Engineering

Technical Standard

TS 0371 : Arc flash hazard assessment and design aspects

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Documents superseded by this standard

The following documents are superseded by TS 0371:

a. TS 0371, Version 2.0.

Significant/major changes incorporated in this edition

Updates in this version of the Technical Standard include:

a. Updated in accordance with the SA Water Technical Standard Template Version 8.0 and the SA Water Style and Writing Standard Version 2.0.

b. Internal references updated.

c. Sec 8.4 – Minor addition to the application of arc fault mitigation schemes for clarity of application.

d. Sec 8.8 – Minor deletion of the requirement above Category 2 and the application of devices independent of protection relays. Added a requirement for consultation with SA Water for integration of such devices.

Document controls

Version history

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1.0	24-09-2020	J. Hamra	First Issue
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Justin Hamra	Principal Electrical Engineer	3.0	13-08-2024

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1 Introduction

SA Water is responsible for the construction and commissioning of an extensive amount of engineering infrastructure such that it is safe and functional.

This standard has been developed to assist in the design, maintenance, construction, and management of this infrastructure.

Arc Flash is a destructive and potentially life-threatening type of electrical fault caused by unintended or accidental connection of energised conductors and/or earth. The result is an explosive release of energy, which is sufficient to melt conductors and change the surrounding air from gas to conductive plasma.

1.1 Purpose

The purpose of this standard is to:

a. Detail a basic understanding of arc flash terminology.

b. Provide an effective arc flash classification process.

c. Recommend industrial practices to minimise the risk of arc flash hazards.

d. Provide a guide for the appropriate selection of personal protective equipment against the activity being undertaken.

e. Outline arc flash cautionary label specifications and application.

f. Provide principles on switchboard design and configuration.

g. Detail arc flash assessment study report requirements.

1.2 Glossary

The following glossary items are used in this document:

Term	Description
AC	Alternating Current
AR	Arc Rated
AREP	Auxiliary Winding Regulation Excitation Principle (Generator type)
ATPV	Arc Thermal Performance Value
BESS	Battery Energy Storage System
CAD	Computer-Aided Design
ETAP	Electrical Transient and Analysis Program
FCL	Fault Current Limiter
HRC	High-Rupturing-Capacity
HV	High Voltage
LV	Low voltage
PLC	Programmable Logic Controller
PPE	Personal protective equipment.
PTW	Power Tools for Windows
RCD	Residual Current Device
SA Water	South Australian Water Corporation
TDRF	Technical Dispensation Request Form
TS	SA Water Technical Standard

Term	Description
VSD	Variable-Speed Drives

1.3 References

1.3.1 Australian and international

The following table identifies Australian and International standards and other similar documents referenced in this document:

Reference	Title
AS/NZS 3000	Wiring Rules
AS/NZS 3008.1.1	Electrical Installations – Selection of cables Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions
AS/NZS 3439.1	Low Voltage Switchgear and Control gear Assemblies – Part 1: Type- tested and partially type-tested assemblies
AS/NZS 60076.5	Power Transformers Part 5: Ability to withstand short circuit
AS/NZS 61439.1	Low Voltage Switchgear and Controlgear Assemblies – General Rules
AS/NZS 61439.2	Low Voltage Switchgear and Controlgear Assemblies – Power switchgear and controlgear assemblies
AS 62271.200	High Voltage Switchgear and Control gear – AC Metal-enclosed Switchgear and Control gear for Rated Voltages Above 1kV and up to and Including 52kV
Energy Networks Australia – NENS 09	National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazards.
IEC 60909-0	Short-circuit currents in three-phase AC systems – Part 0: Calculation of currents
IEC TR 61641	Enclosed low-voltage switchgear and controlgear assemblies – Guide for testing under conditions of arcing due to internal fault
IEEE 1584	Guide for Performing Arc-flash Hazard Calculations
IEEE 1584.1	Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584
NFPA 70E	Standard for Electrical Safety in the Workplace.

1.3.2 SA Water documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Reference	Title
TS 0101	Safety in design
TS 0105	Quality requirements

1.4 Definitions

The following definitions are applicable to this document:

Term	Description
Accepted	Determined to be satisfactory by SA Water's Representative.
Accuracy	The level of closeness of an estimated value – measured or computed – of a quantity to its true or accepted value.
Arc Flash Boundary	The arc flash boundary is the distance from live parts outside of which a person without Arc Rated PPE cannot receive anything greater than a second-degree burn. Outside of the boundary, the assessed energy levels are below 1.2 cal/cm^2. Within the boundary, the energy levels are 1.2 cal/cm^2 or above.
Arc Flash Hazard	A dangerous condition associated with the possible release of energy caused by an electric arc.
Arc Rated PPE	Clothing specified with an ATPV (Arc Thermal Performance Value) expressed in calories per centimetre squared. AR PPE with an ATPV has been specifically tested to provide protection against electrical arcing faults.
Arcing Fault Current	A fault current flowing through an electrical arc plasma. Also referred to as arc fault current or arc current.
ATPV	Arc Thermal Performance Value is the maximum incident energy on a fabric or material that will result in sufficient heat transfer through the fabric or material to cause the onset of anything more than a second degree burn that occurs for energy levels 1.2 cal/cm^2 or above.
Bolted Fault Current	An expected fault current flows where there is close to zero resistance or impedance in the fault path.
Constructor	The organisation responsible for constructing and installing infrastructure for SA Water whether it be a third party under contract to SA Water or an in-house entity.
Contract	A set of documents supplied to the Constructor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.
Designer	The organisation responsible for designing infrastructure for SA Water, whether it be a third party under contract to SA Water, a Constructor, or an in-house entity. A Designer is a person who effects design, produces designs or undertakes design activities as defined in the *Work Health and Safety Act 2012 (SA)*.
Fault Current	The theoretical amount of current delivered at a point on the system during a short-circuit condition.
Incident Energy	The amount of energy impressed on a surface, a certain distance from the source, during an electrical arc event. Incident energy is measured in either calories per centimetre squared (cal/cm^2) or joules per centimetre squared (J/cm^2).
Inspection	Measuring, testing or examining of Works, materials or goods or services (includes raw materials, components and intermediate assemblies) for determining conformity with the Requirements.
Manufacturer	A person, group, or company that owns and operates a manufacturing facility that provides materials for use in SA Water infrastructure.
Primary Protection	The fastest protection relay and/or circuit breaker combination to detect and clear an electrical fault.
Qualified Person	One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.
Requirement	Need or expectation that is stated within the Contract.

Term	Description
Responsible Discipline Lead	The engineering discipline expert identified in the 'Approvers' table (via SA Water's Representative).
SA Water Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): a. Superintendent's Representative (e.g. AS 4300 and AS 2124 etc.) b. SA Water Project Manager. c. SA Water nominated contact person.
Shall and Should	In this standard the word "shall" indicates a requirement that is to be adopted in order to comply with the standard. The word "should" indicates practices which are advised or recommended.
Technical Dispensation Request Form	This form is part of SA Water's Technical Dispensation Request Procedure which details the process by which those required to comply, or ensure compliance, with SA Water's technical requirements may seek dispensation from those requirements.
Terminology	a. Where an obligation is given and it is not stated who is to undertake these obligations, they are to be undertaken by the Constructor. b. Directions, instructions, and the like, whether or not they include the expression "the Constructor shall" or equivalent, shall be directions to the Constructor, unless otherwise specifically stated. c. Where a submission, request, proposal is required and it is not stated who the recipient should be, it is to be provided to SA Water's Representative for review. d. Each word imparting the plural shall be construed as if the said word were preceded by the word "all". e. Each word implying persons shall, where appropriate, also be construed as including corporations. f. "Authorised", "approval", "approved", "selected", "directed" and similar words shall be construed as referring to the authorisation, approval, selection, or direction of SA Water's Representative in writing. g. "Allow" shall mean that the cost of the item referred to is the responsibility of the Constructor. h. "Provide" shall mean "supply and install". i. "Submit" shall mean "submit to the SA Water Representative or their nominated delegate." j. Submissions, requests, proposals are to be provided at least ten (10) business days prior to work commencing or material ordering (unless noted otherwise). k. "Informative" shall mean "provided for information and guidance."
Work	Elements of a project which require design and/or construction.
Working Distance	The dimension between the potential arc point and the head and body of the worker positioned to perform the assigned task. (455 mm – 18 inches for LV and 910 mm – 36 inches for HV up to 15kV).

2 Scope

2.1 Scope and application of this Technical Standard

This Technical Standard covers aspects of the general requirements for the design, review, and maintenance of SA Water's state-wide electrical power assets.

It defines the accepted SA Water practices for performing arc flash hazard calculations and assessments for HV and LV equipment in power systems. This includes:

a. HV and LV switchboards.

b. Power equipment switchgear.

c. Power factor correction equipment.

d. Motor starters and variable speed drives.

e. Harmonic filters.

f. DC Auxiliary Power Supplies.

g. Any other asset containing HV or LV power equipment.

The categorisation of instrumentation and control panels is not required.

The arc flash hazard assessment methodology detailed in this document shall be undertaken during both the engineering design stage and for evaluation of existing equipment. This Technical Standard applies to both new installations and any changes to an installation that are likely to affect the arc flash incident energy levels of existing switchboards or electrical power equipment or for the review of such equipment.

The main aim of this Technical Standard is to provide electrical systems that exhibit safe levels of arc flash through reasonable application of these principles.

Control, instrumentation and SCADA cubicles do not require arc flash analysis or categorisation.

This Technical Standard has been developed to assist in the design, maintenance, installation, and management of this infrastructure. It should be read in conjunction with the associated project specification, drawings and any documents annexed to the project specification. The provisions of this Technical Standard shall apply unless they are specifically deleted or amended in the project specification or drawings, which shall then take precedence.

SA Water encourages and welcomes suggestions as to the improvement of this standard for future releases. These suggestions should be passed through to the SA Water Principal Electrical Engineer.

The currency of this document should be checked prior to use.

2.2 Works not in scope

N/A

2.3 Technical dispensation

Departure from any requirement of this Technical Standard shall require the submission of a Technical Dispensation Request Form (TDRF) for the review and approval (or otherwise) of the SA Water Principal Engineer on a case-by-case basis.

The Designer shall not proceed to document/incorporate the non-conforming work before the Principal Engineer has approved the proposed action in writing via the Technical Dispensation Request Form (TDRF).

SA Water requires sufficient information to assess dispensation requests and their potential impact. The onus is, therefore, on the proponent to justify dispensation request submissions and provide suitable evidence to support them.

Design works that are carried out without being appropriately sanctioned by SA Water shall be liable to rejection by SA Water and retrospective rectification by the Designer/Constructor.

