Forestry: 4%
- Management: 2%

Fatality Rate

The construction industry had the **highest rate** of fatal electrical injuries **(0.7 / 100,000)** followed by **utility (0.4 / 100,000)**. All industries had 0.1 fatalities per 100,000 workers.

Electrical Injuries

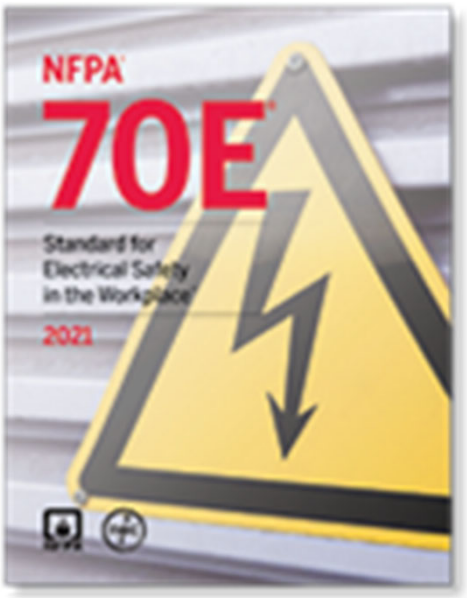
Please share this free resource to save lives

ESFI.org www.facebook.com/ESFI.org www.twitter.com/ESFIdotorg www.youtube.com/ESFIdotorg

> www.i-gard.com

NFPA 70E, Article 120.5 2021

Exception No. 1 to 7:
*An adequately rated permanently mounted **absence of voltage tester** shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements:*



(1) It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work;

*(2) It is **listed and labeled** for the purpose of testing for the absence of voltage;*

(3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground;

(4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.

CSA Z462-21 sec. 4.2.5

g) Use an adequately rated portable test instrument to test each phase conductor or circuit part to verify the absence of voltage. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.

Exceptions:
i) *On electrical systems over 1000 V, noncontact capacitive test instruments may be used to test each phase conductor.*

ii) ***An adequately rated permanently mounted absence of voltage tester may be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets the following requirements:***

1) *It is permanently mounted and installed in accordance with the manufacturer's instructions and tests the conductors and circuit parts at the point of work.*

2) *It is listed and labeled for the purpose of testing for the absence of voltage.*

3) *It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground.*

4) *The test device is verified as operating satisfactorily on any known voltage source before and after testing for the absence of voltage.*

Notes:
1) *For additional information on rating and* ***design requirements for permanently mounted absence of voltage testers, refer to UL 1436.***

2) *See CAN/CSA-C22.2 No. 61010-1-12 for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 V and below.*

3) *For additional information on rating and design requirements for voltage detectors, see IEC 61243-1, IEC 61243-2, or IEC 61243-3.*

What is an Absence of Voltage Tester?

Listed and labeled for the purpose of verifying the absence of voltage refers to UL 1436 Standard for Safety – Outlet Circuit Testers and Similar Indicating Devices.

In this standard in section 5: Glossary the Absence of Voltage Tester (AVT) is defined as:

A permanently-mounted test device that is used to verify that a circuit is de-energized prior to opening an electrical enclosure that contains energized electrical conductors or circuit paths.

An AVT is provided with a test circuit with active indications to verify the absence of phase-to-phase and phase-to-ground voltage.

Construction - *Components*

CONTROL UNIT (CU)

DISPLAY UNIT (DU)

SENSOR LEADS: 8 IN TOTAL (2 PER PHASE & 2 FOR GROUND)

