HIERARCHY OF RISK CONTROL METHODS

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ELECTRICAL SAFETY CONSULTING

ELECTRICAL SAFETY BULLETIN

Occupational health and safety management system Standards (e.g. ISO 45001, CSA Z45001, ANSI Z10, OSHA Guidelines, etc.) and related risk assessment standards (e.g. ISO 31000, CSA Z1002, etc.) outline credible processes for workplace hazard identification and risk assessment (HIRA).

With respect to electrical hazards and NFPA 70E or CSA Z462 an employer's compliant Electrical Safety Program shall include a Risk Assessment Procedure that:

1. Identifies when workers are exposed to electric shock or arc flash hazards (e.g. Job assigned and discrete work task(s) that will be performed);
2. Assess risks (e.g. potential severity of injury or damage to health and likelihood of occurrence); and
3. Implement risk controls according to the hierarchy or risk control methods to eliminate exposure or reduce risk to as low as reasonably practicable (ALARP).

As outlined in NFPA 70E Article 110.3(H)(3) or CSA Z462 Clause 4.1.7.8.5 the following six (6) risk control methods are identified and shall be implemented in the hierarchy listed.

1. Elimination;
2. Substitution;
3. Engineering Controls "Safety by design," "Prevention Through Design (PtD)";
4. Awareness;
5. Administrative Controls (e.g. training and procedures); and
6. Arc Flash & Shock PPE, Tools & Equipment.

Not all hierarchy or risk control methods will be applicable depending on electrical equipment maintenance requirements (e.g. working on energized electrical equipment is justified and authorized), technical feasibility and costs. If elimination is not applicable then the remaining five(5) risk control methods shall be considered.

With respect to likelihood of occurrence a primary focus needs to be qualifications and competency of the Qualified Person, human performance/human error (e.g. culture and behavior) and condition of electrical equipment maintenance.

The table below provides a generic list of electrical hazard related hierarchy or risk control methods that are considered when completing a qualitative risk assessment for the energized electrical work task inventory for an employer's workplace.

An employer's Electrical Safety Program should include an Electrical Safety Design Basis Memorandum to influence capital projects or major electrical equipment retrofit projects. A cost benefit analysis is required for any risk control method specified.

Table 1 – Electrical Safety Hierarchy or Risk Control Methods

Risk Control Method	Description	Comments
Elimination, Isolation, Zero Energy State	Occupational health & safety Regulations require hazardous energy sources to be identified and eliminated as a priority. A zero-energy state should be established and verified before any work is completed without PPE. Reference "Substitution with Safer System, Processes, or Electrical Equipment" below where an indicated risk control method will eliminate exposure to electric shock or arc flash.	Follow [Company] lockout tagout program/policy/practices and related procedures. As a priority Establish an Electrically Safe Work Condition before initiating any repair or alteration work tasks as required by CSA Z462. Testing for absence of voltage is energized electrical work.
Substitution with Safer System, Processes, or Electrical Equipment	Specify Arc Resistant Electrical Equipment (high voltage or low voltage) and arc free/arc resistant low voltage MCCs. Specify low voltage MCCs as "arc free" or "arc resistant designs" with rackable motor starter buckets. Specification of gas insulated switchgear (GIS). Consider fuse-based protection vs molded case circuit breakers. Specific high resistant grounding (e.g. NGR). Installing smaller kVA transformer and higher impedances. Change control voltages from 120VAC to 24VDC.	Can eliminate exposure to arc flash and/or electric shock.

Risk Control Method	Description	Comments
	Specify “Bluetooth” enabled test instruments to be used for inserting into energized electrical equipment for taking voltage or current measurements for trending data. Lowers frequency of exposure. Specifying view windows on electrical equipment doors for internal inspection without opening the door and/or confirming visible disconnect is in open position.	
Engineering “Safety by Design,” Prevention Through Design (PtD)	Proper specification of electrical equipment load break vs non-load break rated. Additional insulation, finger safe components, guarding, , covers and barriers. Increase the size of electrical rooms to allow more working space around low and high voltage switchgear back and front than minimum Code requirements. Ensure all electrical equipment when manufactured has large legible ID signage, front and back and all sections include a section # front and back. Fill space factors in panelboards and MCCs full of typical sized spares to limit any need for adding them after commissioning. Specify the “Main Breaker” section of an MCC as a low voltage SWGR section with rackable main breaker. Specify ALL front or rear access doors to electrical equipment as hinged doors, not bolt on covers. Ensure lighting levels for all electrical equipment are designed to provide adequate work task lighting. Ensure “ground ball studs” are designed and included on single line diagrams, specified and installed for ease of installation of temporary protective grounding clamps. Specify current-limiting devices. Specify IR scanning windows and ultrasonic ports.	Eliminate exposure to electric shock. Eliminate or reduce the likelihood of an abnormal arcing fault occurring. Limit faults to single phase to ground. No requirement to open hinged door or remove bolt on cover. Target incident energy reduction for 75, 100 or 140 cal/cm^2. Where technically feasible attempt to achieve incident energy level as low as possible.