2.4 Hazards

Hazards shall be identified and addressed in accordance with TS 0101.

3 Design criteria

The design criteria must be ascertained and agreed upon with SA Water or its representative during all stages of investigation, concept design, and detailed design to achieve a value-for-money installation that is functional and has minimum or negligible risks to SA Water. The design criteria should consider the following aspects:

a. Safety considerations:

The installations are to be designed for the safety and welfare of construction, operation, maintenance, and the general public, complying with statutory regulations. Wherever possible, electrical equipment and wiring should not be in areas classified as hazardous.

b. Life cycle costs:

Designs should be innovative and incorporate the appropriate techniques and technology, in conjunction with the selection of appropriate equipment, to minimise the life cycle costs while satisfying operational functionality and process risk management and maintenance requirements. Energy consumption must be given particular attention in this respect.

c. Security of operation:

Designs should consider the failure of a single item of equipment or a fault in a particular area of an installation is confined to the associated part of the installation and does not affect the continuous operation of the remaining parts of the installation, where possible.

d. Reliability:

The installations are to be designed to minimise the likelihood of a failure, taking into consideration the electricity supply characteristics, ambient conditions, load characteristics and operation and maintenance requirements.

e. Upgradability:

The installations are to be designed to facilitate future upgrades, where applicable.

f. Interchangeability:

The installations are to be designed to maximise the interchangeability of components and assemblies as far as practical to improve flexibility and reduce the spare parts inventory.

g. Operation, maintenance, and fault-finding facilities:

The installations are to be provided with suitable and adequate facilities to allow ease of operation, maintenance and fault finding.

h. Environmental considerations:

The installations are to be designed and suitable equipment selected to avoid or minimise unacceptable impact on the environment, as far as possible.

3.1 Arc fault verification requirement

All switchboards shall be designed to provide personal protection in the event of an internal arcing fault.

The assembly shall limit the damage of the switchboard to the section affected by the fault, thus allowing the unaffected part to be put back into service.

LV assemblies with a rating of arc flash category 3 or above and all HV assemblies shall be verified with respect to their ability to withstand internal arcing. The manufacturer shall confirm the successful assessment in accordance with either Appendix ZD of AS 61439.1(LV) and IEC62271.200 (HV) or as per the criteria specified in IEC TR 61641, Criteria 1 to 7. Test reports or certificates issued by certified independent testing laboratories should be made available in the predesign stage.

The prospective fault currents shall be used for designs and are to be based on the worst-case operating scenarios, with a contribution that can be expected from any connected load. When specifying new assemblies, the 'ultimate' fault current contribution from the utility should be allowed in the calculations; yet, for assessment of existing assemblies, the 'maximum' fault current will suffice.

3.2 Design expectations

As part of a detailed design, the Designer is expected to undertake the following design activities as a minimum:

a. Site investigations to gather all required information and data to develop a site power systems model and undertake arc flash assessment studies where:

   i. Existing model data or raw data exists; it will be provided by SA Water. However, it is the responsibility of the Designer to confirm the accuracy of the model prior to use.

   ii. Model data does not exist; the Designer shall seek all data and develop a new model.

b. Perform and submit an arc flash assessment report in accordance with this Technical Standard, including calculations, arc flash category ratings, photographs of relevant existing assets, relevant sections of equipment manuals, arc flash label templates and any required protection setting changes, such as, upstream to reduce the arc flash risk to as low as is reasonably practicable.

c. Submit native data files of the power systems model developed and arc flash calculations carried out for future use, for example, SKM PowerTools, PowerCAD, etc. to SA Water as part of the project completion documentation. This may include data files in Excel or CAD file format. Drawings of single-line diagrams should include data such as cable sizes and lengths, protection relay model numbers, circuit breaker models/types/basic settings and basic transformer and generator parameters. Cable schedules, protection relay settings and protection reports should be provided in an easily editable format, such as Excel.

d. For brownfield sites, if it is found during the detailed design stage that the arc flash or reticulation philosophy requirements cannot be achieved, the Designer shall engage with the Superintendent's Representative (SA Water's Representative) to discuss the options available and agree on an approach, that is, to reduce the arc flash risk, within the scope of the upgrade project.

It is recommended that arc flash studies be updated when a major modification or renovation takes place and at intervals not exceeding five (5) years.

4 Methodology

This section outlines the preferred methodology for the calculation of arc flash parameters for SA Water's 'existing' and 'proposed' assets. It is expected that some rigour be applied when specifying parameters relating to the configuration of existing assemblies. Opting for 'worst-case' scenarios around assembly configurations may lead to unjustifiably high energy levels.

4.1 General

Although consideration of arc faults is a requirement of AS/NZ 3000, there is currently no clear regulatory framework for the calculation and assessment of arc fault hazards in Australia other than the recommended guidelines provided by *Energy Networks Australia – NENS 09 – National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazards*.

The current accepted practice in Australia is to apply the internationally accepted calculation methods provided in the latest revision of IEEE-1584 (*Guide for Performing Arc Flash Hazard Calculations*) to determine arc flash incident energy levels. A guide for the scope and deliverable requirements of this calculation method can be found in the latest revision of IEEE-1584.1 (Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584)

Once the incident energy levels are established, the equipment can be given an arc flash hazard classification. Classifications have been derived from standards such as the American *National Fire Protection Association standard NFPA 70E – Standard for Electrical Safety in the Workplace*.

It is important to note that incident energy calculations and the resultant arc flash classification represent the worst-case situation. It represents the hazard present with equipment doors or panels open and busbars or conductors exposed to personnel. It does not consider the reduction of risk when panel doors/panels are securely closed, nor of arc-rated switchgear or switchboards where the arc blast is either contained or safely re-directed. **The impact of these and other arc mitigation measures on equipment classification should be carefully assessed on an individual basis.**

Personal Protective Equipment (PPE) requirements in relation to arc flash have been determined from both NFPA 70E and NENS 09 standards and have been considered as industry norms in the development of this Technical Standard.

4.2 Calculation method

Calculation of the arc flash incident energy at each location in an electrical network requires detailed analysis and calculation of short-circuit fault levels throughout the network. Although this may be determined by hand for simple systems, for more complex systems, it is common practice to calculate through electrical modelling software. For complex systems with multiple operating scenarios, many electrical modelling software packages allow the IEEE-1584 calculations to be performed in software. There are several modelling software packages that are used to create power system models and perform arc flash hazard assessments. For example, SKM Power Tools for Windows (PTW), Electrical Transient and Analysis Program (ETAP), DIgSILENT, PowerCAD and EasyPower.

4.3 Collection of power system data

The available fault currents at different locations in the electrical network are dependent on the capability of the main power supply to provide and sustain a short circuit. The fault current contribution should be confirmed with the power supply utility under the following conditions:

a. Maximum (or ultimate) three-phase symmetrical fault level and corresponding X/R ratio.

b. Minimum three-phase symmetrical fault level and corresponding X/R ratio.

4.3.1 Generators (alternators, solar PV, BESS)

For power systems fed via local generation permanently installed at a site, the following data should be collected:

a. kVA rating and power factor values from the nameplate.

b. Impedance characteristic.

c. Details of excitation system and field forcing, if applicable, such as AREP.

4.3.2 Transformers

The following information should be collected for transformers:

a. Primary and secondary voltage ratings.

b. Vector group.

c. kVA rating.

d. Tap position.

e. Transformer impedance (%Z) and X/R ratio.

In the absence of impedance details, typical values per AS/NZS 60076.5 may be used.

4.3.3 Cables

In general, the data for the following cables should be collected:

a. Main cable from the utility connection up to the site's main switchboard.

b. Cables used to provide alternate supply sources, such as generator cables.

c. Cables supplying sub-distribution boards and feeding significant motor loads.

Once the data for the power cables has been collected, the relevant electrical parameters (cable impedance) should be obtained from the cable manufacturer's catalogue or standard cable parameters listed under AS/NZS 3008.1.1.

4.3.4 Protective devices

The time taken by the protective device to interrupt an arcing fault on the downstream circuit is a critical factor in incident energy calculations. The protection settings and trip characteristics of the primary, backup, and largest outgoing feeder protection overcurrent device should be obtained from design documents for new installations and data from the site and existing protection relay settings for existing installations.

4.3.5 Switching points

All switching points in the electrical system that could affect the fault current levels should be identified by investigating the switchboard configuration and single-line drawings. This includes HV and LV switching points such as:

a. Secondary selective changeover arrangements.

b. Ring main switches.

c. Contingency and backup supply arrangements, etc.

4.3.6 Loads

Data related to all regenerative power system loads should be collected. This includes:

a. Large (>37 kW rated) direct online and bypass soft starter connected induction motors.

b. Large motors connected through four quadrant (regenerative type) Variable Speed Drives (VSDs).

It is noted that although the sub-transient fault contribution from motors generally decays quite rapidly (over a few electrical cycles), the resulting fault contribution may have a significant impact on the available incident energy at the electrical switchboard.

The following information should be collected for the motors:

a. Motor kW rating.

b. Motor power factor.

c. Starting (locked rotor) current.

4.4 Prepare software model of the power system

The power system simulation model should be prepared using industry-wide accepted power system simulation software (such as ETAP, SKM PTW, DIgSILENT, EasyPower, PowerCAD, etc). The electrical power system simulation software should be compliant with the latest applicable standards for short circuit and incident energy calculations.

The model should include sufficient detail to allow for simulations under maximum and minimum fault current scenarios.

As a minimum, the power system simulation model should include the components of the electrical system from the utility point of supply to the busbars of the switchboards under assessment. Any additional sources of fault current (large induction motors, supplementary/backup generation) should also be included in the simulation model. Any assumptions for the modelling data should be clearly documented and justified in the arc flash assessment report.

4.4.1 Determine the power system switching scenarios

The switchboard's switching scenarios (operating modes) may significantly impact the results of the arc flash calculations. For radial (single feed) switchboards, only one switching scenario needs to be considered. However, for complicated supply arrangements, several operating modes may be possible; these include:

a. Sites with more than one electrical utility supply.

b. Secondary selective switchboards (Main-tie-main arrangements).

c. Embedded generation may be operated islanded from the electrical utility.

d. Switchboards with supplementary/emergency generation, etc.

The operating modes relevant to the power system or switchboard under assessment should be mutually agreed between the asset owner and Power Systems Engineer at the outset of the study and reflect realistic operational scenarios.

4.5 Calculate maximum and minimum bolted fault currents

To identify the worst-case incident energy level at the electrical equipment, calculations for fault currents under both maximum and minimum fault currents are necessary, according to IEC 60909. This is because the overcurrent protection devices employ inverse time protection characteristics, which can result in a disproportionate increase in the fault clearing times (and hence the arcing duration) with a relatively small decrease in the fault current.