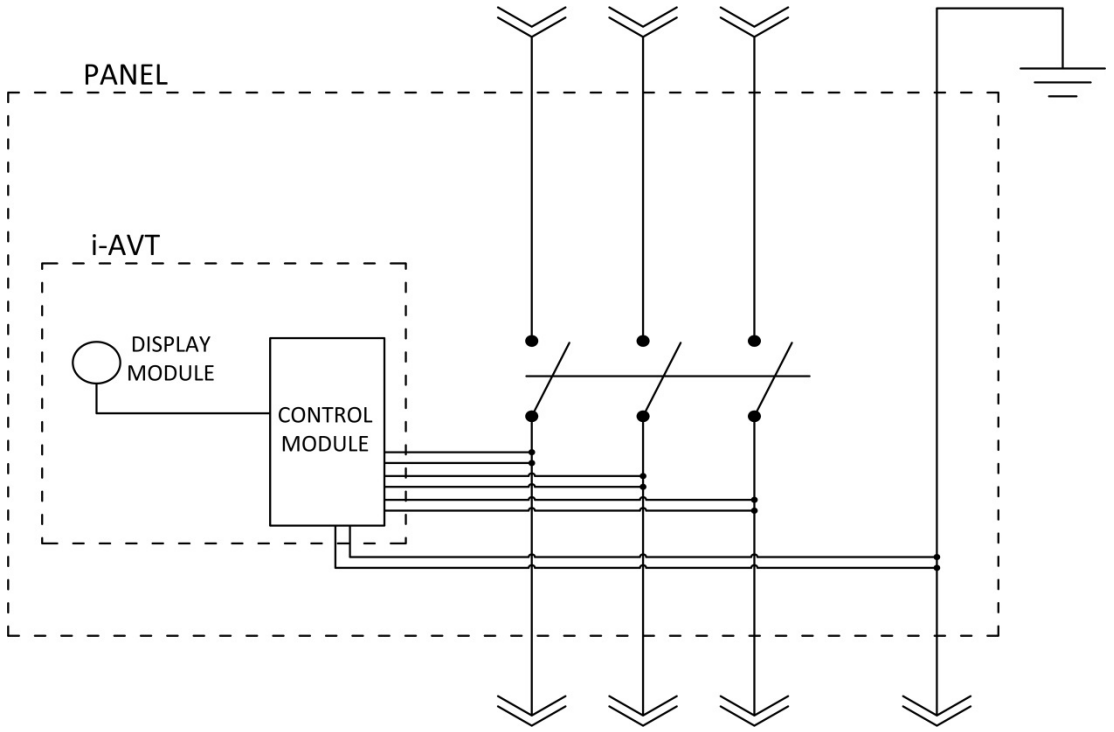
CAT5 CABLE

Construction – *Features (cont.)*

1. Internally fused (500mA)
2. Control Unit consists of a top board and bottom board.
3. Power is derived from the bus when live.
4. Secondary power source is from a supercapacitor (located on the top board).

Application

- **Two sensor leads are connected to each phase and two sensor leads are connected to ground**



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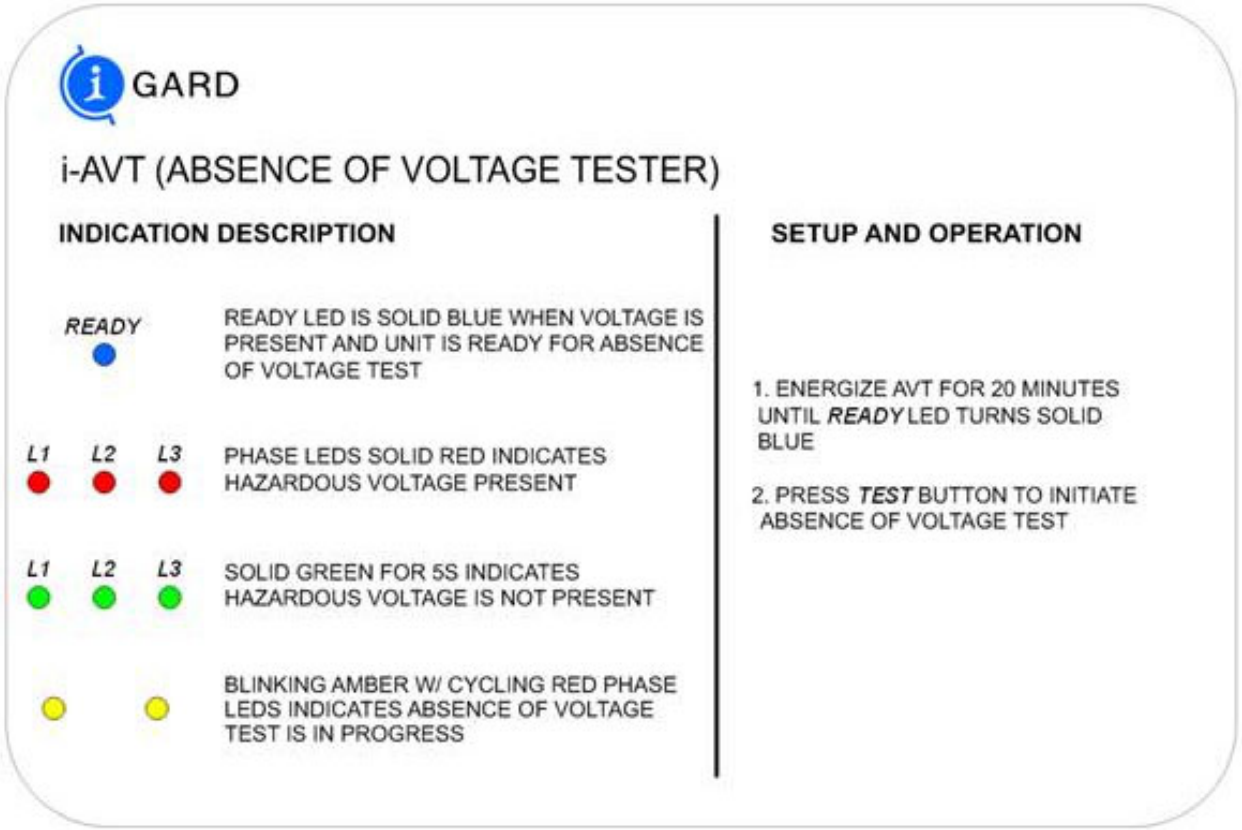
Operation



- **20min to charge super capacitor**
- **About 10 tests per charge**
- **Charge remains after 15 hours**

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New Safer and Quicker Approach

De-energize Electrical Equipment

Apply Locks / Tags as per LOTO Instructions

Press Button on Absence of Voltage Tester
Wait 10-15 seconds

i-AVT

Simple, intuitive, better.

