

Live-Dead-Live Testing – The Final Barrier Between Life and Death

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NECA SAFETY PROFESSIONALS CONFERENCE Atlanta, GA



OSHA Electrical Safety Laws & Regulations

OSHA 29CFR1910, Subpart S is 'Da Law'

OSHA requires exposed energized parts to be "Deenergize" before employees can work on them

Deenergized is defined as "Free from any electrical connection to a source of potential difference and from electrical charge; not have a potential difference from that of earth." [Identical to NFPA 70E]

But OSHA also states electrical equipment cannot be considered "deenergized" unless:

- > It's been "deenergized" and placed under LOTO, if not then it shall be treated as "energized"
- > We have procedures to "deenergize" the equipment
- > Equipment has been disconnected from all sources of electricity
 - o Can't use selector switches, push buttons or control circuits for primary isolation
- > Stored electrical energy has been discharged
- > Stored non-electrical energy has been blocked or relieved
- > Qualified person attempts to start the equipment
- > Qualified person uses test equipment to verify it's "deenergized"
- > The test equipment is checked for proper operation after the test, but only for > 600 volts



This is why NFPA 70E's "Electrically Safe Work Condition" should be used rather than "Deenergized"

NFPA 70E – Premier Standard for Electrical Safety

- NFPA 70E is not a regulation or law, but it an industry consensus standard for electrical safety
- *OSHA's **General Duty Clause** (OSH Act of 1970) may apply to employers who fail to implement NFPA 70E, but only after an employee is seriously injured or killed
- While NFPA 70E is the premier electrical safety standard it is not perfect nor does it claim to be

*OSHA Letters of Interpretation July 25, 2003 & Oct 18, 2006



What is the General Duty Clause?

OSH Act of 1970

Table of Contents **General Duty Clause** Complete OSH Act Version ("All-in-One")

SEC. 5. Duties

(a) **Each Employer:**

(1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;

(2) shall comply with occupational safety and health standards promulgated under this Act.

(b) **Each Employee shall comply** with occupational safety and health standards and all rules, regulations and orders issued pursuant to this Act **which are applicable to his own actions and conduct.**

<https://www.osha.gov/laws-regs/oshact/section5-duties>

What is an Electrically Safe Work Condition (ESWC)?

According to NFPA 70E Article 100, an ESWC is defined as:

"A state in which an electrical conductor or circuit part has been:

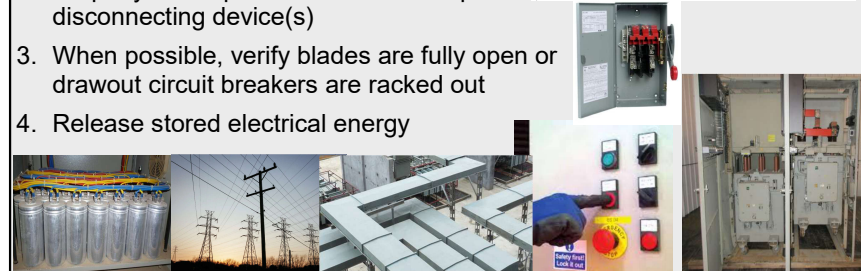
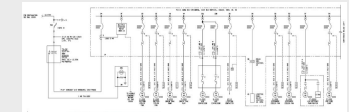
- *disconnected from energized parts*
- *locked/tagged in accordance with established standards*
- *tested for the absence of voltage and*
- *if necessary, temporarily grounded for personnel protection."*

However, **section 120.6** contains 8 mandatory steps that must be implemented in specific sequence when establishing and verifying an ESWC



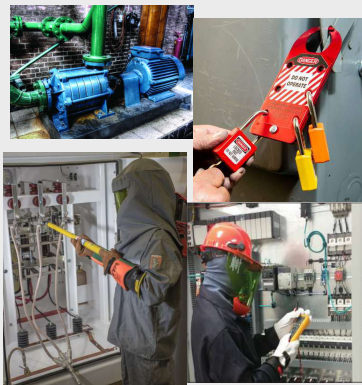
8 Steps of Electrically Safe Work Condition (Steps 1 – 4)

1. Determine all sources using up to date drawings, ID tags, etc.
2. Properly interrupt load current then open disconnecting device(s)
3. When possible, verify blades are fully open or drawout circuit breakers are racked out
4. Release stored electrical energy



8 Steps of Electrically Safe Work Condition (Steps 5 – 8)

5. Block or relieve stored non-electrical energy
6. Apply LOTO per company procedures
7. **Test for absence of voltage “Phase-to-Phase” and “Phase-to-Ground”**
8. If needed, install Temporary Protective Grounds (TPG) to develop an Equipotential Zone (EPZ)



Step 7 – Testing for the Absence of Voltage “Phase”

Currently step 120.6(7) directs:

*"Use an adequately rated portable test instrument to test each phase conductor **at each point of work** 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 the test instrument is operating satisfactorily through verification on any known voltage source."

