

DC System Considerations

Workshop 2

Product

- DOE Electrical Safety Handbook Material for Consideration

Focus

- Shock, Arc Flash, Burn Hazards
- DC Hazard Sources
 - Capacitors
 - Power Supplies
 - Batteries
 - PV systems
 - Fuel cells

Approach

- The group proposed several typical DC work scenarios and performed ISM analysis: Hazards, controls, PPE, and other considerations

Example Task Description	Hazardous exposures	Practices	PPE	other
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<p>UPS Battery maintenance and replacement; 240V (+/-) Bank >1kWh Note- See NFPA 70E 320</p>	<p>Shock Burn – High current across tool or jewelry Explosion-short terminals Arc? (note 2) Chemical – must be analyzed for task and equipment</p>	<p>Disconnect from load (sw) Split bank to reduce voltage to 120v or less No work where pos & neg are proximate Add'l barrier if low spacing / replacement problem</p>	<p>Elect/chem. Resis gloves (@ <100v / electric optional) Consider sealed batteries. No jewelry Min. FR clothing</p>	<p>Probe extensions 12” clearance above batteries (70e) Eng best practice – tilt out batteries Non-sparking / insulated rated tools 70e 320.9 IEEE 484 1187 1188 Problem: 70E requires non-sparking / insulated equipment. All equipment may not be available.</p>
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1. Common to all the DC systems is the use of contactors , relays, breakers and disconnect switches. These must be specifically listed and rated for the DC service encountered.
2. 500amp AND 250 V probable lower threshold for arc flash injury

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<p>Assembly / maintenance of PV array</p> <p>Test/measurement</p> <p>300-400v</p> <p>7-100 amps</p>	<p>Shock</p> <p>ARC FLASH</p> <p>N/A</p> <p>Non-DC interface-system tie, etc</p>	<p>Last connection at/near middle of bank – reduces current</p>	<p>V- gloves</p> <p>V—tools</p> <p>eye prot, hard hat, etc as applicable</p>	<p>Need best practice ppe guidance</p> <p>NEC 690</p>

Example Task Description	Hazardous exposures	Practices	PPE	other
misc equipment testing < 600V HI current / lo voltage, >1kW PS	AC service Current to 1000's of amps– burns Capacitors- to kJoules Arc flash hazards	Guard terminals	Gloves Gen';l ppe as needed	

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<p>As above, >600V@5mA or more</p>	<p>Capacitance in DC cable – stored energy 30pF / ft painful shock only (startle) Unguarded BNC connector – possible 500v shock Floating PS / connectors- non-grounded outer conductor X-ray @ vacuum UV</p>	<p>Short out cables when disconnecting – shorting plug eng. Control – bleeder resistors; interlock switches, Crowbar interlocked to line power. Voltage test Verify w/ HV probes if possible Hard ground/short for verification Labeling/ Safe out / Guarding/ Eng. Control shielding</p>	<p>Gloves if handling live cables V-rated grd stick ~10 kJ; Ear prot. UV eyewear</p>	<p>BNC=500v SHV=5kV MHV hazard – can cross connect to BNC Consider active noise canceling ear protection</p>

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Cap bank testing and safing	<p>Arc- how to calculate? Lloyd method (LNL), SLAC method? Blast Shock – depends on voltage Explosion- joule value</p>	<p>LOTO charging system. Eng controls: Observable crowbars and resistors. Time constant 10 sec to minutes- slow access by adding bolts, panels, etc. Less desirable: procedures, signs</p>	<p>(Oberon has 100cal ballistic suit.) Face shields, ear prot, safety glasses, Ground hook – hard / soft</p>	<p>Grounding may be part of LOTO verification Must detect for open elements w/capacitance meter – depends on total energy and design of bank.</p>
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<p>Inductor Unplanned disconnection- Superconducting Research Magnet Synchrotron Dipole Magnet</p>	<p>High voltage shock- uncontrolled voltage Hi Magnetic field- normal use With superconductor, you cannot assume a fast discharge when power is removed.</p>	<p>Snubbers – limit voltage to a few volts Administrative- training Built in volt & ammeters Not 100% reliable Can measure @ current measuring resistor Restrict magnetic tools</p>	<p>N/A Note- Non elect ppe require: cryogenic hazards</p>	<p>No medical implants, pacemakers, etc.</p>

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Fuel cells-test/measurement	Little energized exposure Shock hazard depends on how many are stacked Ex: 200kW/240-480V Arc hazard-relatively safe (see note 2)	Eng.controls-guarding terminals	Verification risk low v-Gloves, tools general industrial hazard -ppe as appropriate	Easy to de-energize – turn off reactants.