Laboratory Safety Handbook
University of Oklahoma, Laboratory for Electrical Energy & Power Systems

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Contents

Chapter 1

Method of Work

1.1 Principles of Electrical Safety

Any laboratory personnel that includes students and faculty may be involved in the fabrication or modification of electrical circuits, taking power measurements and operating electrical switch-gear. All users must appreciate the dangers of electrical hazards that evade most of the human senses including touch, sight, smell and hearing. Mitigating the risks requires all to follow a safety philosophy of common sense and additional controls which will be described in this document. In order to reduce the risk of an electrical incident, this laboratory will follow a strict method of work.

1.1.1 Nature of power systems research

Experimental research in electrical phenomena often leads to unorthodox and unconventional tests and procedures in the pursuit of new discoveries and innovations. Therefore, working in this laboratory entails a high degree of risk since there is often no prior experience in what to expect. This does not mean we should be risk averse and fear the unknown. However, by taking appropriate steps and following approved procedures, the risks and hazards can be effectively managed.

1.1.2 Training and induction

New users of the laboratory must be properly supervised and undergo a safety induction checklist covering basic safety, review of the method of work (this document), emergency procedures and other policies. Sufficient training is required to interact with and operate electrical equipment and not accidentally or intentionally circumvent engineering safety controls.

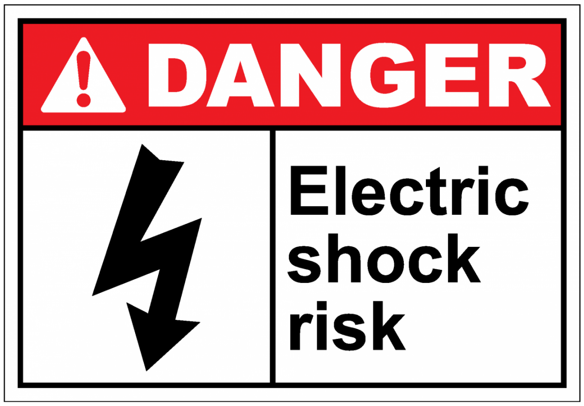

Figure 1.1: Risk of electric shock signage that should be placed near any experimental test circuits

1.1.3 Laboratory Authority

The Laboratory Director, Dr. Paul S. Moses, and the Lab Manager, Wanghao Fei, have full supervision authority over all experimental activities and access in the laboratory in Rooms 210 and 218 (hangar high bay areas). That is, their permission must be sought whenever entering laboratory spaces. The lab director must also be advised and present whenever 208 V three-phase or higher voltage work is being done.

1.1.4 Test before you touch

A fundamental safety control that shall be applied is to verify the circuit and supply is dead to prove an electrically safe work condition. A prove-dead/lock-out checklist will be described in this document.

1.1.5 Working alone

When using mains sources where wiring has been fabricated or modified by laboratory users, it is forbidden to operate these devices alone. In other words, all students must have active supervision by a faculty member before operating such circuits. It is not permitted at anytime to work alone in the laboratory.

1.1.6 Signage

All experimental circuits must have hazard warning signs in plain view, even if the circuit is not energized (e.g., Fig. 1.1). Restricted entry and high voltage enclosure warning signs should be respected by all personnel, whether or not they are a member of the lab (e.g., Figs. 1.2 and 1.3)

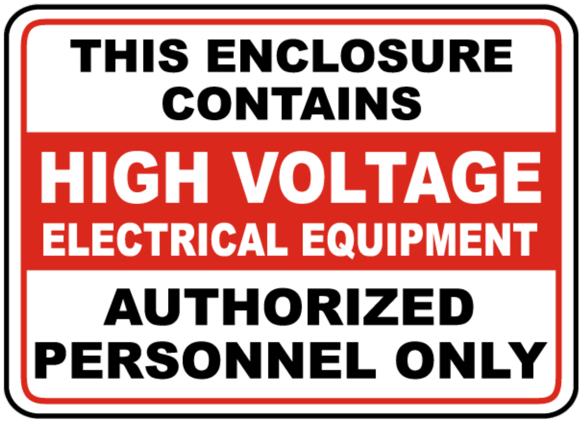

Figure 1.2: High voltage enclosure warning signage that should be used in any testing chamber involving three-phase mains voltages

Figure 1.3: Restricted entry signage that should be located for the benefit of non-lab users to avoid accidental entry

1.1.7 Pilot lights and circuit protection

Where possible, all energized experimental circuits shall be indicated by warning pilot lamps that must illuminate when the circuit is energized or about to be energized. All wiring must conform to gauges following NEC ampacity and be protected by at least two upstream circuit protection (e.g., fuses and breakers). The circuit breaker/fuse size must agree with the wiring capacity.

1.1.8 Live experiments and testing

Where possible, all experimental circuits shall be covered with a minimum of exposed wire and conductors/terminals. The use of banana plugs is recommended where possible and glass/perspex enclosures of test circuits. Before energizing the circuit, someone must independently check the circuit before energizing. It may be necessary to do spot-checks with digital multi-meters while the circuit is operating. Always do so with the approval of the supervisor and use safety gloves if operating with single-phase and three-phase mains voltages. A live experiment should never be left unattended.

1.1.9 Personnel Protection Equipment (PPE)

Safety gloves must be used when moving measurement probes or operating switch gear for three-phase circuits. Safety glasses or eye shields are mandatory for any circuit tests of any mains voltage. Hard hats and high visibility vests may be necessary for operating the crane and high risk activities. Rubber sole shoes are mandatory at all times.