UNSAFE, do not open

TEST in progress

SAFE to open

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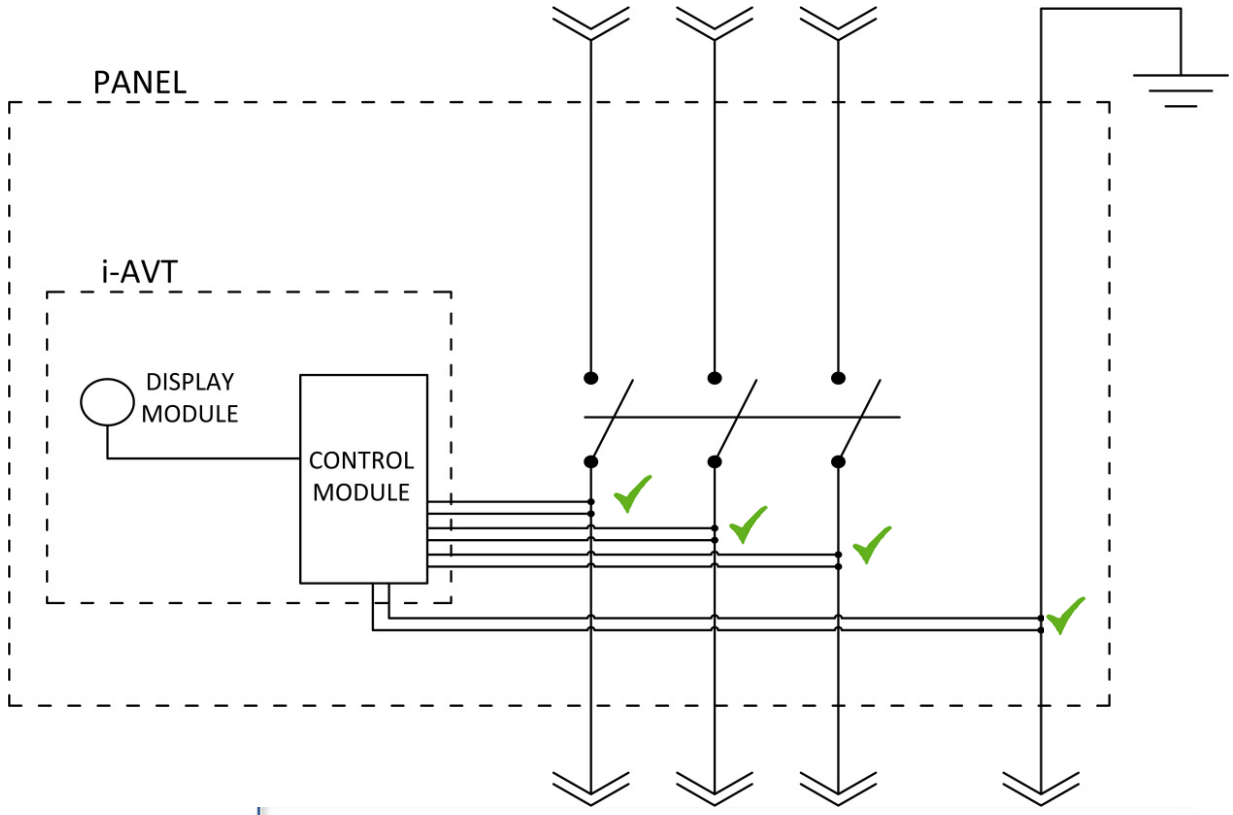
What Happens Once The Test Button is Pressed?

Step 1 **(The test process will not commence until Step 1 of the safety protocol is complete):**