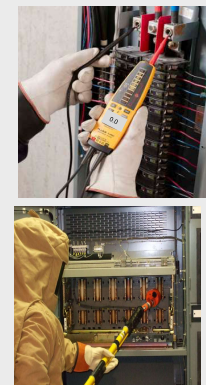
Unofficially called "Live-Dead-Live" testing

"On systems over 1000 volts, noncontact capacitive test instruments is permitted to be used to test each phase conductor."

NOTE: OSHA's electrical LOTO requires an attempt to start the equipment to ensure it doesn't start, AKA "verification of isolation". This is not found in NFPA 70E 120.6 but rather 120.5(B)(5)

This is the basis of LOTOTO – "Lockout-Tagout-Tryout"

* Added during 2024 version of NFPA 70E



What is “Live-Dead-Live” Testing? ≤ 1kV



LIVE

Verifies DMM & Leads are Working
Prior to Test
PPE May be Required



DEAD

Verify Part(s) are Deenergized
Phase to Phase/Phase to Ground
PPE is Required



LIVE

Verifies DMM & Leads are Working
After Test
PPE May be Required

What is “Live-Dead-Live” Testing? >1kV



LIVE

Verifies Voltage Detector is Working
Prior to Test
PPE May be Required



DEAD

Verify Each Phase is Deenergized
PPE is Required



LIVE

Verifies Voltage Detector is Working
After Test
PPE May be Required

Gap #1 – Limitation of the Word “Phase”

*Phase is defined as “A distinct stage of development or particular stage in a periodic process or phenomenon often expressed as an angle.”

The word “Phase” is related to the word “Phasor” which is limited to only alternating current (AC)

Electrical workers commonly use “Phase” to describe the ungrounded energized lines, conductors or parts of an AC system

* American Heritage Dictionary

Technical Textbook Definitions of “Phase”

***Phasor** – A line representing magnitude and direction of a quantity, such as voltage or current with respect to time.

***Phase Angle** – An angle between two phasors; denotes a time shift

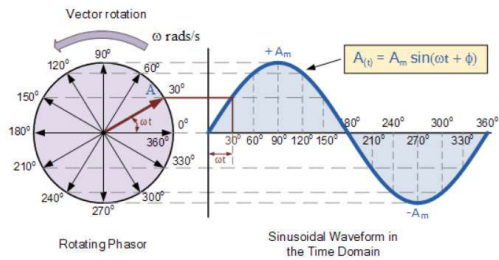
****Phase Voltage** – The amount of voltage measured across a single-phase of a three-phase load or power supply.

****Phase Shift** – A change in the phase relationship between two quantities of voltage or current.

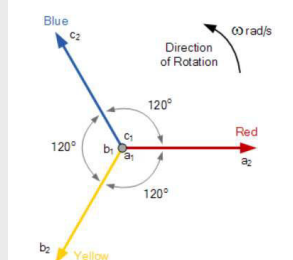
* Grob's Basic Electronics

** Delmar's Standard Textbook of Electricity

"Phase" Only Applies to Alternating Current (AC)



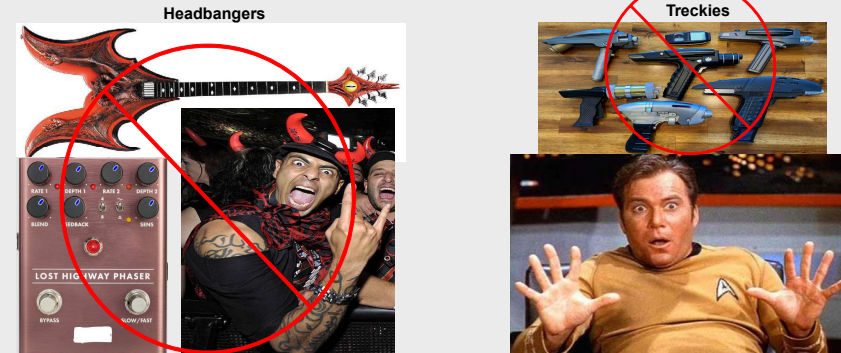
Phasor Diagram of an ac Sinusoidal Waveform



Three-Phase Phasor Diagram

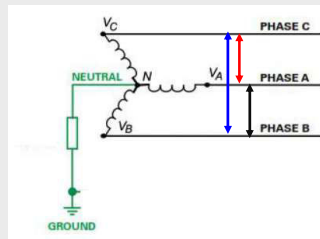
Apologies for Two Groups of Very Special People

Because we're speaking of "Phasors" and NOT "Phasers"

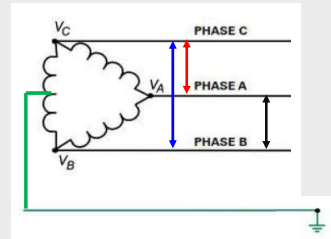


What Is Phase-to-Phase Testing?