Some situations where this can occur are shown in the figures below:

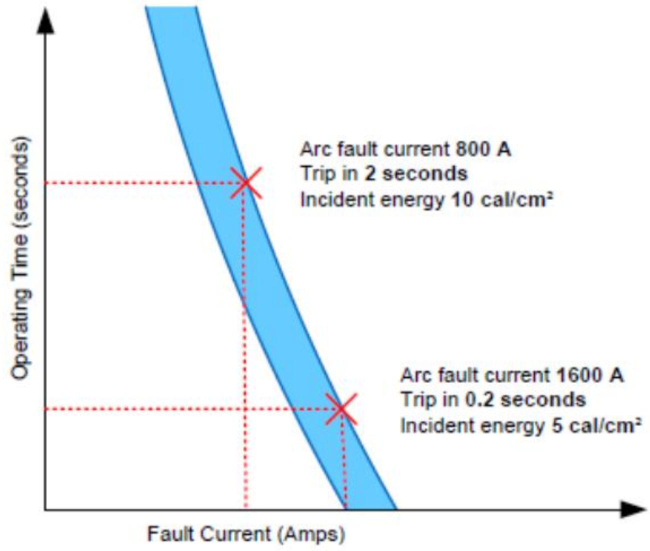


Figure 4-1: Typical LV fuse curve

The fuse curve is so steep that an 800 A fault current takes ten times longer to clear as compared to a 1,600 A fault current.

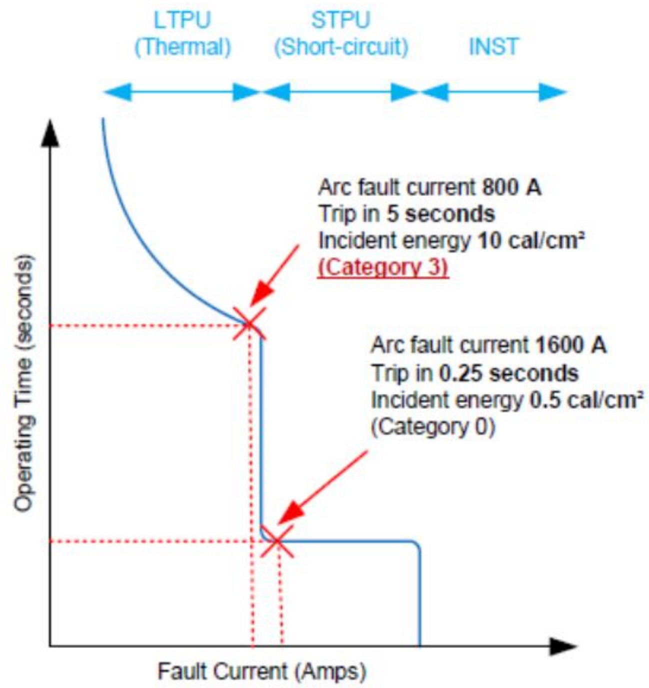


Figure 4-2: Typical LV circuit breaker curve

A small reduction in fault current causes fault to be cleared on Long-time Pick Up (LTPU) in 5 seconds (s) rather than Short-time Pick Up (STPU) in 250 ms.

The fault current calculations should, therefore, consider the following:

a. All possible/realistic operating scenarios of the system.

b. Maximum and minimum pre-fault voltage factors (c-factors) as per IEC 60909.

c. Fault current levels (phase and earth) with and without motor and generation contributions.

4.6 Calculate arcing current using IEEE 1584

Currents associated with electrical arcing faults are always less than the prospective three-phase bolted fault current level of the system due to the arcing resistance.

For electrical installations between 0.208 kV and 15 kV, IEEE 1584 provides equations to estimate the arcing current, depending upon several factors, including:

a. The prospective three-phase bolted fault current.

b. The nominal voltage of the equipment.

c. The bus gap, that is, the gap between adjacent phases at a possible arcing point and enclosure size.

d. The electrode configurations.

For accurate arcing current calculations, the bus gap should be obtained from the switchboard manufacturer; however, in the absence of the manufacturer's information, typical bus gaps based on IEEE 1584 may be employed.

4.7 Determine the arcing duration

The duration of the arcing current (fault clearing time) used for incident energy calculations will depend on a number of factors, including:

a. The tripping characteristics of the protective/detection devices that would interrupt the fault.

b. The location of the fault. In general, there are three possible locations on a switchboard at which an arcing fault could occur, as shown in Figure 4-3: Arc fault locations vs. protection device selection.

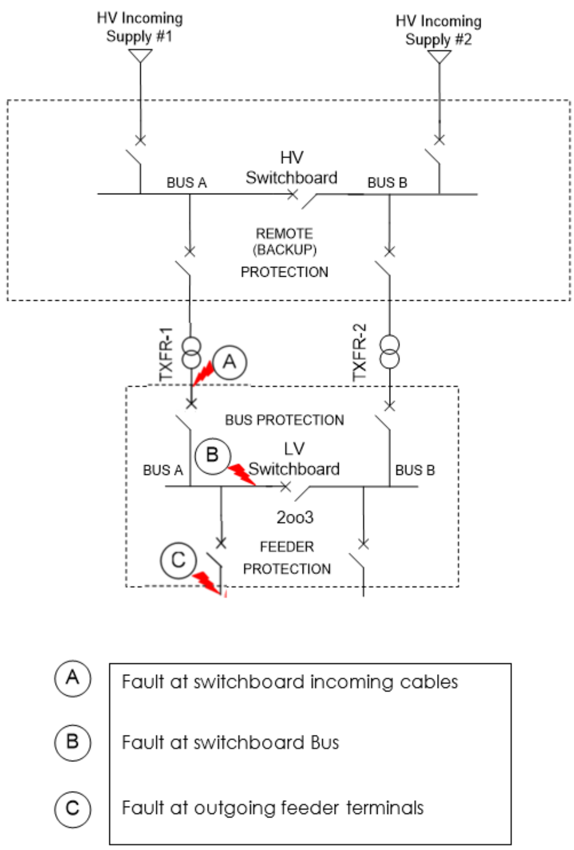


Figure 4-3: Arc fault locations vs. protection device selection

It can be seen from the above figure that faults at the three locations will have different arcing times associated with them. For faults at location C (downstream of a feeder circuit), the associated trip device would be the outgoing feeder circuit breaker. Assuming that the protection system is well-coordinated, it is expected that the protection settings of the outgoing feeder circuit breaker will be set to more sensitive levels compared to the incoming and upstream (remote) breaker settings. The incident energy associated with a fault at location C would generally be less than at locations B and A.

Similarly, the incident energy at location A is the most severe, as the expected tripping time of the remote upstream protection is expected to be the highest. In most cases, the upstream circuit breaker will be on the primary (HV) side of the distribution transformer feeding the switchboard under assessment.

4.7.1 Forms of segregation (LV switchboards)

The form of segregation of the switchboard under assessment – AS/NZS 3439.1 and AS/NZS 61439.2 outline the forms of segregation for switchgear assemblies. Primarily, these forms describe the varying configurations of physical barriers used in the separation of functional units of switchgear from each other.

For existing switchgear assemblies, the identification of arc-fault clearing location is tied to the issue of arc propagation. Although the physical barriers used for segregation in switchgear assemblies are not guaranteed to impede arc propagation through the different functional units (unless proven by verification tests), it is reasonable to assume that segregation assemblies would have some impact on the selection of the protective device for determining the arcing duration.

The figures given below illustrate the possible impact of the switchboard's form of segregation on the arc flash propagation through the functional units.

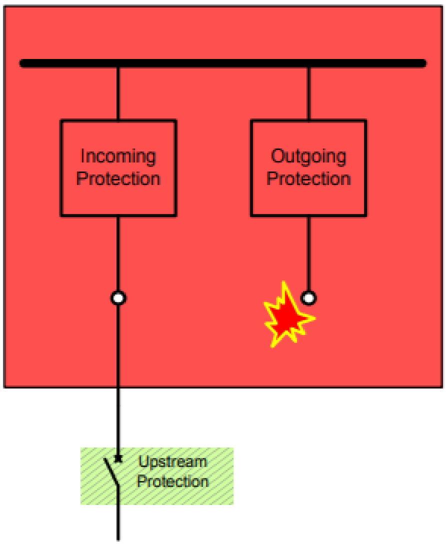


Figure 4-4: Arc fault propagation for form 1 switchboards

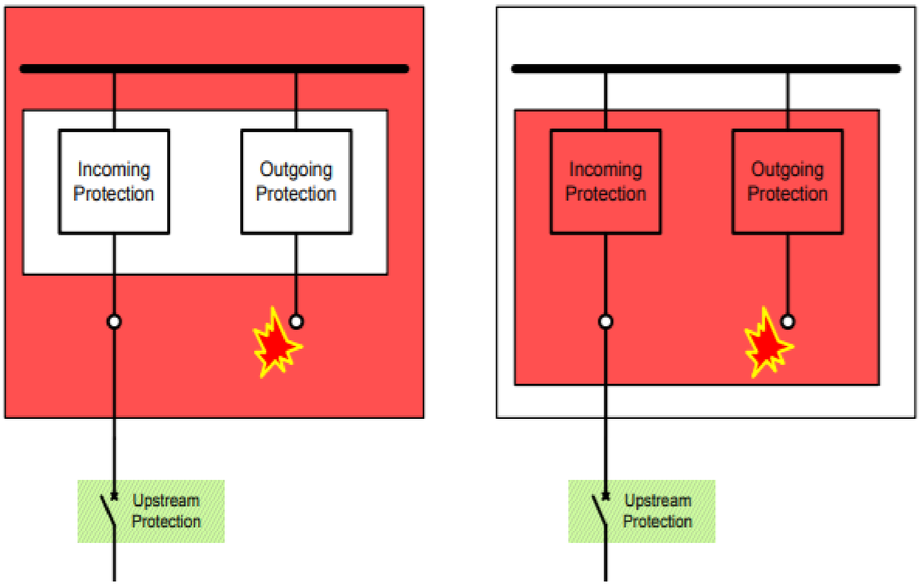


Figure 4-5: Arc fault propagation for Form 2a (left) and Form 2b (right) switchboards