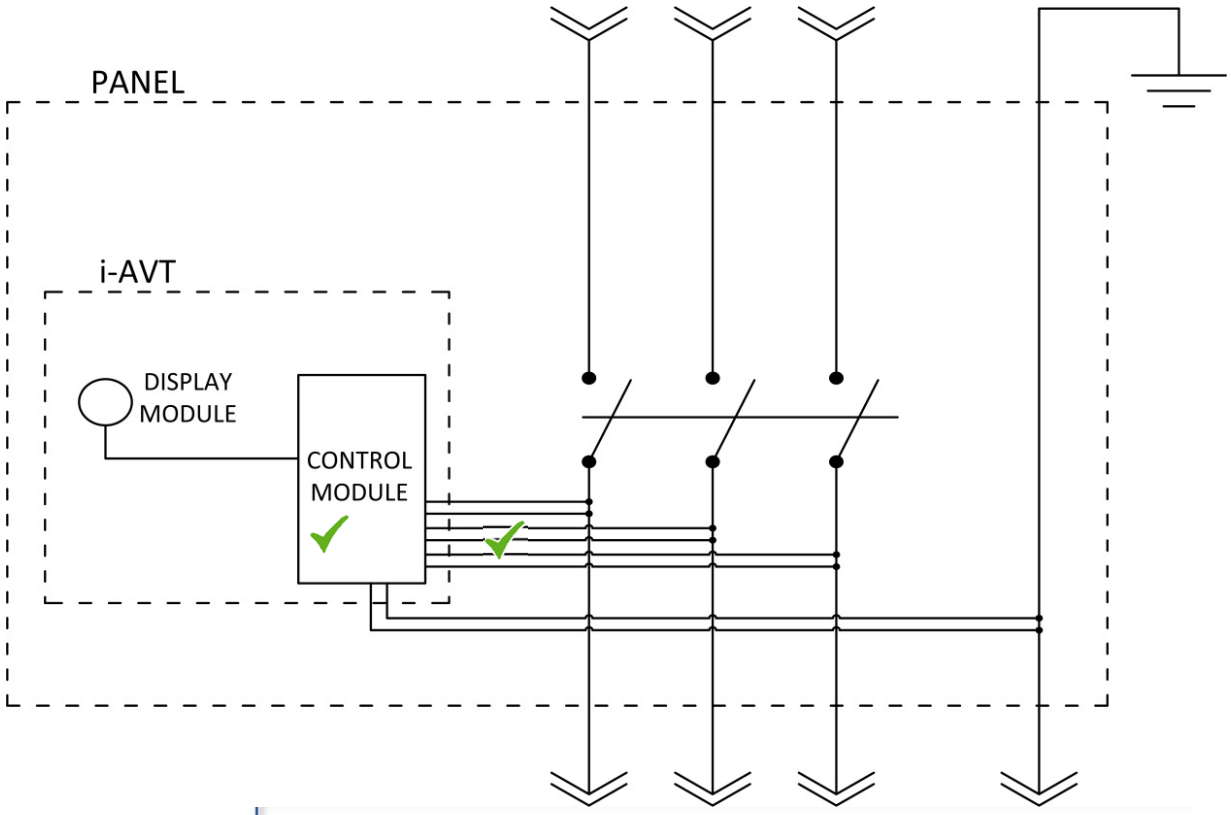
- ☑ **Supervisory circuit verifies that the phase voltage lights are off.**
- ☑ **Supervisory circuit verifies that the sensor leads are connected**



What Happens Once The Test Button is Pressed?

Step 2 **(The test process will not commence until Step 2 of the safety protocol is complete):**

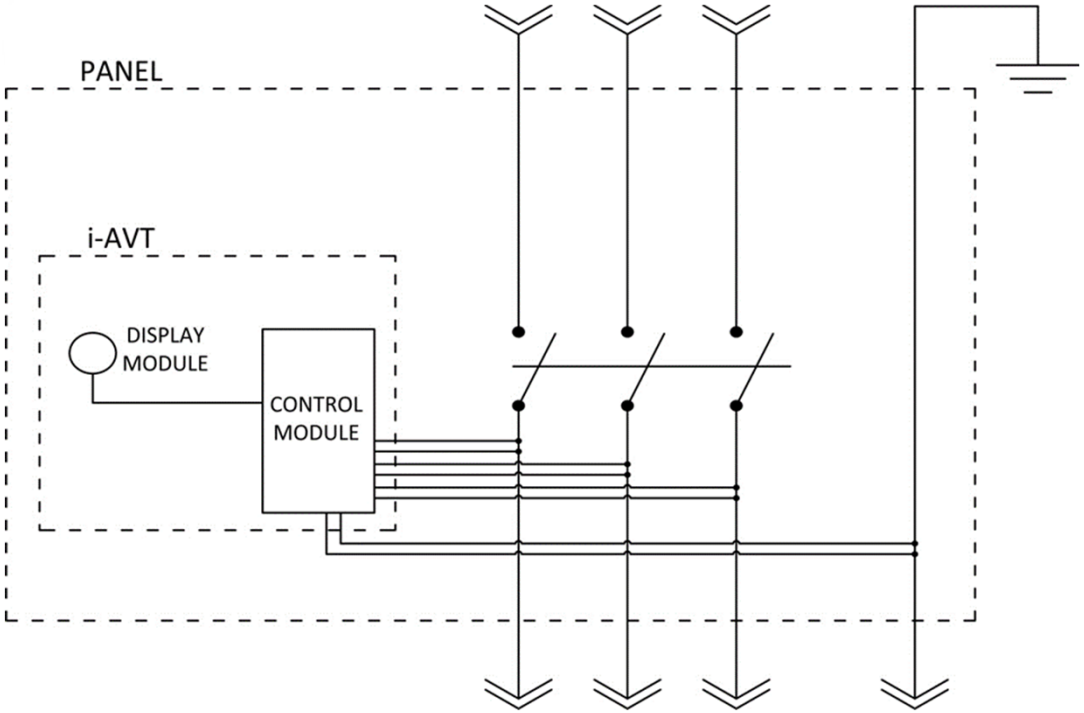
- ☑ **Verify that the energy level on the bus is low enough to perform the test**
- ☑ **Verify that the voltage source is sufficient to perform the test.**



What Happens Once The Test Button is Pressed?