Testing Phase-to-Phase is measuring electrical potential (voltage) across two points of the ungrounded AC conductors, i.e. "The Phases"



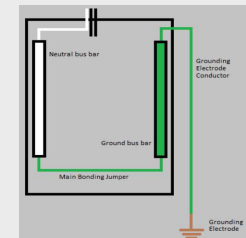
A to B
A to C
B to C



Phase-to-Ground – What is Ground?

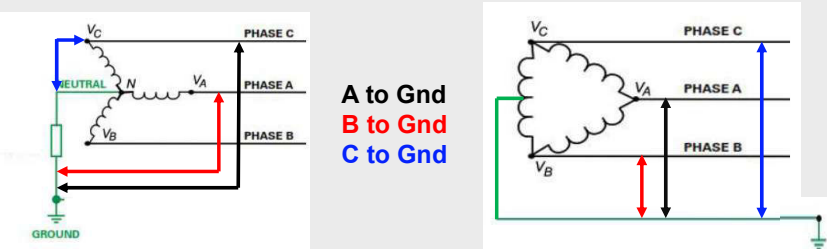
The term "Ground" can be associated with:

- The Equipment Grounding Conductor (EGC)
- The Grounding Electrode, GEC, MJB, etc.
- The intentionally Grounded Conductor, aka "neutral"
- The plethora of other "Grounding and Bonding points listed in NEC article 250
- Or any part bonded or connected to "Da Earth"



What Is Phase-to-Ground Testing?

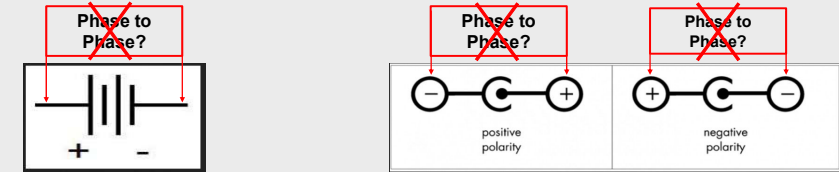
Testing Phase-to-Ground, is measuring electrical potential (voltage) across two points of all ungrounded AC conductors to anything that is "Grounded"



What About DC Systems?

Direct current (dc) is only identified by its "polarity" or "pole" either Positive (+) or Negative (-)

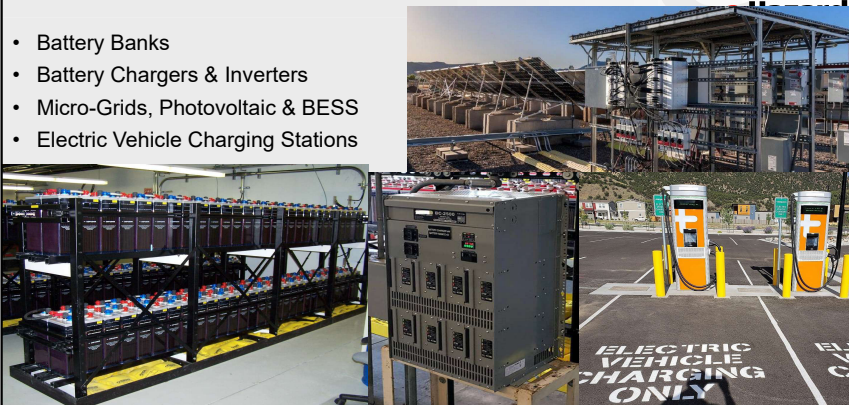
Would any respectable electrical engineer or technician ever call a polarity or pole a "phase" or claim this is across a "phase to phase"?



Phase ≠ DC

DC Systems are Very Common & Becoming More Prevalent

- Battery Banks
- Battery Chargers & Inverters
- Micro-Grids, Photovoltaic & BESS
- Electric Vehicle Charging Stations



Identifying DC Polarities

Red = Positive (+)
Black = Negative (-)



PV Combiner

130 VDC Battery Charger

Industrial Control Relay

Common Warning Labels on DC Equipment



INVERTOR
WARNING - Dual Supply
Isolate AC and DC
before carrying out work

WARNING



Electric shock
hazard
The DC conductors
of this photovoltaic
system are
ungrounded and
may be energized

WARNING

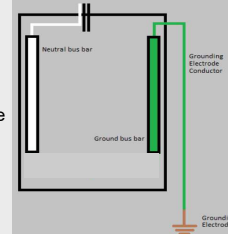
ELECTRICAL SHOCK HAZARD
DO NOT TOUCH TERMINALS
TERMINALS ON BOTH LINE AND
LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION

What About Ungrounded Systems?