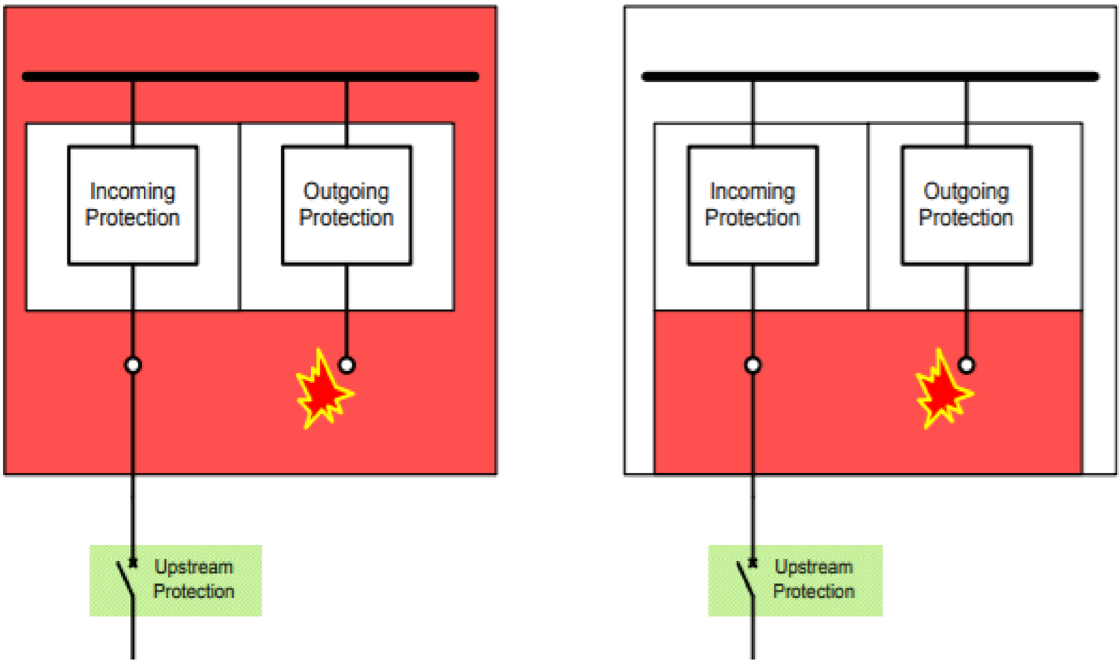


Figure 4-6: Arc fault propagation for Form 3a (left) and Form 3b (right) switchboards

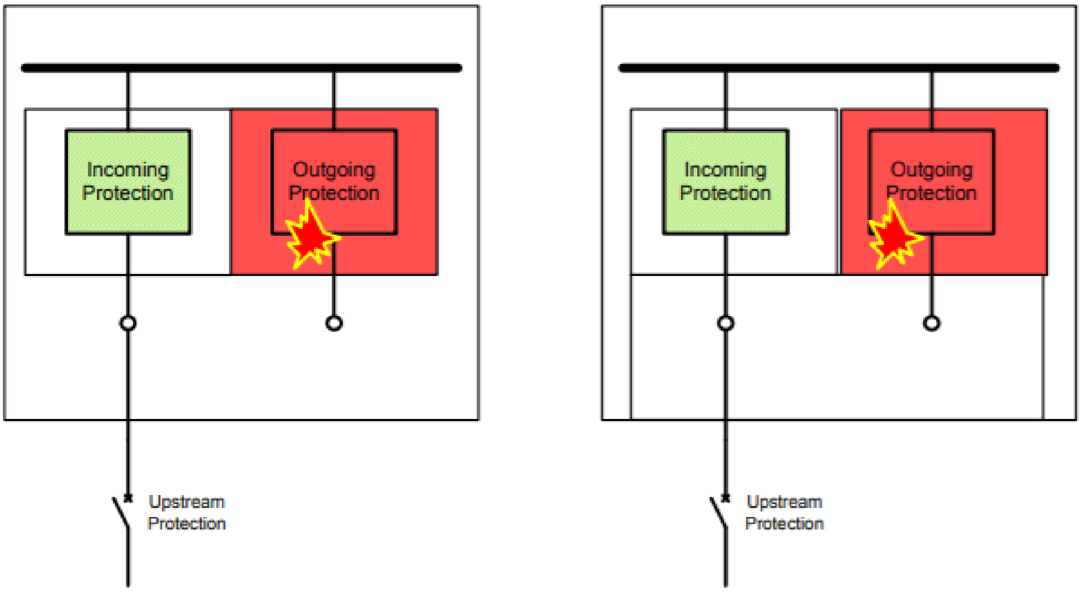


Figure 4-7: Arc fault propagation for Form 3a (left) and Form 3b (right) switchboards

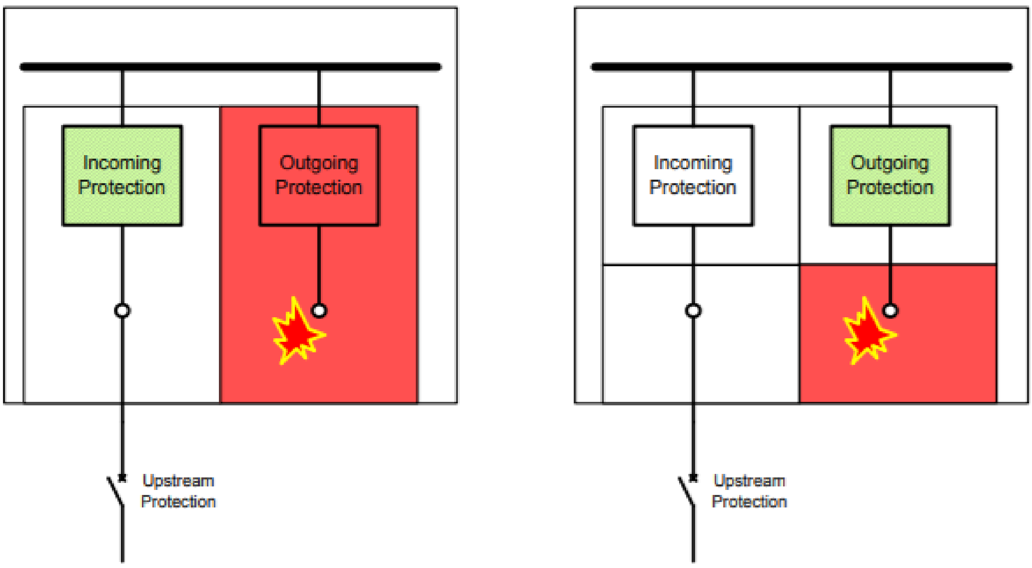


Figure 4-8: Arc fault propagation for Form 4a (left) and Form 4b (right) switchboards

Based on the above basic principles, if the switchgear enclosure being assessed contains a protective device with the line side terminals that are not fully segregated, then an arcing fault can only be cleared by the next upstream device.

In general, SA Water uses low voltage switchboards of form 3b or 4a segregation; therefore, the arcing times should be based on the protection characteristics of the device upstream of the switchboard.

4.8 Calculate the incident energy and arc flash boundary

The first step in calculating incident energy is determining the working distance. As defined by IEEE 1584, the working distance is the separation distance between the closest possible arcing point and the body of the person conducting work. Generalised working distances based on the voltage class of the equipment are provided in IEEE 1584 and should be used for the assessment where physical inspection is not possible.

Once the working distance associated with the switchboard under investigation has been identified, empirical equations provided in IEEE 1584 should be used to estimate incident energy levels. The basic inputs to the calculation are as follows:

a. The equipment operating voltage.

b. Working distance associated with the operating voltage.

c. Calculated arcing current (maximum and minimum).

d. Arcing time, that is the action time of the associated protective device.

IEEE 1584 also provides the empirical formulae to determine the distance from the switchboard at which the incident energy is not considered a major hazard to unprotected personnel. This distance is termed the 'Arc Flash Boundary.' Based on IEEE 1584, the incident energy at the arc-flash boundary equals 1.2 Cal/cm^2, which relates to the threshold for a second-degree burn.

4.9 Determine the arc flash classification

When the worst-case arc flash incident energy has been determined, each piece of equipment can be given the appropriate arc flash classification. The arc flash classification adopted by SA Water closely relates to table 130.7(C) of NFPA 70E.

Table 4-1: SA Water arc flash classifications

Category	Incident Energy
CATEGORY 0	Incident Energy below 1.2 cal/cm^2
CATEGORY 1	Incident Energy 1.2 to < 4 cal/cm^2
CATEGORY 2	Incident Energy 4 to < 8 cal/cm^2
CATEGORY 3	Incident Energy 8 to < 25 cal/cm^2
CATEGORY 4	Incident Energy 25 to < 40 cal/cm^2
UNACCEPTABLE DANGER	Incident Energy above 40 cal/cm^2

It is noted that the arc flash classification levels listed in Table 4-1 and the associated PPE Requirements assume that the working personnel will be directly exposed to an arcing fault, such as switchboard panel doors opening at the time of fault or incorrectly fastened or forced open by the internal pressure developed by the arc.

4.9.1 Arc classification modifiers

Arc flash classification based on incident energy calculations does not consider the risk reduction introduced through various mitigation measures.

4.9.1.1 Arc-rated switchgear

Modern HV and LV switchboards can be designed to withstand an internal arc fault blast. This equipment is specially verified and certified so that any escaping arc fault energy is contained or redirected, and injury to people is limited to less than second-degree burns.

Switchboards intended to provide increased security against the occurrence or the effects of internal arcing faults have been designed and tested according to the methods outlined in AS/NZS 3439.1 Appendix ZC and ZD or AS/NZS 61439.1 Appendix ZC and ZD. This is an optional switchboard specification, and AS/NZS 3439.1 or AS/NZS 61439.1 verification does not automatically infer that the equipment has been tested to contain and limit exposure to an arc fault. It must be specifically requested from the switchboard manufacturer before design and construction.

According to NFPA 70E guidelines, arc-rated and tested equipment is equivalent to "Below Category 1" arc flash classification.[1]

[1] This applies only when all doors and panels are closed. With doors/panels open, the classification reverts to the IEEE incident energy-derived classification.

4.9.1.2 Optimised protection settings

Selecting appropriate protection devices and settings can greatly reduce arc fault incident energy. Setting optimisation is achieved by reducing the protection settings as much as possible while maintaining time and current discrimination between protective devices in the electrical system.

4.9.1.3 Task-specific classification

Further to the above, the arc fault exposure risk may vary depending on the task performed. For example, circuit breaker switching is considered a lower-risk task than racking out a circuit breaker. NFPA 70E Table 130.7(C) (15) (A) (a) provides guidance with examples of electrical operation and maintenance activities and the impact on PPE requirements.

4.9.1.4 Maintenance and condition

The risk of arc fault occurrence and the effectiveness of any mitigation measures is highly dependent on equipment maintenance and condition.

Existing equipment will require a physical inspection and assessment of condition when considering its arc fault classification.

4.9.1.5 Arc flash detection

Optical arc fault detection devices help to detect and assist in the speed of operation of protective devices under arc fault conditions. Optical arc fault detection devices can be used to detect the flash of light emitted early in the arc flash event and trigger the operation of circuit breakers well in advance of the normal trip caused by arc fault current.