Step 3

- Verify if the phase A to ground RMS voltage is <3V $_{RMS}$
- Verify if the phase B to ground RMS voltage is <3V $_{RMS}$
- Verify if the phase C to ground RMS voltage is <3V $_{RMS}$
- Verify if the phase A to phase B RMS voltage is <3V $_{RMS}$
- Verify if the phase B to phase C RMS voltage is <3V $_{RMS}$
- Verify if the phase C to phase A RMS voltage is <3V $_{RMS}$



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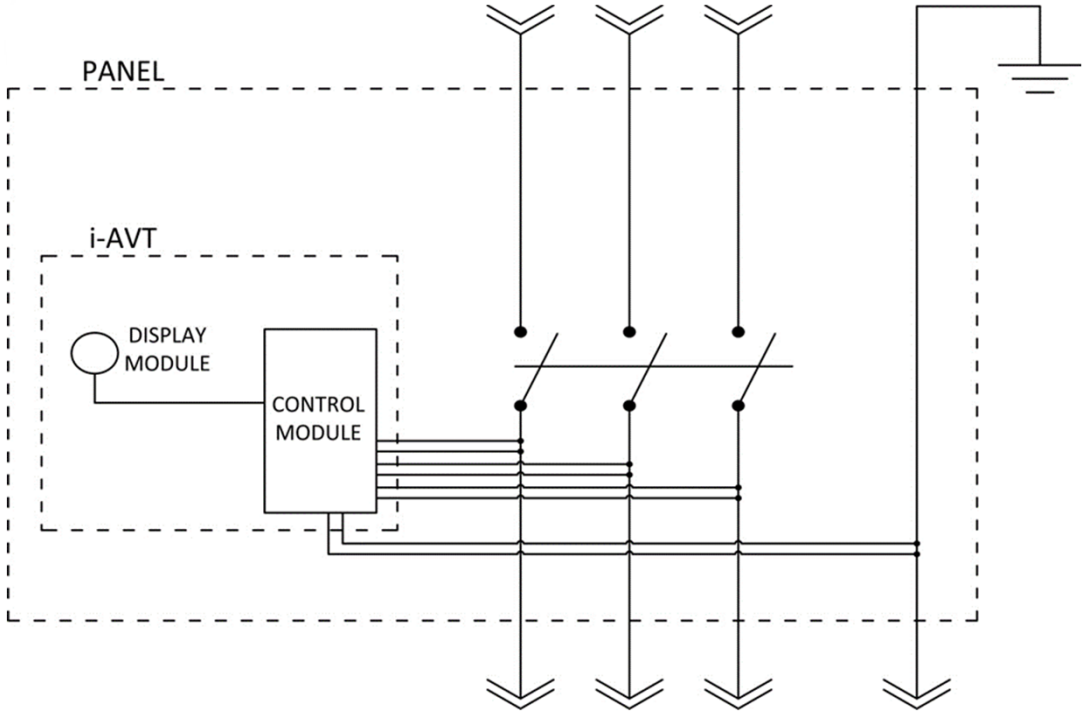
What Happens Once The Test Button is Pressed?

Step 4

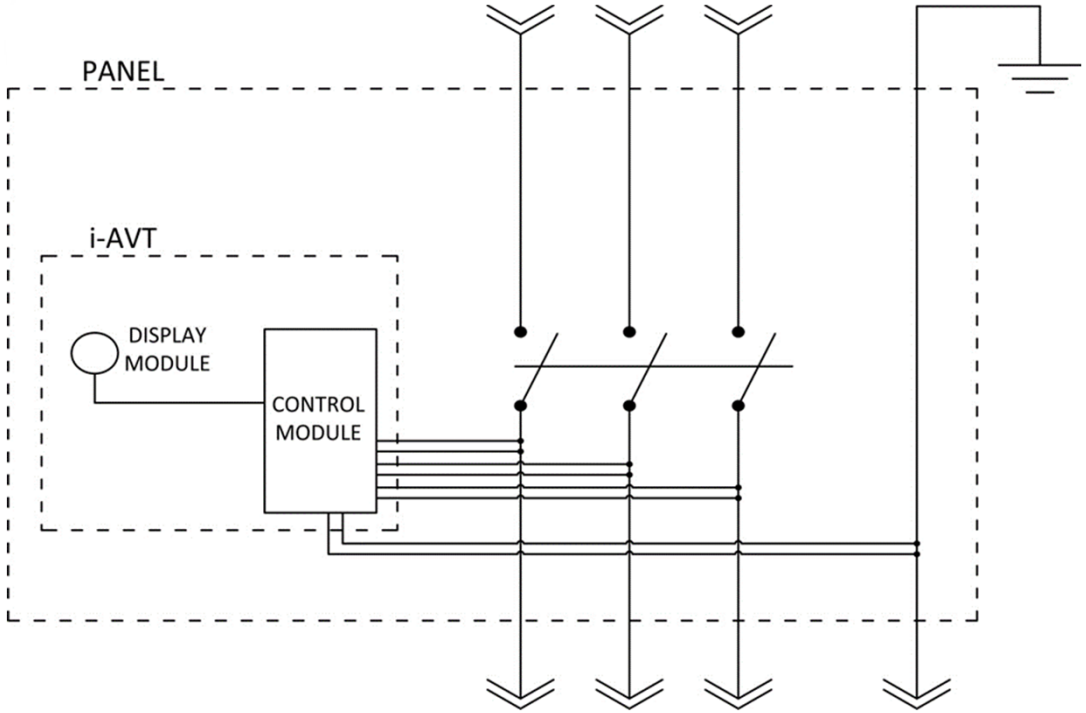
- ☑ Verify if the phase A to ground DC voltage is <3V $_{RMS}$
- ☑ Verify if the phase B to ground DC voltage is <3V $_{RMS}$
- ☑ Verify if the phase C to ground DC voltage is <3V $_{RMS}$
- ☑ Verify if the phase A to phase B DC voltage is <3V
- ☑ Verify if the phase B to phase C DC voltage is <3V
- ☑ Verify if the phase C to phase A DC voltage is <3V



What Happens Once The Test Button is Pressed?