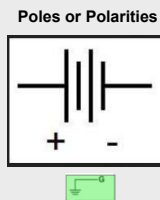
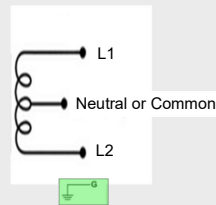
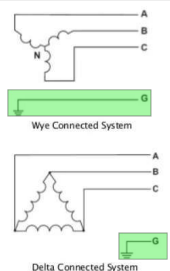
In an ungrounded system, all active conductors are not bonded/grounded to the earth, either through a solid or resistance/impedance connection

- Often called "Floating Systems" (AC or DC)
- Common in industrial facilities with 3 Φ delta systems where equipment can continue to operate after experiencing a single-phase ground fault
- Single-phase ungrounded circuits in healthcare facilities, nuclear power plants and other critical locations
- When tested to "ground" ungrounded AC systems may detect "phantom or ghost" voltages due to capacitive coupling when using high impedance digital multi-meters
- But with ungrounded dc systems, capacitive coupling does not exist

WARNING
ELECTRIC SHOCK HAZARD
THE DC CONDUCTORS OF
THIS PHOTOVOLTAIC SYSTEM
ARE UNGROUNDED AND
MAY BE ENERGIZED



What About Testing Ungrounded Systems?



3 Phase AC Ungrounded
Phase to Phase ✓
Phase to Ground ?

Single Phase AC Ungrounded
Phase to Phase ?
Phase to Ground ?

~~**DC Ungrounded or Grounded**
Phase to Phase
Phase to Ground~~

Ungrounded Systems Require Ground Fault Detection

Per the National Electrical Code (NEC)

- Section 250.21 for ac systems
- Section 250.167 for dc systems

When testing voltage to ground, ungrounded systems with ground fault detection, DMM will display 'x' voltage reading when tested to ground through the detection system

However, reliance on an equipment warning circuit, which can be taken out of service, IS NOT acceptable for the worker safety



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One Device – Different Sources & Many LOTO Points

Coil (5&6) and Contact Set 1&2
Grounded 120 VAC
Source #1
LOTO Point #1

Contact Set 7&8
Ungrounded 130 VDC
Source #2
LOTO Point #4

Contact Set 9&10
Ungrounded 120 VAC
Source #3
LOTO Point #5

Coil (5 & 6) and Contact Set 1 & 2
Grounded single-phase 120 VAC Circuit Source #1
LOTO Isolation Point #1

Contact Set 19 & 20
Ungrounded 130 VDC Circuit Source #2
LOTO Isolation Point #2

Contact Sets 3 & 4 and 21 & 22
Same ungrounded 130 VDC as Circuit Source #2
LOTO Isolation Point #3

Contact Set 7 & 8
Same ungrounded 130 VDC as Circuit Source #2
LOTO Isolation Point #4

Contact Set 9 & 10
Ungrounded single-phase 120 VAC, Circuit Source #3
LOTO Isolation Point #5

Contact Set 19&20
Ungrounded 130 VDC
Source #2
LOTO Point #2

Contact Sets 3&4 and 21&22
Ungrounded 130 VDC
Source #2
LOTO Point #3

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One Device – Different Sources = Many Different LOTO Points

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This single device has 3 sources:

- Grounded 120 VAC single-phase circuit
- Ungrounded 120 VAC single-phase circuit
- Ungrounded 130 VDC circuit

Phase-to-Phase doesn't apply to any of them
Phase-to-Ground only applies to one

Additionally, 5 different LOTO Isolation Points may be needed to replace the relay

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Recommendations For Improvement Opportunity #1

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- “Special precautions shall be used when performing Live-Dead-Live (LDL) absence of voltage tests of ungrounded AC or DC systems.”
- “When verifying the absence of voltage of ungrounded AC or DC systems, do not check only one phase or polarity to ground.
 - For ungrounded AC systems, test ‘phase-to-phase’ or ‘phase/leg to neutral/common’ and ‘phase-to-ground’
 - For ungrounded DC systems, test across the ‘positive’ (+) polarity to the ‘negative’ (–) polarity and each polarity to ground

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Gap #2 – Reperforming Live-Dead-Live Testing

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Section 120.5(B)(6) requires Retesting for Absence of voltage (LDL Testing):

- ‘Test Before Touch’ every exposed part within the defined work area
- When circuit conditions change
- When the job location has been left unattended

But this information is housed in the LOTO section (120.5) rather than ESWC section (120.6)

Reperforming Live-Dead-Live Testing

But What About When:

- Circuit conditions don't change?
- The job location has NOT been left unattended?
- The "defined work area" is a single piece of equipment that has a large footprint?

e.g. MCCs, Switchgear, etc. containing many individual cubicles, enclosures and parts fed by different sources, APU, UPS, cross ties, auto-transfer switches, etc.