The operating times of arc-detection devices can be used as part of the incident energy calculation, or the presence of the device can be applied as a modifier to the arc flash classification.

4.9.1.6 Arc quenching

Devices can be used in conjunction with an arc flash detection system to clear an arcing fault within a few milliseconds. An arc flash quenching device extinguishes an arc much faster than a circuit breaker by applying a rapid bolted short circuit between phases or between phases and earth close to the arcing fault location. This causes a collapse in the arc voltage, rapidly extinguishing the arc. The bolted short circuit current flows through the quenching device until it is interrupted by the primary protection device.

4.9.1.7 Other mitigation measures

Some arc flash mitigation measures that may be considered might include any combination of the following measures (in general order of complexity):

a. Upstream circuit breaker setting modifications, zone-selective interlocking, differential relaying, or fuse changes.

b. Replacement of a problematical switchboard with a switchboard rated to control an arc fault.

c. Upgrade of switchboard form type or extended securing of access doors or lids.

d. Installation of an intermediate protection device between the power source and recipient switchboard (secondary of supply transformer, FCL device).

e. Remote operation (open/closing) of circuit breakers.

f. Fixed circuit breakers over rackable circuit breakers for new installations/upgrades.

g. Insulation of exposed live components between phases and phases and earth.

h. Remote racking facilities.

i. Installation design considerations for isolation and maintenance tasks.

j. Enclosure of problematical switchboards in restricted areas, using physical barriers.

k. Installation of fast detection arc flash equipment schemes.

l. Employing a ‘maintenance mode’ to temporarily reduce the trip setting of a circuit breaker so that it trips more quickly.

m. Installation of active arc elimination equipment, such as ultra-fast short-circuit earthing devices.

n. Installation of voltage-indicating devices.

Where the mitigation methods described above do not reduce incident energy levels to Category 2 or below, then **remote switching/racking** of HV and LV circuit breakers and feeders shall be implemented as an additional feature. This reduces exposure levels by allowing workers to undertake switching/racking operations (remote tripping, closing, or racking) at a safe distance from the switchboard. A label shall be installed adjacent to the device to indicate where remote switching or racking is available.

5 Task-specific PPE selection

5.1 Methodology

Given that most of the switchboards currently installed at SA Water facilities do not include special means for detection and interruption of arcing faults and that the switchboards are not of form 4b construction, it is expected that the worst-case incident energy levels on the switchboards will be high.

The equivalence of arc-rated equipment and 'Below Category 1' arc fault classification should be negotiated with the Client and/or Operator, and an agreed operational philosophy must be applied consistently.

For SA Water sites, a task- and condition-based PPE selection criteria has been selected that is consistent with NFPA 70(E) Article 100 – Information Note 1, which states:

"The likelihood of occurrence of an arc flash increases when energized electrical conductors or parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. An arc flash incident is not likely to occur under normal operating conditions when enclosed energized equipment has been properly installed and maintained".

The standard further refers to Table 130.5(C) for examples of tasks that increase the likelihood of an arc flash incident occurring. A high-level summary of the task breakdowns and likelihood of arc-flash occurrence as per NFPA 70(E) is provided in Table 5-1.

Table 5-1: NFPA 70(E) Table 130.5(C) summary

High level task description	Equipment condition	Likelihood of arc flash
Visual inspections, reading of panel meters, and examination of insulated cables without manipulation.	Any	No
Electrical (energized) work, racking of circuit breakers, examination, and manipulation of insulated cables, and opening compartments, which include bare live electrical circuits.	Any	Yes
Normal operation of circuit breakers (switching), opening of hinged doors on panel boards to access escutcheon mounted devices on switchboards.	Any	No

Based on the likelihood of arc flash occurrence, as indicated in the above table, lower PPE categories may be assigned for tasks requiring minimal interaction with live electrical equipment. SA Water will follow a risk-based approach to determine access and PPE requirements for each arc flash assessed installation separately.

The following basis for PPE requirements shall be applied for SA Water assets:

Table 5-2: Task-specific basis of PPE

<table>
<tr><th rowspan="2">Activity descriptor</th><th colspan="2">Switchboard is internally arc rated</th><th colspan="2">Switchboard is not internally arc rated</th></tr>
<tr><th>Doors closed</th><th>Doors open</th><th>Doors closed</th><th>Doors open</th></tr>
<tr><td>Operating non-switching controls</td><td>Minimum PPE for site</td><td>Based on greater of Location A or Location B incident energy</td><td>Minimum PPE for site</td><td>Based on greater of Location A or Location B incident energy</td></tr>
<tr><td>Visual inspection</td><td>Minimum PPE for site</td><td rowspan="2">Based on greater of Location A or Location B incident energy</td><td>Minimum PPE for site</td><td rowspan="2">Based on greater of Location A or Location B incident energy</td></tr>
<tr><td>Electrical work</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Switching</td><td>Minimum PPE for site</td><td>Based on greater of Location A or Location B incident energy</td><td>Based on greater of Location A or Location B incident energy</td><td>Based on Location A incident energy</td></tr>
<tr><td>Racking</td><td>Minimum PPE for site</td><td>Based on greater of Location A or Location B incident energy</td><td>Based on greater of Location A or Location B incident energy</td><td>Based on Location A incident energy</td></tr>
</table>

Note: Locations (A, B) relate to Figure 4-3: Arc fault locations vs. protection device selection.

5.2 Activity definitions and explanations

The following sections define and explain the activities around and in switchboards that relate to the category of PPE that shall be used for both Incomer and Non-Incomer circuits.

Table 5-3: Task specific PPE category groups

<table>
<tr><th></th><th colspan="2">Task-specific PPE category</th></tr>
<tr><th>Activity</th><th>Doors closed</th><th>Doors open</th></tr>
<tr><th>Incomer and Non-Incomer circuits</th><th></th><th></th></tr>
<tr><td>Racking</td><td>Category X or N/A</td><td>Category X or N/A</td></tr>
<tr><td>Switching</td><td>Category X or N/A</td><td>Category X or N/A</td></tr>
<tr><td>Electrical work</td><td>Category X or N/A</td><td rowspan="2">Category X or N/A</td></tr>
<tr><td>Visual inspection</td><td>Category X or N/A</td></tr>
<tr><td>Operating controls</td><td>Category X or N/A</td><td>Category X or N/A</td></tr>
</table>

5.2.1 Operating controls definition

Operating Controls is the activity undertaken by trades and non-trades personnel during routine operation of a switchboard's control switch and pushbutton facilities. This activity descriptor applies to:

a. People (Operators and Tradespeople) interacting with control or monitoring devices mounted on the front panel or escutcheon of a switchboard or control panel.

b. Only locations on a switchboard or control panel that are designed to be accessed by non-electrically qualified people.

c. Opening hinged doors to access escutcheon devices.

d. Does not apply to the operation of large load circuit breakers that may be in the immediate vicinity.

The underlying assumption for applying a reduced PPE requirement for operating controls is that since access to these controls does not compromise the arc flash category that deems it safe to conduct this task, the likelihood of occurrence of an arc fault impacting the Operator is remote.

Where access to these controls does compromise the arc flash category, the higher arc flash category must be adhered to, and the appropriate PPE used or access should not be gained.

5.2.2 Operating controls explanation

The operation of controls on doors or escutcheons designed for this purpose is deemed a low-risk activity. However, depending on the condition of the switchboard under assessment, a higher category of PPE may be applied. The switchboard must be inspected for the integrity of fastening devices and covers and there should be no vents or louvres facing towards the inspecting personnel. Consideration shall always be given to the impact of the operation, which may result in the switching of heavy current devices in the vicinity of the Operator.

5.2.3 Visual inspection definition

Visual inspection is the activity undertaken during routine physical and visual examinations of the switchboards. This activity descriptor also applies to:

a. People reading panel meters (provided that all doors are closed).

b. People present in the vicinity of or passing near live switchboards, provided no work (such as switching) is being carried out on the switchboard by others.

c. Opening hinged doors to access escutcheon devices.

The underlying assumption for applying a reduced PPE requirement for visual inspections is that since the state of the electrical equipment is not being changed, the likelihood of occurrence of an arc fault is remote.

5.2.4 Visual inspection explanation

a. Visual inspection with doors closed is always deemed a low-risk activity. But, depending on the condition of the switchboard under assessment, a higher category of PPE may be applied. The switchboard must be inspected for the integrity of fastening devices and covers and there should be no vents or louvres facing towards the inspecting personnel.

b. Visual inspections with doors open pose a higher risk of arc flash. The following should be considered for selecting the PPE for open-door visual inspections:

    i. If the line side busbars and terminals are fully insulated or phase barrier, select the PPE category based on Location B (busbar) incident energy assessment.

    ii. If the line side busbars and terminals are not fully insulated or phase barrier, select PPE based on Location A (line side) incident energy assessment.

5.2.5 Electrical work definition

Electrical work refers to:

a. Connecting/disconnecting electricity supply to electrical equipment or installation.

b. Installing, removing, adding, testing, replacing, and altering electrical equipment or an electrical installation, including testing for dead circuits.

c. Cover removal or opening hinged doors on equipment that could contain exposed energised equipment for the purpose of inspection or maintenance.

5.2.6 Electrical work explanation

Live electrical work on switchboards should generally be avoided unless the hazard associated with powering off is deemed significant. If energised or 'live' electrical work is unavoidable, a risk assessment must be undertaken before the work starts, and it must be carried out by competent people. The PPE selection for live electrical work should be based on the worst-case incident energy results (Location A).

5.2.7 Switching definition

Switching refers to changing the state of a functional unit, such as:

a. Test for dead circuit.

b. Lock/unlock the cubicle using the interlock key.

c. Operation of an isolator, fuse switch, contactor, or circuit breaker.

d. Fuse removal/insertion.

e. Manual spring charging.

f. Operating earthing mechanisms.

g. Install/remove equipment service tags.

5.2.8 Switching explanation

Although switching is considered a low-risk activity by NFPA 70(E), a conservative approach to the selection of the switching PPE is recommended.

a. For switchboards that have been verified 'internal arc controlled,' switching activities with the doors closed require minimum level "standard" PPE.

b. For non-verified internal arc-controlled boards, recognising that there is little probability of an arc flash occurrence on the line side terminals during switching, appropriate PPE should be selected based on the following criteria:

    i. If the line-side busbars and terminals are fully insulated or phase barriered – select the PPE Category based on Location B (busbar) incident energy assessment.

    ii. If the line-side busbars and terminals are not fully insulated or phase barriered – select the PPE category based on Location A (line side) incident energy assessment.