Step 5

- ☑ Verify if the phase A connection loop has continuity
- ☑ Verify if the phase B connection loop has continuity
- ☑ Verify if the phase C connection loop has continuity



What Happens Once The Test Button is Pressed?

Step 6 – repeat Step 3 **AC voltage check**

Step 7 – repeat Step 4 **DC voltage check**

Step 8 – repeat Step 5 **Continuity verification check**

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What Happens Once The Test Button is Pressed?

- Verify that the phase voltage lights are off.
- Verify that the sensor leads are connected via injecting signal.
- Verify that the energy level on the bus is low enough to perform the test
- Verify that the voltage source is sufficient to perform the test.
- Verify if the phase A RMS voltage is <3V $_{RMS}$
- Verify if the phase B RMS voltage is <3V $_{RMS}$
- Verify if the phase C RMS voltage is <3V $_{RMS}$
- Verify if the phase A DC voltage is <3V $_{RMS}$
- Verify if the phase B DC voltage is <3V $_{RMS}$
- Verify if the phase C DC voltage is <3V $_{RMS}$
- Verify if the phase A connection loop has continuity
- Verify if the phase B connection loop has continuity
- Verify if the phase C connection loop has continuity
- Verify if the phase A RMS voltage is <3V $_{RMS}$
- Verify if the phase B RMS voltage is <3V $_{RMS}$
- Verify if the phase C RMS voltage is <3V $_{RMS}$
- Verify if the phase A DC voltage is <3V $_{RMS}$
- Verify if the phase B DC voltage is <3V $_{RMS}$
- Verify if the phase C DC voltage is <3V $_{RMS}$
- Verify if the phase A connection loop has continuity
- Verify if the phase B connection loop has continuity
- Verify if the phase C connection loop has continuity

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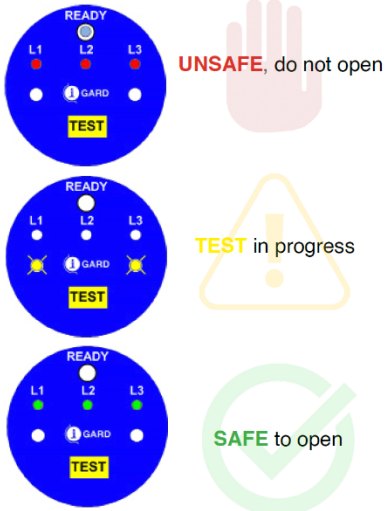
What Happens Once The Test Button is Pressed?

i-AVT

Simple, intuitive, better.



These verification tests are performed in sequence and the next test can only be initiated if the previous verification test has been passed.

Only when all verification tests are passed in sequence will all 3 phase green lights illuminate to indicate absence of voltage.

All this only takes 10 seconds and with the door to the electrical equipment closed.

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In Section 12 of UL 1436 there are specific construction and operation clauses related to the AVT product including the following:

- **An AVT shall be provided with the means for the user to initiate the test for absence of voltage.**
- **An AVT shall provide the user with a visual indicator to confirm the absence of voltage after the absence of voltage test has been performed. The visual indication shall be green.**
- **The AVT shall incorporate a supervisory test circuit to verify that the tester is functioning properly before and after the AVT performs voltage measurements.**
- **The AVT supervisory circuit has incorporated a secondary power source and shall have no internal failure that would affect performance.**
- **The AVT visual indicator shall only illuminate green when all phase-to-phase and phase-to-ground voltages measure less than 3VAC or 3VDC.**
- **The AVT visual indicators shall not illuminate green unless the phase and ground leads are in direct contact with the circuit conductors being tested.**
- **The AVT visual indicator shall not illuminate green if a phase lead is connected to ground or the ground lead is connected to a phase conductor.**
- **The AVT shall comply with the Standard for Functional Safety IEC 61508 and achieve a SIL 3 rating.**

	I-Gard	Panduit	Grace Technologies
	i-AVT	VeriSafe AVT (VS-AVT-C02-L03)	Voltage Test Station P-S10S210M2RX-V
			