Real Life Incidents That Forever Impact Many Lives

- The following incidents involved real people just trying to make a living
- Some occurred with high voltage (> 600 volts) equipment while others with low voltage (< 600 volts) equipment
- All involved were qualified persons performing "routine work"
- All incidents would forever impact not only the injured worker but countless others

Incident # 1 – 13.5kV Switchgear 'Routine' Clean & Inspection

On October 20th, 2021 a near fatal electric shock accident occurred during "routine clean and inspection" of 13.8kV switchgear at a large nuclear power plant in the Southwestern US

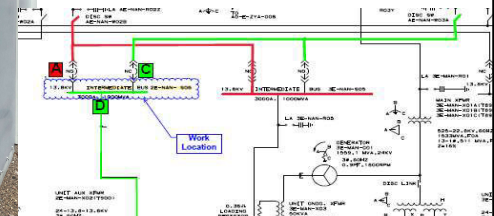


Incident #1 – 13.8kV Switchgear

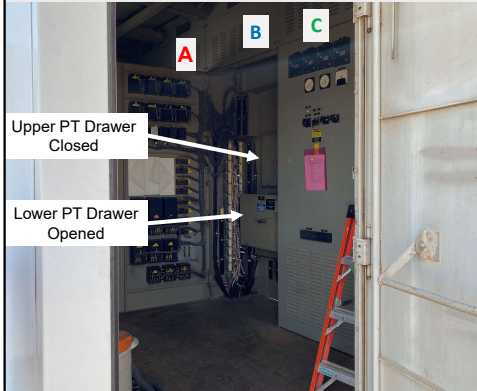


Switchgear consists of 5 cubicles – AA, A, B, C and D

- Bus has three different sources, two feeders and one hard tie to another switchgear
- Main source entering "C" cubicle in an ESWC
- Hard tie in "D" cubicle in an ESWC
- Alternate source entering "A" cubicle is Energized and flagged off (front & back)

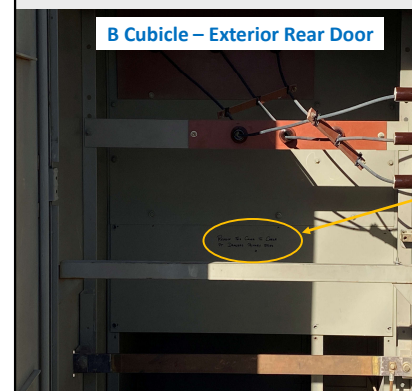


Incident #1 – What Happened?

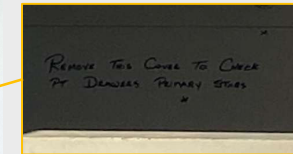


- Electrician's work instructions directed him to "Inspect the stabs in the back of the potential transformers (PT) drawers"
- Two PT carriage drawers are located inside the "B" cubicle
- Unsuccessfully attempted to access the PT stabs from the front of the drawers
- Decided to access PT connections from exterior rear door of "B" cubicle

Incident #1 – What Happened?

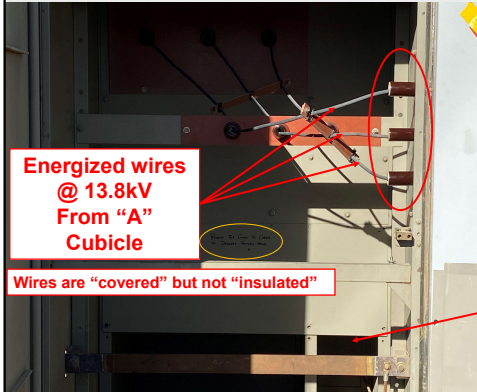


When the rear door of "B" cubicle opened this is what he saw a hand written note



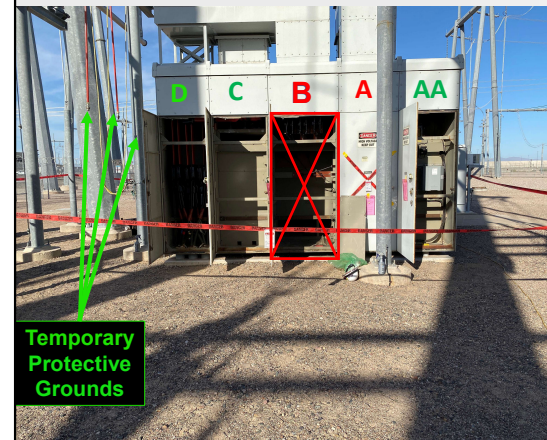
"Remove This Cover To Check PT Drawers Primary Stabs"

Incident #1 – What Happened?