Risk Control Method	Description	Comments
	Specify disconnect switches with view window. Design includes appropriate interlocks. Ensure “panic hardware” is specified on the inside of all doors for defined electrical rooms. Following the completion of an incident energy analysis review the results and reduce incident energy levels >75, 100 or 140 cal/cm^2. Target incident energy ≤75.0 cal/cm^2. Installation of permanently installed supplemental absence of voltage Test Portals or Automatic Voltage Testers (AVTs). Remote racking or on-board racking for low and high voltage switchgear. Remote opening and closing of circuit breakers when deemed in an abnormal equipment condition or when designed into the electrical equipment operating from control system HMI. Real time electrical equipment temperature sensor or IR monitoring. Increasing the working distance. Manual racking tools extended in length or use Amydyne “Extend-a-Rack”. For more complex power systems consider other protective device relaying schemes: 1. Zone-Selective Interlocking (ZSI). 2. Differential Relaying. 3. Consider lockable maintenance mode reduction switches to reduce incident energy when energized electrical work tasks are required to be completed. 4. Arc Flash Detection Relay. 5. Energy-reducing Active Arc Flash Mitigation System. 6. Blown Fuse Operation for Switches.	
Warning Signs and Barricading	Install door signage on defined Electrical Room doors. “Danger High Voltage,” “Danger 4160V,” or “Danger 600V” etc. “Danger Authorized Personnel Only.” Also include electrical ID signage e.g. BU-100, Electrical Room 100, etc..	Comply with regulations. Reinforce policy and training of workers with signage.

Risk Control Method	Description	Comments
	Install “Danger High Voltage” signage on high voltage electrical equipment. Install Arc Flash & Shock Warning Equipment Labels or provide “Arc Flash Hazard Results Tables” from the arc flash hazard incident energy calculation report. Ensure an Electrical Work Zone is created with barricading (e.g. red “Danger” tape).	Keep unprotected workers out of the work area and eliminate potential for interruption of work.
Administrative	Follow the policies, practices and procedural requirements of the Electrical Safety Program. Include specific policies e.g. Working Alone, No Jewelry, Non-Conductive Side Rail Ladders, Energized Electrical Work Permit, use of Energized Electrical Job Safety Planning form, etc. Ensure single line diagrams are as-built and available for reference. Ensure panel schedules are as-built and legible. Ensure all defined electrical rooms have unique ID # and descriptions installed on the outside of all doors. Additional signage should indicate “Danger Authorized Personnel Only” and “Danger 4160V, Danger 600V, etc.” Manage human performance to limit potential for human error. Provide safe installations training when updated NFPA 70 or CE Code Part I Standards are updated. Provide generic Arc Flash & Shock training to QEWs, TQWs & QIWs, including emergency release of an electrically shocked worker. Provide lockout/tagout program training to appropriate workers. Provide Electrical Safety Program Roll Out Orientation Training (ROOT) to appropriate workers.	Qualification training provides knowledge to be applied to electrical hazard identification and the required hierarchy of risk controls methods to be applied to reduce risk. Competency is separately validated/verified by the employer. Ensure HR policies, practices and processes consider “human performance” and controls to mitigate or reduce likelihood of human error. Manage human error pre-cursors. Training on policy and practice requirements ensures workers understand their roles and responsibilities. Where required the use of an Electrical Safe Work Procedure can reduce likelihood of occurrence, ensures consistency, knowledge transfer and retention. Can be used to “refresh” competency.

Risk Control Method	Description	Comments
	Provide Electrical Safety Awareness training to appropriate Non-Electrical Workers. Develop and use Electrical Safe Work Procedures when required for complex jobs, unique electrical equipment, knowledge retention and consistency of execution. Develop and implement of formal Electrical Equipment Maintenance Program. Use an Electrical Safety Design Basis Memorandum to influence "Substitution," "Safety by Design/Prevention Through Design (PtD)" for all capital projects and electrical equipment retrofit projects. Use electrical equipment engineering specifications that stipulate "Substitution," "Safety by Design/Prevention Through Design (PtD)" where technically feasible and considering cost benefit to incident energy reduction. Install 8.5 X 11 "Notice" signage on arc resistant electrical equipment, and electrical equipment that includes incident energy reduction safety by design options for alertness to all workers and to enforce procedural requirements.	Ensure electrical equipment maintenance requirements are defined, are approved, budgeted for and implemented.
Arc Flash & Shock PPE, Tools and Equipment	Potential severity of injury or damage to health is managed with the application of appropriate arc flash & shock, PPE, tools and equipment. Exposure to electrical hazards can be eliminated or to a recoverable residual injury. Some arc flash & shock PPE can actually contribute to a reduction in likelihood of occurrence (e.g. probe extenders, arc flash suit hood ventilation system that brings fresh air to the front of the hood, proving unit, etc.). Use temporary guarding of exposed energized conductors and circuit parts when required (e.g. rubber insulating blankets or line hose) for low and high voltage enclosed and OH electrical equipment.	Note: Specific two arc-rated arc flash PPE levels, everyday/task wear and arc flash suit. Specify other tools and equipment that improve comfort (e.g. cotton liner gloves worn under rubber insulating gloves), arc flash suit hood ventilation system that brings fresh air to the front of the hood, light weight arc flash suits, etc.). Procure arc flash PPE with specific requirements to

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	Specify “escape strap” on arc flash suit jacket or “escape strap” vest to be used for emergency release of an electrically shocked worker or a worker that is exposed to arc flash. Specific magnetic red “Danger” tape to simplify the set-up of an Electrical Work Zone (e.g. www.uline.com).	ensure quality and performance features are procured (e.g. true color grey lens, “Escape Strap”). Ensure proper storage of arc flash & shock PPE, tools and equipment. Manage inventory. Need to ensure dielectric testing of rubber electrical protective equipment/hot sticks and temporary protective grounds, pre-use checks/inspections, care, use and maintenance.

RELEVANT RESOURCES

FREE DOWNLOADS

https://twbesc.ca/esp-free-tools

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