5.2.9 Racking definition

Racking is the process of connecting or disconnecting the functional unit from a bus via an integrated mechanism.

5.2.10 Racking explanation

a. For switchboards that have been verified as 'internal arc controlled,' racking in/out of the functional units (with doors closed) does not require special PPE. The selection of PPE to be used during racking with doors open should be based on the following criteria:

   i. If the line side busbars and terminals are fully insulated or phase barriers, and the racking device is a moulded case circuit breaker, supported and guided by a frame assembly – select the PPE category based on Location B (busbar) incident energy assessment.

   ii. If the line side busbars and terminals are not fully insulated or phase barriered, or the racking device is not a moulded case circuit breaker supported and guided by a frame assembly – select the PPE category based on Location A (line side) incident energy assessment.

   iii. If the line side busbars and terminals are fully insulated or phase barriered, and the racking device is an air circuit breaker supported and guided by a rigid frame assembly fitted with fail-safe mechanical trip interlocks (cannot be withdrawn or inserted into the busbar when the circuit breaker is closed) and equipped with busbar shutters – select the PPE category based on Location B (busbar) incident energy assessment.

b. For switchboards that have not been verified as 'internal arc controlled,' PPE selection for racking with doors open is a high-risk activity, and the PPE selected should be based on the worst-case incident energy result (Location A).

   If racking is being carried out with the doors closed, the following criteria are recommended:

   i. If the line side busbars and terminals are fully insulated or phase barriered, and the racking device is a moulded case circuit breaker supported and guided by a frame assembly – select the PPE category based on Location B (busbar) incident energy assessment.

   ii. If the line side busbars and terminals are not fully insulated or phase barriered, or the racking device is not a moulded case circuit breaker supported and guided by a frame assembly – select the PPE category based on Location A (line side) incident energy assessment.

   iii. If the line side busbars and terminals are fully insulated or phase barriered, and the racking device is an air circuit breaker supported and guided by a rigid frame assembly fitted with fail-safe mechanical trip interlocks (cannot be withdrawn or inserted into the busbar when the circuit breaker is closed) and fitted with busbar shutters – select the PPE category based on Location B (busbar) incident energy assessment.

6 Arc flash cautionary labels

A suitable quality arc flash cautionary label shall be produced for each switchboard or equipment item requiring such labelling to inform people of potential arc flash consequences and the required levels of Arc Rated PPE required for different activities. The labels shall be logically located in relevant positions on the equipment so that they are easily seen and read.

All the information required for the arc flash cautionary label shall be captured in tabular format and shown on the Engineering Design Protection Grading drawings (Design Summary or Primary Design).

The following information shall be included on the arc flash cautionary label:

Table 6-1: Arc flash cautionary label information

	Information	Example
1	Site – main information	Hallett Cove WWTP
2	Site – sub-information	Pump Station No. 2
3	Equipment – main description	PP-01 VSD Panel
4	Equipment – sub-description	Incoming cables and busbar
5	Arc Fault Level	8.49 kA for 0.4 sec
6	Arc Fault Certification Status	Certificate reference or 'Unknown'
7	Date	12/08/2019
8	Company performing assessment	Norfolk Engineering
9	Voltage (kV)	0.4
10	Incident Energy at Working Distance (cal/cm^2)	0.84
11	Arc Flash Boundary (closest approach distance) (m)	0.4
12	Report details	Arch flash performed by Norfolk Engineering per document 13937-04
13	Validity	Valid until 1/8/2024 (Validity will be void if any changes are made to this electrical installation.)
14	Notes	Common label applies to each VSD on this panel. If energy levels exceed 40 cal/cm^2 – follow risk assessment.
15	A table of minimum arc rated PPE requirements against operational activities with doors open and doors closed.	*(Refer to Figure 6-1 and Figure 6-2 for examples)*

It is important that the arc flash labels are posted in appropriate locations and be visible, securely attached, and maintained in legible condition. For switchboards that exhibit an arc flash category exceeding Category 2 for any 'Doors Closed' activities, posting of 'General PPE Information' and 'Danger' labels shall be in an appropriate location outside of the stated arc flash boundary.

The bottom of the label should be placed 1.5 m from ground level. A 'warning' label shall be applied for arc flash ratings that do not exceed Category 1. A 'danger' label shall apply for ratings Category 2 and above.

Typical arc flash cautionary labels are provided in Figure 6-1 and Figure 6-2 for reference. Visio copies of these examples are available on request from SA Water.

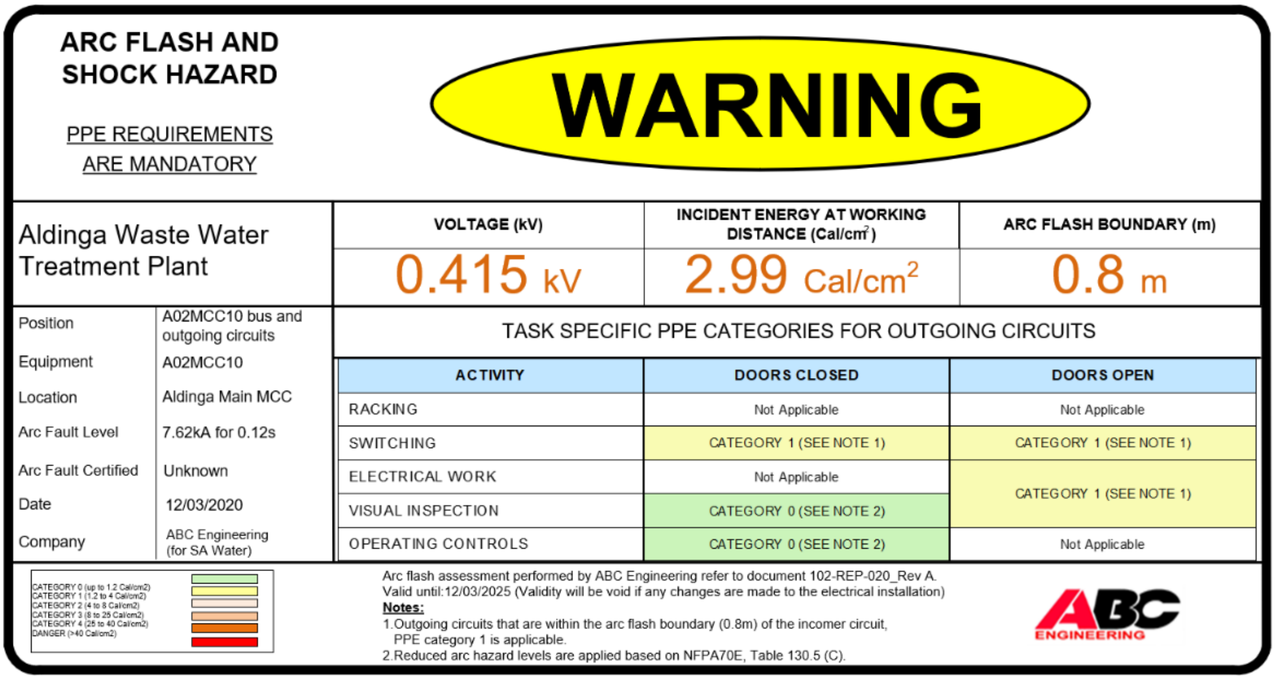


Figure 6-1: Arc flash 'Warning' label example

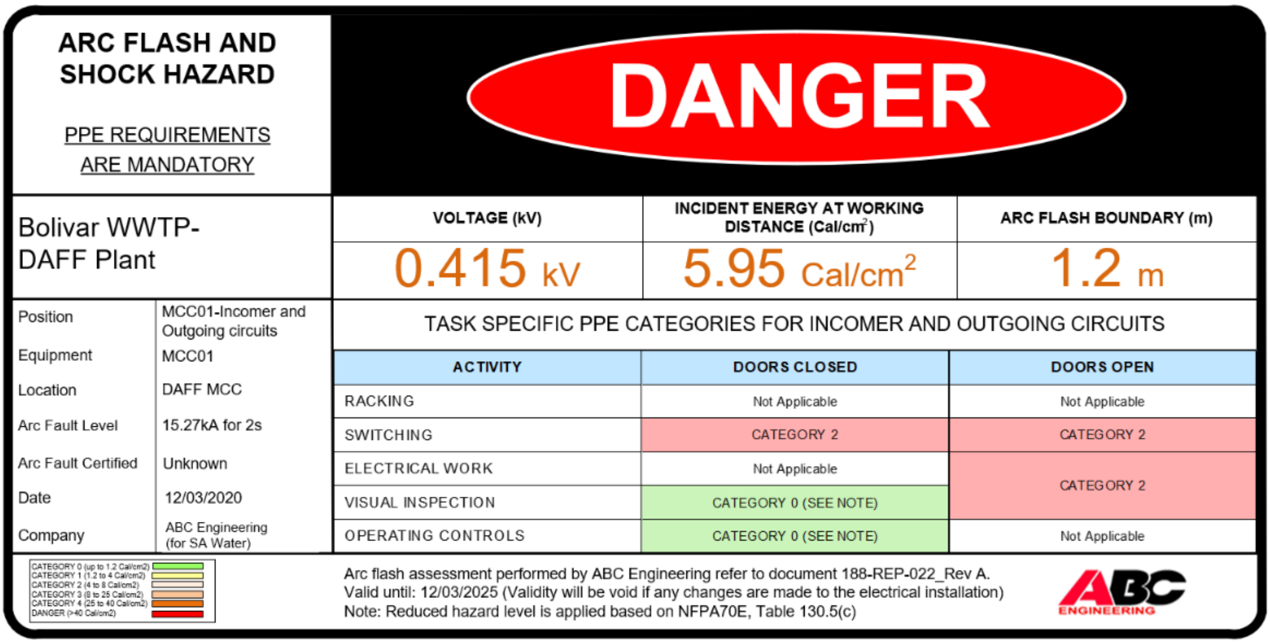


Figure 6-2: Arc flash 'Danger' label example

An example of the positioning of arc flash labels on a switchboard can be seen in Figure 6-3.