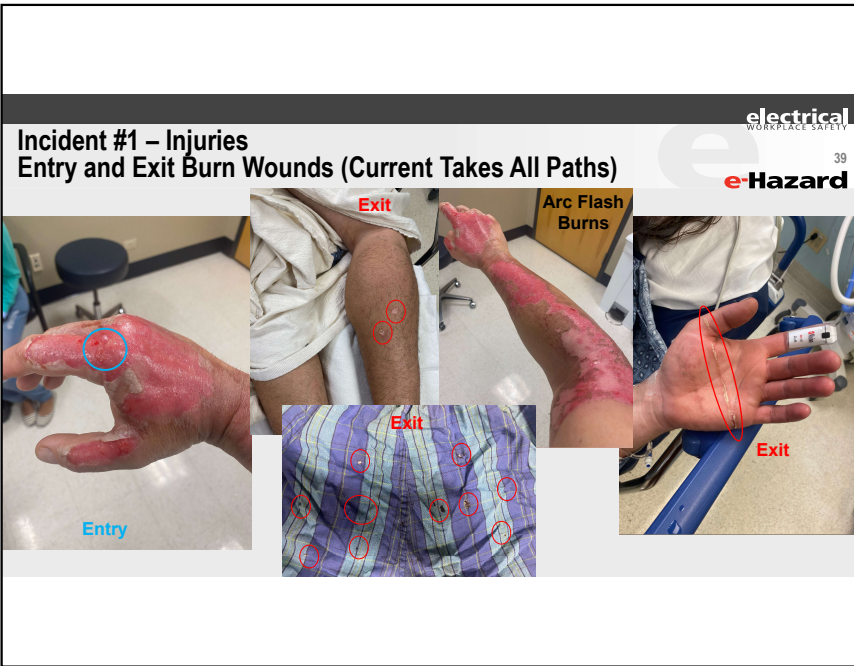
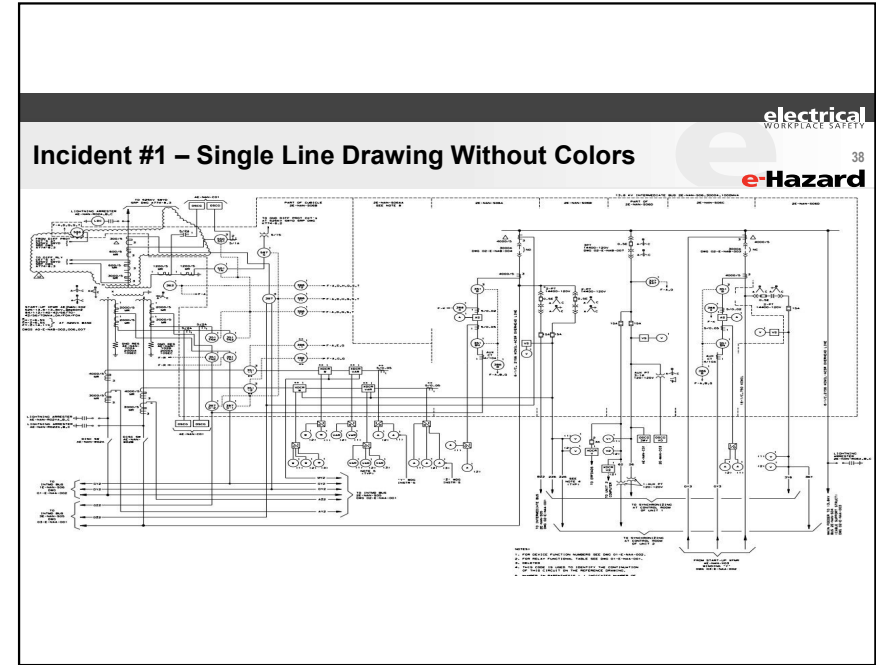
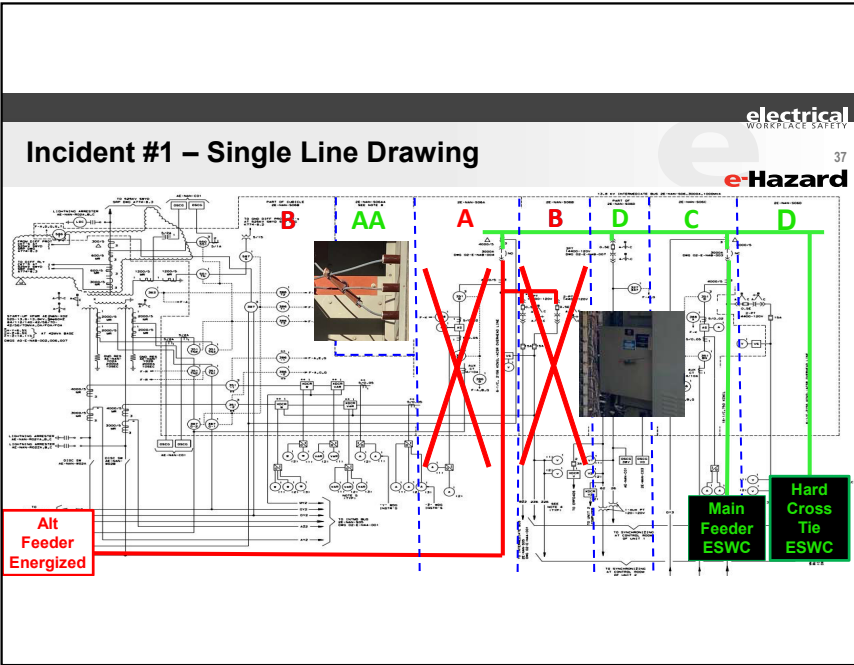