UL 1436 Requirements			
A permanently-mounted test device that is used to verify that a circuit is de-energized prior to opening an electrical enclosure that contains energized electrical conductors or circuit paths	**YES**	**YES**	**YES**
12.1.2 - An AVT shall be provided with the means for the user to initiate the test for absence of voltage.	**YES**	**YES**	**NO**
12.1.3 - An AVT shall provide the user with a visual indicator to confirm the absence of voltage after the absence of voltage test has been performed. The visual indication shall be green.	**YES**	**YES**	**NO**
12.1.5 - The AVT shall incorporate a supervisory test circuit to verify that the tester is functioning properly before and after the AVT performs voltage measurements.	**YES**	**YES**	**NO**
12.1.4 - The AVT supervisory circuit has incorporated a secondary power source and shall have no internal failure that would affect performance.	**YES, SUPER CAPACITOR**	**YES, BATTERY**	**NO**
12.1.6 - The AVT visual indicator shall only illuminate green when all phase-to-phase and phase-to-ground voltages measure less than 3VAC or 3VDC.	**YES**	**YES**	**No**
12.1.7 The AVT visual indicators shall not illuminate green unless the phase and ground leads are in direct contact with the circuit conductors being tested	**Yes, product architecture and operation ensures green lights can only illuminate once contiuuity check is complete.**	**Yes, product architecture and operation ensures green lights can only illuminate once continuity check is complete.**	**No means of verifying that leads are connected.**
12.1.8 - The AVT visual indicator shall not illuminate green if a phase lead is connected to ground or the ground lead is connected to a phase conductor.	**Yes, product architecture and operation ensures green lights cannot illuminate if any lead is misconnected**	**Yes, product architecture and operation ensures green lights cannot illuminate if any lead is misconnected**	**No means of verifying that leads are properly connected**
12.1.9 12.1.9 The visual indicator shall not illuminate green unless the secondary power source is operational	**Yes, product architecture and operation ensures green lights can only illuminate if the secondary power source is operational**	**Yes, product architecture and operation ensures green lights can only illuminate if the secondary power source is operational**	**No secondary power source available**
12.2.1 - The AVT shall comply with the Standard for Functional Safety IEC 61508 and achieve a SIL 3 rating.	**Yes, product is tested and approved to SIL3 safety rating**	**Yes, product is tested and approved to SIL3 safety rating**	**No the voltage test port is not tested to SIL 3 rating and failsafe in operation**

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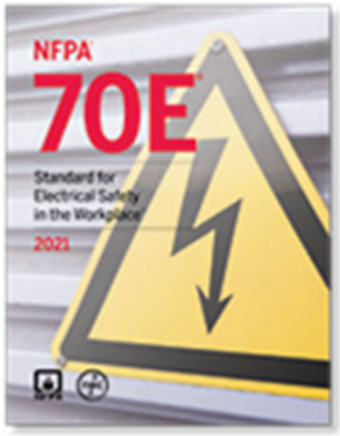

Exception No. 1 to 7:
*An adequately rated permanently mounted **absence of voltage tester** shall be permitted to be used to test for the absence of voltage of the conductors or circuit parts at the work location, provided it meets all of the following requirements:*

NFPA 70E 2021-120.5 (7) Exception 1.				
Description				
(1) It is permanently mounted and installed in accordance with the manufacturer's instructions	YES	YES	YES	YES
(1) and tests the conductors and circuit parts at the point of work;	NO Test Function	NO - hand held tester is in contact with the test port, no verification that test port is in contact with circuit.	YES	YES
(2) It is listed and labeled for the purpose of testing for the Absence of Voltage	NO	NO	YES	YES
(3) It tests each phase conductor or circuit part both phase-to-phase and phase-to-ground	Only Phase to Ground	YES - with hand held tester	YES	YES
(4) The test device is verified as operating satisfactorily on any known voltage source before and after testing for the Absence of Voltage	NO	NO - no means to verify the test port, the hand held meter requires access to a known voltage source	YES	YES
Note 1: Meets rating and desgin requirements for absence of voltage testers described in UL 1436	NO	NO	YES	YES

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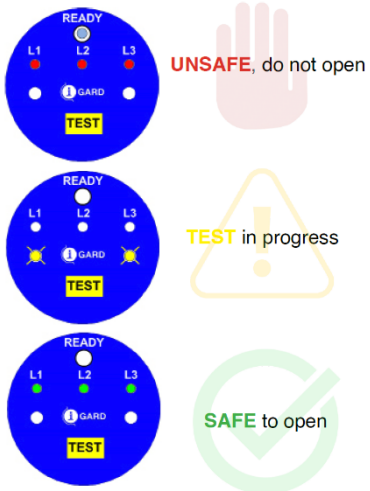
i-AVT

Simple, intuitive, better.



The i-AVT allows for the Absence of Voltage test to be initiated via the press of a button and completes the test in 10 seconds and allows the test to be conducted prior to opening an electrical enclosure thereby reducing the risk of exposure to shock or electrocution hazards.

The i-AVT provides visual indication of the presence of voltage via 3 phase voltage red lights connected directly to the circuit conductors, thereby indicating that hazardous voltage is present.

The i-AVT provides positive indication of the Absence of Voltage via 3 Green LED lights.

The i-AVT provides a continuity check to ensure that all leads are connected and connected properly.

The i-AVT is maintenance free with secondary power source built-in to the control module.

The i-AVT is SIL-3 rated ensuring that it will not provide a false positive.

What is SIL-3 and What Does it Mean?

IEC 61508 defines SIL using requirements grouped into two broad categories: hardware safety integrity and systematic safety integrity.