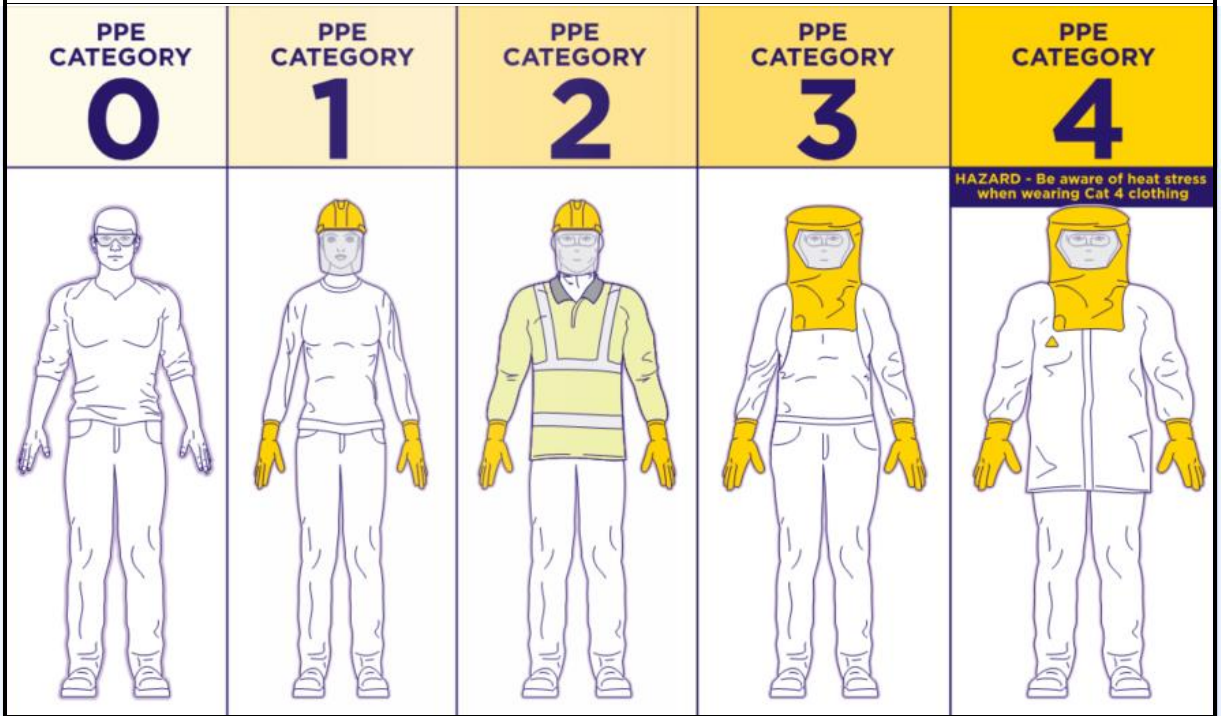
Figure 6-3: Example positioning of arc flash labels

In addition to the abovementioned warning/danger labels, a general PPE label similar to that of Figure 6-4, which contains protective clothing details that need to be worn for the various incident energy levels, shall be posted at the entrances to areas and/or on the protective enclosures on which the arc flash assessment has been undertaken. SA Water Representatives may be sought for guidance on suitable locations.

This general information will be provided on a suitably formatted sign made using functional material, separate from the arc flash rating signs, and located in a prominent and relevant position.

ARC FLASH CATEGORIES - PPE REQUIREMENTS

APPLY PPE CATEGORIES LISTED BELOW
AS SPECIFIED BY INDIVIDUAL EQUIPMENT SIGNS ON THIS SITE



Incident Energy below 1.2 cal/cm²	Incident Energy 1.2 to < 4 cal/cm²	Incident Energy 4 to < 8 cal/cm²	Incident Energy 8 to < 25 cal/cm²	Incident Energy 25 to < 40 cal/cm²
MINIMUM PPE FOR SITE (Specified on a per-site basis.)	Arc-Rated Clothing - Minimum Arc Rating of 4 cal/cm² (16.75 J/cm²): **Arc-rated long-sleeve shirt and pants or arc-rated coverall**	Arc-Rated Clothing - Minimum Arc Rating of 8 cal/cm² (33.5 J/cm²): **Arc-rated long-sleeve shirt and pants or arc-rated coverall**	Arc-Rated Clothing - Minimum Arc Rating of 25 cal/cm² (104.7 J/cm²): **Appropriate clothing system to meet the minimum arc rating**	Arc-Rated Clothing - Minimum Arc Rating of 40 cal/cm² (167.5 J/cm²): **Appropriate clothing system to meet the minimum arc rating**
This is a suggested minimum:	**Arc-rated face shield**	**Arc-rated arc flash suit hood or arc-rated face shield and arc-rated balaclava**	**Arc-rated arc flash suit hood**	**Arc-rated arc flash suit hood**
Sturdy covered footwear	**Industrial work boots**	**Industrial work boots**	**Industrial work boots**	**Industrial work boots**
Long sleeve shirt and pants	**Safety glasses or safety goggles**	**Safety glasses or safety goggles**	**Safety glasses or safety goggles**	**Safety glasses or safety goggles**
Safety glasses or safety goggles – if specified.	**Hearing protection (ear plugs)**	**Hearing protection (ear plugs)**	**Hearing protection (ear plugs)**	**Hearing protection (ear plugs)**
	Heavy-duty leather gloves	**Heavy-duty leather gloves**	**Arc Rated Gloves**	**Arc Rated Gloves**
	Hard Hat	**Hard Hat**	**Hard Hat**	**Hard Hat**

Figure 6-4: General PPE information label example

Figure 6-5: Example label to be used where space is limited

All equipment rated Category 3 and above not located in a dedicated switch room, where practical, should have the arc flash boundary suitably identified through cordoning/fencing (preferred) or a painted zone on the ground.

For HV or LV switchboards that have been verified 'internal arc controlled' (with doors closed) and where an arc flash study has not been performed, the labelling shall adhere to the following convention:

a. A warning label is placed on every relevant door of the switchboard indicating that under no circumstances should that specific door be opened unless the switchboard has been fully de-energised by qualified people. A typical label format is included in Figure 6-6. For an example of which doors these labels should be applied to, refer to Figure 6-7.

Figure 6-6: Typical door label for internal arc-controlled switchboards

Figure 6-7: Example positioning of warning labels

7 Assessment outcome and control

The arc flash assessment study and calculation report shall be documented, covering the following as a minimum:

a. Different operational scenarios were considered in the study.

b. Worst-case scenario calculation results, including arc flash boundary, incident energy category at the working distance, the arc flash safety in design approach and outcomes.

c. A summary of arc flash PPE categories.

d. All applicable arc flash cautionary labels.

e. Arc flash mitigation measures and recommendations, as applicable.

f. Software model shall be included as a deliverable with any associated data and reference files.

Changes to the electrical equipment, protection devices, and settings (except for changes recommended as part of the arc flash assessment study) will affect the energy levels of the arc flash incident. If these changes occur after the final arc flash assessment study, the arc flash energy levels shall be re-assessed in accordance with the requirements of this document.

8 Switchboard design and configuration principles

The power reticulation strategy that SA Water intends to implement is based on the following power reticulation configuration and switchboard design principles outlined in this section.

8.1 HV power reticulation philosophy

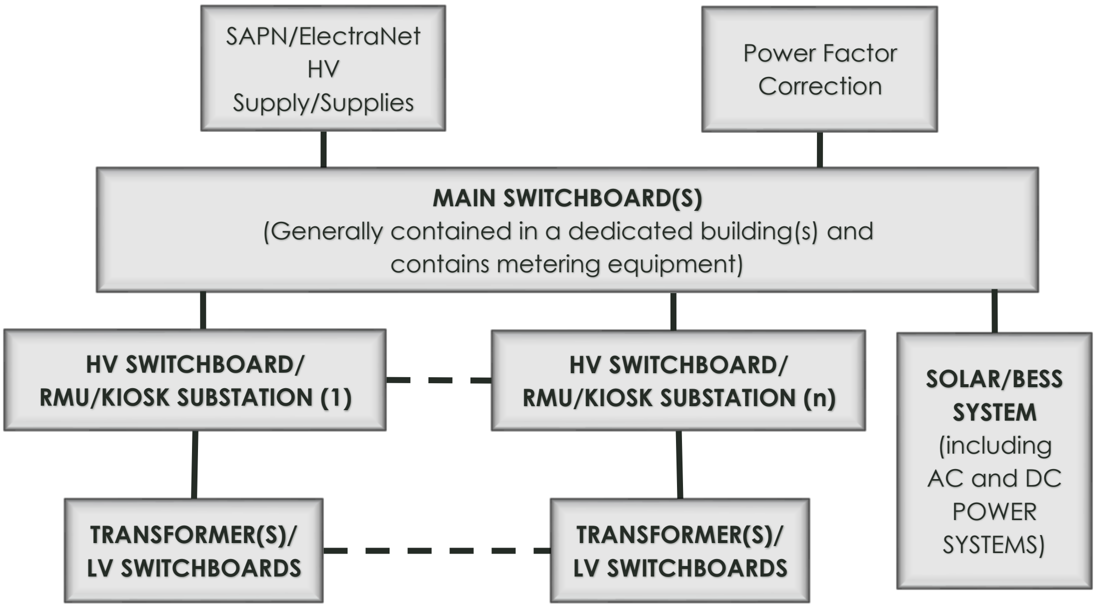


Figure 8-1: HV power reticulation philosophy

8.2 LV power reticulation philosophy

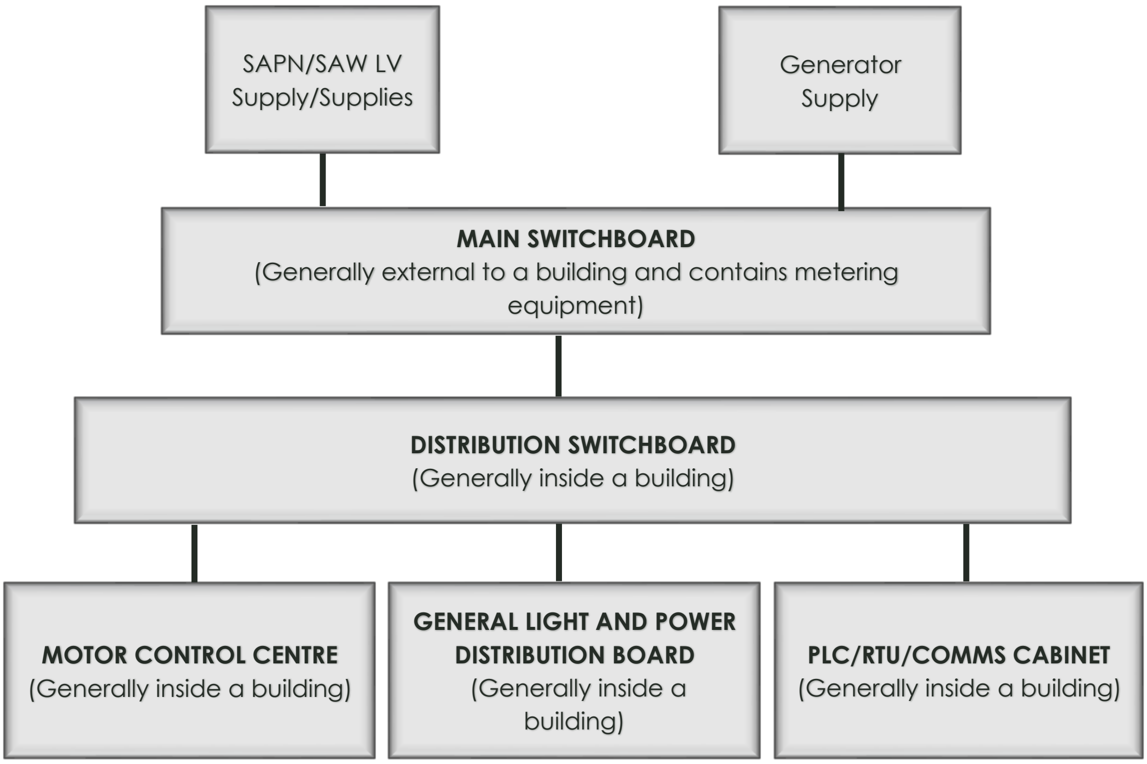


Figure 8-2: LV power reticulation philosophy

Table 8-1: Switchboard configuration approach

Description	Arc fault control required to AS61439 (Appendix ZD(1))	Maximum permitted arc flash category rating (with doors open)(2)	Maximum permitted arc flash category rating (with doors closed)(2)
Main switchboard	Yes	2(2b)	0
Distribution switchboard	Dependent on arc flash assessment	1 (2c)	0
Motor control centre	Dependent on arc flash assessment	1	0
General light and power distribution board	No	0	0
PLC/RTU/Comms cabinet	No	N/A (Arc flash-free zones)	N/A (Arc flash-free zones)