In his desire to do high quality work according to work order instructions and the unauthorized hand written note **HE MISSED THIS**

Removed bottom panel, crawled into the space and nearly lost his life



"B" Cubicle also contained 13.8kV energized parts and should have been flagged off too



Incident #1 – Just Before the Accident

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“I thought about performing another Live-Dead-Live test before reaching up to check the PT stabs, BUT I already did one at the start of the job.”

Statement of Injured electrician while in the hospital

Incident #2 – Why Live-Dead-Live Test Every Exposed Part

April 18, 2020

“Simple and Routine” Job Nearly Caused a Fatality!



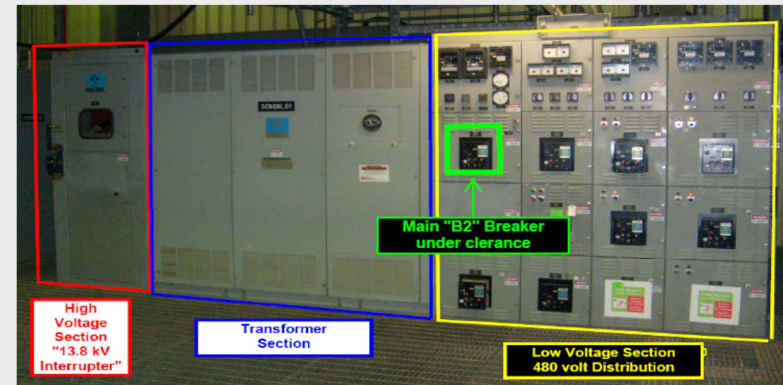
Connect 480V, = 500 kW, 3-Phase Generator



To 480V Low Voltage Switchgear

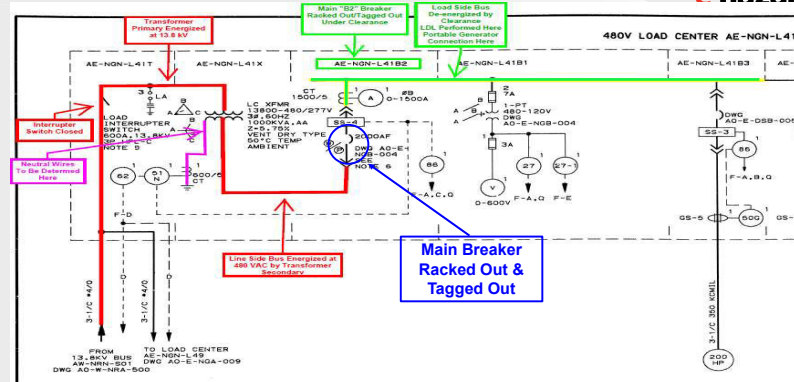
Incident #2 – Parts of 480V Low Voltage Switchgear