1.1.10 Arc Flash

Watch this short video https://www.youtube.com/watch?v=xV0BYz7Obd4) (warning, this may contain distressing scenes as the person involved did die). This was caused by a misaligned circuit breaker being used in the panel.

Arc flash is becoming a very important area of focus after several incidents like these. Arc flash can occur from poorly designed or degraded switchgear, poor connections, loose wiring, dust contamination and misaligned components.

In my lab, it may be necessary to open electrical panels to effect connections. When doing so, make sure you are supervised, have the appropriate PPE and have made sure the supply is deenergized. At no times will these panels be opened up while energized.

When operating the switches to energize or de-energize a circuit, always face away and do not stand directly in front of the panel. This will reduce the risk of severe injury should the unlikely happen. Always throw switches swiftly and not hold the switch in a partially open/closed state which would raise the risk of arcing.

Figure 1.4: Safety work-flow process that must be incorporated into all experimental procedures

1.1.11 Safety work-flow

When conducting an experiment, the general safety process and workflow of Fig. 1.4 should be followed along with checklist procedures.

1.2 Checklist - Planning Electrical Work

1. Begin a discussion with the supervisor of the scope of work and experimental procedure to be followed.

2. Identify the risks and hazards and make sure everyone has reached an understanding including the following:

   - Do you fully understand the scope of work?
   - Am I trained and qualified to perform this work safely?
   - Have I performed this task before; if not, have I discussed the details with my supervisor
   - Have I thought about possible safety hazards associated with the work and taken steps to protect myself and my team against them?
   - Have I determined whether or not I will be near exposed energized parts?
   - Have I applied a lockout/tagout device?
   - Did I verify protective devices and test equipment are functioning correctly?

- Have I verified the circuits are de-energized?
- Do I know the voltage levels involved and exposure risks?
- Do I have the necessary PPE?
- Do I feel all my safety concerns have been answered?

3. Identify the engineering safety controls
4. Review emergency procedures and shutoff actions

1.3 Checklist: Prove Dead and Lock/Tag out Procedures

To be performed under the supervision of an authorized faculty personnel. The purpose of this procedure is to verify an electrically safe work condition exists before conducting circuit modifications or leaving the work site. It is intended to reduce the risk of shock form (1) residual charge, (2) incorrect isolation of the wrong circuit, (3) unexpected backfeeding from other circuits and (4) mechanical or electrical failure of the isolation device.

1. Install lockout device on main panel master circuit breaker and padlock it
2. Isolate the circuit from at least two main switches and/or visually assure circuit has been disconnected from all energy sources
3. Verify zero ammeter and voltmeter readings on the test setup
4. Use a separate voltmeter for the following zero volt verification (ZVV) tests
5. Verify voltmeter works by testing it on a utility outlet or battery
    - Make sure that the selected voltmeter is on the correct setting (ac/dc) and has a range capable of the highest anticipated voltage of the test circuit
6. Perform ZVV on all terminal combinations and exposed conductors for inputs and outputs of the test apparatus:
    - neutral-to-ground (for single phase circuits)
    - line-to-ground (for single and three phase circuits)
    - line-to-neutral (for single and three phase circuits, if available)
    - phase-to-phase for each phase (for three phase circuits)
    - positive-to-negative (for dc circuits)
    - positive-to-ground (for dc circuits)
    - negative-to-ground (for dc circuits)
7. Test voltmeter again on a known live source to verify its function

Figure 1.5: Always lockout main panel circuit breakers and ensure two line breaks between the point of connection and the source (open-points)

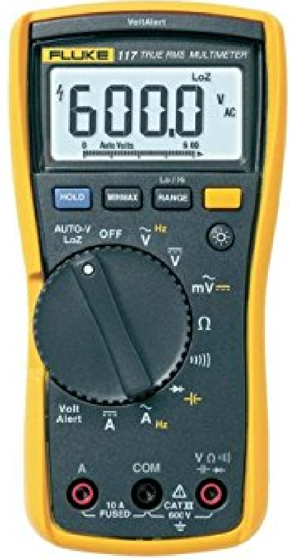

Figure 1.6: Always use verified instruments for proving an electrically safe work condition

1.4 Checklist: General Procedures for Energizing Low Voltage Circuits (50-1000 V_{rms} and 120-1500 V_{dc})

1. Adorne appropriate Personal Protection Equipment (PPE)
    - For Low Voltage circuits, the minimum PPE shall be rubber-sole shoes and safety glasses
2. Before effecting circuit connections, check the circuit is isolated from all energy sources in at least two breaks
    - Energy sources such as mains supplies, batteries and large capacitors should be isolated
3. Verify voltmeters and ammeters are functioning and are set to the appropriate scale
    - If possible, instruments should be positioned so that operator can take readings without having to be near the circuit
4. Verify the correct wire gauge and insulation has been used for the expected current and voltage levels

- Where possible, protect circuits with correctly rated fuses and/or circuit breakers

5. Once wiring is complete, have a faculty supervisor verify the connections and experimental procedure

    - Verify safety ground connections to the apparatus
    - Even if the same circuit is being energized after some length of time, it is necessary to visually check the wiring again (e.g., in case of loose connections or unexpected tampering)
    - Verify plan for quickly removing power should a problem occur

6. Place safety barriers, signage and controls around the test area
7. Commence experiment
8. At the end of the experiment, perform isolation, prove dead and lock/tag out procedures