The i-AVT is a Type B element with a Hardware Fault Tolerance (HFT) of 0 and so it must have a Safe Failure Fraction (SFF) of ≥99% in order to have a SIL of 3.

Every component in the i-AVT product has been selected based on its safety failure fraction and the design architecture has several layers of redundancy and diagnostics.

SFF is calculated by: $$SFF = \frac{\lambda S + \lambda Dd}{\lambda S + \lambda Dd + \lambda Du}$$

SAFE FAILURES

DANGEROUS DETECTED FAILURES

DANGEROUS UNDETECTED FAILURES

SIL	Probability of Dangerous Failure	PFD (power)	Risk Reduction Factor
1	0.1–0.01	10^{-1} – 10^{-2}	10–100
2	0.01–0.001	10^{-2} – 10^{-3}	100–1000
3	0.001–0.0001	10^{-3} – 10^{-4}	1000–10,000
4	0.0001–0.00001	10^{-4} – 10^{-5}	10,000–100,000

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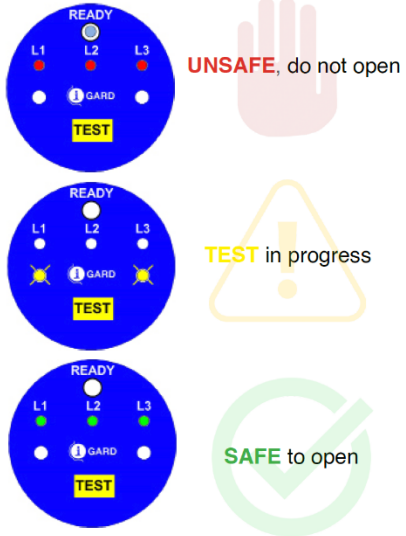
i-AVT

Simple, intuitive, better.



If your process to establish an electrically safe work condition involves wearing PPE and opening cabinet doors to measure voltage, you could benefit from installing Absence of Voltage Testing technology.

If your process to establish an electrically safe work condition relies on multi-meters that may not be calibrated for the task, you could benefit from installing Absence of Voltage Testing technology.

If your process to establish an electrically safe work condition takes longer than 10 seconds and is not as simple as pressing a button, you could benefit from installing Absence of Voltage technology.

If your process to establish an electrically safe work condition relies of voltage indicating and voltage test ports that do not meet the requirements of NFPA 70E 120.5 Exception 1, you could benefit from installing Absence of Voltage technology.

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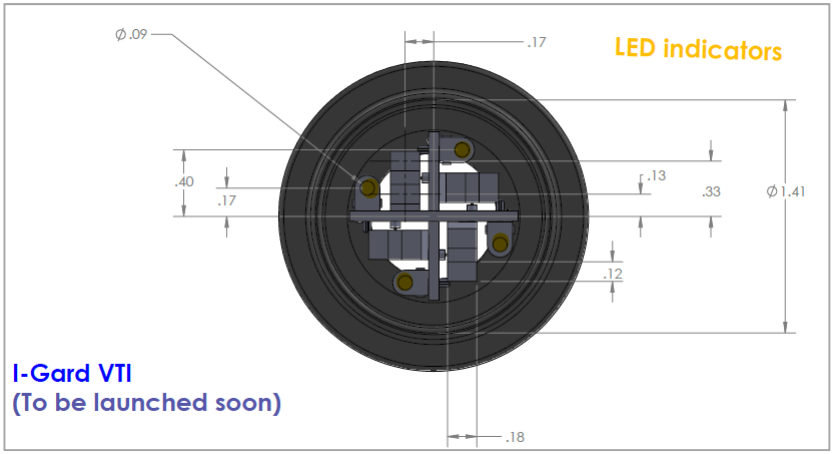
If you need to conduct an Absence of Voltage Test, choose a product listed and labeled for the purpose.

If you want voltage indication or to measure voltage for troubleshooting, we will soon be launching the Voltage Test Indicator (VTi)



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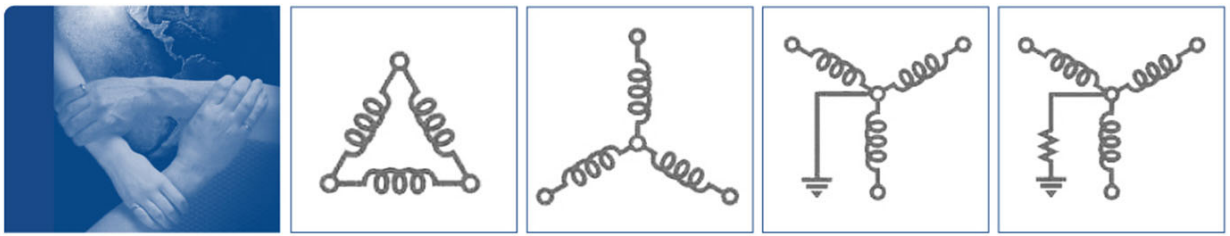
Unparalleled Protection

Thanks for your attention

Stay connected for our upcoming webinars:

May 18: Transformer Protection using Surge Suppressors
June, Date TBC: I-Gard Differentiators

> www.i-gard.com



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