Notes:

1. Applicable to incomer, main busbar and outgoing connections on switchboards rated at arc flash Category 3 and above.
2. Maximum arc flash category rating:
   a. In general, the desired category rating of any new switchboard is Category 0. However, it is acknowledged that this is not always possible.
   b. Main Switchboard – **Category 2:**

      The Designer should set out to achieve a Category rating of no more than '2', but SA Water will accept up to a Category '4' rating if complexity, cost, and timing factors provide suitable justification.
   c. Distribution Switchboard – **Category 1:**

      The Designer should set out to achieve a Category rating of no more than '1', but SA Water will accept up to a Category '2' rating if complexity, cost, and timing factors provide suitable justification.

8.3 General design requirements for switchboards

All LV switchboards rated above 250 Amps and all HV switchboards shall be verified to provide arc flash energy control. The arc flash energy control shall be valid for any arc flash event occurring at any point within the switchboard.

a. Where an arc flash event is controlled using specific blast chutes and vents external to the switchboard, signage shall be provided clearly stating the area around the switchboard with restricted access. Arc chutes and vents shall be configured so that arcing exhaust gases are evacuated to the exterior of the switchboard/building in a way that does not present a hazard to people.

b. If a switchboard has been designed with different sections of the switchboard having different arc flash category ratings and these sections have been verified to provide arc flash control to other sections, cableways between the sections shall not compromise the arc fault control function of either section.

c. Incoming and outgoing feeds from any module within the switchboard shall be protected such that accidental live contact when working in the module is not possible, for example, accidental dropping of small items such as bolts, screws, and washers, which could create a short circuit or an arc flash event.

d. Segregation between vertically arranged modules shall be a minimum of IP4X to prevent small items from falling vertically between modules.

e. Segregation between modules and busbar sections shall be a minimum of IP4X.

f. Segregation between modules and cable zones shall be a minimum of IP2X.

g. Switchboards that exhibit a high arc flash category on the income side of the main switch that cannot easily be designed and rated to be arc fault controlled shall be fitted with the highest form of phase conductor insulation prior to the main switch.

   Once this is achieved, the required stipulation for arc flash labelling may be modified to indicate the arc flash category of the remainder of the switchboard.

   A suitable ‘Danger’ label shall be placed on the incomer section that clearly states that this section of the switchboard shall not be accessed while power is applied.

   The relevant arc flash report should indicate the category at the incomer but explain the risk assessment process that has led to the additional control measures and mitigation strategy.

   Other mitigation options to be considered for the isolation of main switches in these situations include the facilities to provide:

   i. Remote operation of the incoming circuit breaker.
   ii. Remote racking of the incoming circuit breaker (if possible).
   iii. Fibre optic sensing to detect arc flash to enable tripping of the upstream circuit breaker as quickly as possible.

   Every effort is to be made in the design of such switchboards so that the arc flash category rating seen on the incomer side is minimised.

8.4 Main switchboards

Main Switchboards shall typically be designed as standalone switchboards, which may contain a main circuit breaker(s), emergency generator circuit breaker, solar supply input, manual or automatic transfer switch, supply authority metering and CTs, and the site MEN link.

All new Main Switchboards shall be designed to handle the ultimate fault withstand level from the network feeding it and shall be arc fault contained, with an absolute maximum arc flash energy rating of less than 40 cal/cm^2, that is, a maximum of Category 4, but preferably an arc flash energy rating of less than 8 cal/cm^2 (Category 2 or below).

Where a Category 4 arc flash energy rating or less cannot be achieved due to limitations of the existing upstream protective device, the Designer shall liaise with the relevant electrical utility provider to modify/replace the upstream protective device to reduce the associated risks. For HV switchboards, the inclusion of mitigation schemes should be considered during the design studies as an option to minimise the impacts of arc faults. This shall be undertaken through consultation with SA Water, the Network Service Provider and an understanding of the criticality of the process plant with which it is associated.

8.5 Distribution switchboards

Distribution Switchboards shall typically be designed as standalone switchboards, containing a main incoming circuit breaker, power metering and distribution circuit breakers to supply power to various plant areas and equipment. Where this is not possible, and a distribution section is to be situated within a switchboard, these sections must be sealed from the rest of the switchboard or have an insulating barrier installed.

The need for arc fault control of any new Distribution Switchboard shall be determined by the arc flash assessment conducted on each site, restricting arc flash energy to a rating of < 4 cal/cm^2 (Category 1).

A Distribution Switchboard will typically supply the following loads:

a. Other local power distribution switchboards.

b. Local motor control centres.

c. Local control panels.

d. General light and small power distribution boards.

e. Proprietary standalone process equipment packages.

f. Power conditioning equipment.

g. UPS systems, etc.

8.6 Motor control centres

Motor Control Centres shall typically be designed as standalone switchboards, containing a main incoming circuit breaker, power metering, motor starting and control equipment, such as circuit breakers, contactors, relays, overloads, soft starters, etc. and suitable interfaces to the wider control system, such as segregated PLC/RTU section or facilities to interface to a separate PLC/RTU panel.

The need for arc fault control of any new Motor Control Centre shall be determined by the arc flash assessment conducted on each site, restricting arc flash energy to a rating of < 4 cal/cm^2 (Category 1).

Consideration should also be given to the location of any Variable-Speed Drives (VSDs). Where space and the installation environment/methodology allow, VSDs shall be IP54, mounted external to the switchboard, that is, mounted on the switchroom building's internal wall.

Multiple Motor Control Centres shall be considered for areas where:

a. Category 1 arc flash energy ratings cannot be achieved using one switchboard.

b. The required maximum demand is greater than 800 Amps.

c. The board length introduces supply, transportation, construction, or installation issues.

d. There are benefits in providing electrical redundancy in the system.

e. There are benefits to carrying out future board replacement programs.

8.7 Distribution boards or sections rated ≤ 250A

Low voltage distribution boards and control panels incorporating low voltage distribution sections pose a potential risk to people, as typically, these boards are not designed with specific arc fault control measures and are often accessed by non-electrically qualified workers, such as, operations or maintenance people.

All low-voltage distribution boards and control panels for this purpose shall have a maximum current rating of ≤ 250A. Multiple distribution boards/control panels shall be installed if a current rating above 250A is required.

These boards typically contain a main incoming circuit breaker, power metering, distribution circuit breakers, lighting and emergency control circuits, RCD testing facilities, surge protection, etc.

These boards shall typically be designed as follows:

a. Maximum rating of 250 Amps and protected by a maximum 250 Amp adjustable circuit breaker located within the upstream switchboard, such as within the Distribution Switchboard or Motor Control Centre.

b. Arc flash energy rating of < 1.2 Cals/cm^2, that is Category 0. This will allow acceptable safe access to Operators in appropriate standard PPE, that is, clothing with typically > 80 per cent natural fibre and standard safety glasses.

c. Where attainment of Category 0 cannot be achieved, the capacity of the distribution switchboard and associated protective devices shall be reduced to a level lower than 250 Amps, which achieves a Category 0 rating. For example, the installation of multiple lower-rated distribution boards.

d. If it is not possible to demonstrate Category 0 attainment through calculation, providing distribution boards with upstream protection limited to 63 A or less will be an acceptable mitigation outcome.

e. For boards or sections that are accessible to people without an electrical license, such as the PLC cabinet or telemetry section, a minimum degree of protection of IPXXC, that is, 2.5 mm diameter holes at least 100 mm distant from live parts, shall be provided. In addition, arc flash energy exposure at the position of operation or inspection must be Category 0. Also, all cabling exposed to touch must be double insulated in line with AS/NZS3000 requirements.

To minimise the size of these types of boards, all three-phase outlet circuit breakers shall be supplied directly from the Distribution Switchboard or respective local Motor Control Centre.

Low voltage distribution boards shall not be contained within other switchboards unless it can be demonstrated that they are fully isolated (in an arc flash perspective) from the rest of the switchboard and achieve a Category 0 arc flash rating themselves.

8.8 Arc detection systems

Arc fault detection devices using optical technology, in combination with current measurement sensors, or similar mitigation devices, shall be integrated into all HV switchboards and for LV switchboards rated **800 A or more**. The arc detection system shall be independent of any protection relays and can be used to trigger the operation of circuit breakers well in advance of the normal trip caused by arc fault current alone. Integration of such devices shall be engineered on a case-by-case basis in consultation with SA Water.

Arc fault detectors shall be located in order to detect arc faults which occur:

a. At the point of switchboard connection to the incoming supply.

b. In the incoming circuit breaker compartment.

c. Along the main busbar (unless this is fully insulated).

d. Along the distribution busbar (unless this is fully insulated).

e. In outgoing circuit breaker compartments.

f. In motor starter compartments, except where protected by HRC fuses, which limits the peak cut-off current to less than 17 kA, and the line side, which is fully insulated.

The switchboard Manufacturer shall perform tests to verify the performance and safety of arc detection systems and provide certified test reports to SA Water. Where optical arc flash detection protection is installed, warning labels are to be attached to the switchboard and in a prominent position on each switchroom personnel access door. The mounting height of the warning labels must be at least 1500 mm from the floor level.