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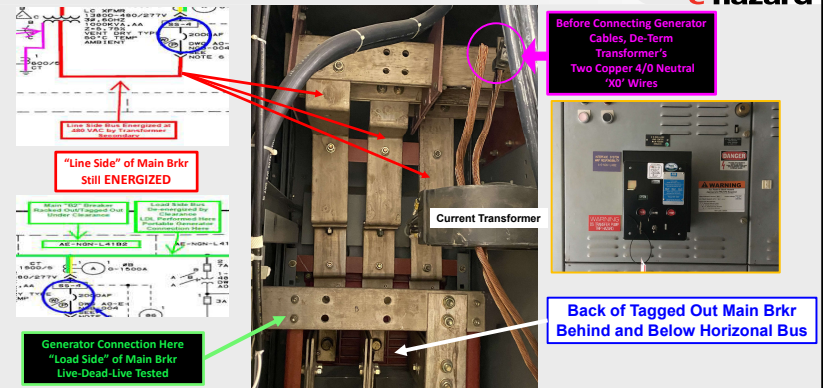
Incident #2 – Single Line Drawing

43

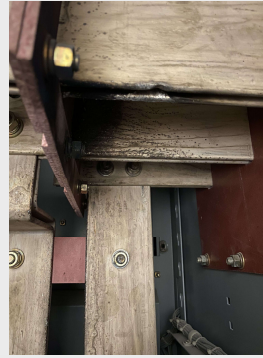
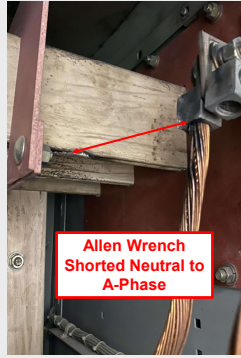


Incident #2 – Bus Segments Inside Rear Main Compartment

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Incident #2 – Bridged Phase-to-Ground



Not An Isolated Case

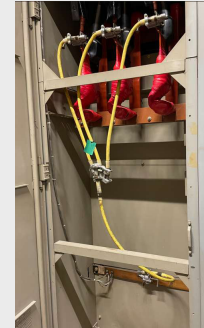
- **May 3, 2015**, experienced electrician at the Los Alamos DOE Testing Laboratory in NM suffered a serious arc flash burns during "routine clean and inspect" of 13.8kV switchgear
- **In 2016**, experienced electrician at an undisclosed US DOD Government facility suffered a serious electric shock when he accessed the wrong cubicle in 13.8kV switchgear
- **April 18, 2020**, experienced electrician working at a water treatment plant in AZ suffered a serious arc flash burn while attempting to connect a portable generator to low voltage (480V) switchgear
- **December 19, 2020**, experienced NETA technician at a university in TX, suffered a serious electric shock when he touched 12.5kV parts inside a switchgear that he was thought was deenergized
- **October 20, 2021**, experienced electrician at a nuclear power plant in WI suffered serious electric shock when he moved to another location to check PTs in 4.16kV switchgear
- **November 16, 2025**, experienced electrician at a nuclear power plant in IL was electrocuted while working on 13.8kV disconnect associated with the Iso-phase bus

Every one of these cases and countless others, if LDL testing was performed/reperformed would have discovered the hazardous voltage thus Prevented The Accidents!

Recommended Instructions To Bridge Gap #2

"Prior to starting work activities, an initial Live-Dead-Live (LDL) shall test each exposed electrical conductor or circuit part within the defined work area to verify the absence of hazardous voltage while wearing the appropriate electric shock and/or arc flash PPE."

"Whenever transitioning from the original work area, e.g. moving from one compartment, enclosure or part of the same equipment to a different area, then an LDL check shall be performed to test every exposed part(s) at each new point of work, unless temporary protective grounds (TPG) are installed and physically visible on the part about to be touched."



*Sources of Electrical Fatalities 2011 – 2021





* Source Electrical Safety Foundation International (ESFI), IEEE ESW2023-12

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Summary & Key Takeaways

- "Phase" only applies to AC circuits, develop clear instructions for DC circuits using "Positive (+) and Negative (-) Polarity or Poles"
- Qualifications are based on training, not job title or college degree
- Ungrounded systems are unique and require understanding of special testing
- Initial Live-Dead-Live (LDL) Absence of voltage testing must be performed correctly before touching any parts – for AC, DC, grounded and ungrounded systems
- Reperform LDL testing whenever moving from one location to another of the same equipment, when returning from breaks and when conditions change
- NEVER assume a part is in an ESWC unless you've tested it yourself or you see TPG physically attached to the part about to be touched
- NEVER become complacent or overconfident because the job is "Routine"
- Ensure your DMM is in the correct setting (AC or DC) and rated for the voltage
- Whenever you're unsure, **STOP!** and ask for assistance (Stop Work Authority)

**Always remember an ESWC is the Last Line of Defense Between
YOUR Life  or YOUR DEATH! **

Thank You And



Live
Long
and
Prosper

&



Rock
On







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Q & A / Discussion



George T. Cole
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Questions?

