



**Engineering**

**Technical Standard**

# **TS 0371 - Arc Flash Hazard Assessment and Design Aspects**

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**Government of  
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Only the current revision of this Standard should be used which is available for download from the SA Water website.

## Significant/Major Changes Incorporated in This Edition

Nil.

This is the first issue of this Technical Standard.




## Document Controls

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# 1 Introduction

Arc Flash is a destructive and potentially life-threatening type of electrical fault, caused by unintended or accidental connection of energized 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 Technical Standard is to:

- Detail a basic understanding of arc flash terminology;
- Provide an effective arc flash classification process;
- Recommend industrial practices to minimize the risk of arc flash hazards;
- Provide a guide for the appropriate selection of personal protective equipment against the activity being undertaken;
- Outline arc flash cautionary label specifications and application;
- Provide principles on switchboard design and configuration; and
- Detail arc flash assessment study report requirements.

## 1.2 Acronyms, Abbreviations and Definitions

The following acronyms, abbreviations and definitions in Table 1-1 are used in this document:

**Table 1-1 - Acronyms, Abbreviations and Definitions**

Term	Description
<b>AC</b>	Alternating Current
<b>Arc Flash Boundary</b>	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 <sup>2</sup> . Within the boundary the energy levels are 1.2 cal/cm <sup>2</sup> or above.
<b>ATPV</b>	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 <sup>2</sup> or above.
<b>Arc Rated (AR) PPE</b>	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.
<b>Arcing Fault Current</b>	A fault current flowing through an electrical arc plasma. Also referred to as arc fault current or arc current.
<b>Arc Flash Hazard</b>	A dangerous condition associated with the possible release of energy caused by an electric arc.
<b>AREP</b>	Auxiliary Winding Regulation Excitation Principle (Generator type)
<b>Backup Protection</b>	Should primary protection fail to operate, backup protection is the next protection relay and circuit breaker combination to detect and clear an electrical fault. For an arcing fault occurring on a switchboard's main incomer, this is typically the first upstream feeder protection.
<b>Bolted Fault Current</b>	An expected fault current flowing where there is close to zero resistance or impedance in the fault path.
<b>Contributing Branch</b>	A connection to the switchboard through which a portion of the total arcing fault current originates.

Term	Description
<b>Electrical Shock</b>	Physical stimulation that occurs when electrical current passes through the body.
<b>Fault Current</b>	The theoretical amount of current delivered at a point on the system during a short-circuit condition.
<b>Flash-protection Boundary</b>	An approach limit at a distance from live parts that are uninsulated or exposed outside of which a person cannot receive anything greater than a second degree burn during an electrical arc event. Also referred to as 'closest approach distance'.
<b>Hazard Risk Category</b>	A rating category number used by NFPA 70E to classify the expected incident energy that may exist within the specified working distance, due to an arcing fault.
<b>HV</b>	High Voltage
<b>Incident Energy</b>	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 <sup>2</sup> ) or joules per centimetre squared (J/cm <sup>2</sup> ).
<b>Qualified Person</b>	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.
<b>PPE</b>	Personal protective equipment.
<b>Primary Protection</b>	The fastest protection relay and/or circuit breaker combination to detect and clear an electrical fault.
<b>Working Distance</b>	The dimension between the potential arc point and the head and body of the worker positioned to perform the assigned task. (455mm – 18 inches)

## 1.3 References

### 1.3.1 Australian and International Standards

Any Standard referred to in this Technical Standard shall be of the latest edition (including amendments) of that Standard at the date of calling of tenders.

Table 1-2 identifies Australian and International standards and other similar documents referenced in this document:

**Table 1-2 - Australian and International Standards**

Number	Title
AS 2067:2016	Substations and high voltage installations exceeding 1kVac
AS/NZS 3000:2018	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 3439.1:2002	Low Voltage Switchgear and Control gear Assemblies – Part 1: Type- tested and partially type-tested assemblies
AS/NZS 60076.5	Power Transformers Part5: Ability to withstand short circuit
AS/NZS 61439.1:2016	Low Voltage Switchgear and Controlgear Assemblies – General Rules
AS/NZS 61439.2:2016	Low Voltage Switchgear and Controlgear Assemblies – Power switchgear and controlgear assemblies



Number	Title
AS 62271.200:2005	High Voltage Switchgear and Control gear – AC Metal-enclosed Switchgear and Control gear for Rated Voltages Above 1kV and up to and Including 52kV
IEC 60909-0:2016	Short-circuit currents in three-phase AC systems – Part 0: Calculation of currents
IEC TR 61641:2014	Enclosed low-voltage switchgear and controlgear assemblies - Guide for testing under conditions of arcing due to internal fault
IEEE 242:2001	Protection and Coordination of Industrial and Commercial Power systems
IEEE 551 – 2006	Recommended Practise for calculating AC Short circuit currents in Industrial and Commercial Power Systems
IEEE 141:1993	IEEE Recommended Practice for Electric Power Distribution in Industrial Plants
IEEE 1584 - 2013	Guide for Performing Arc-flash Hazard Calculations

### 1.3.2 SA Water and External Documents

Table 1-3 identifies the SA Water standards and other similar documents referenced in this document:

**Table 1-3 - SA Water and External Documents**

Number	Title
-	Australian Electrical Arc Flash Hazard Management Guideline- March 2019
ENA NENS 09 – 2014	Energy Networks Australia – National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazards
NFPA 70E – 2018	Standard for Electrical Safety in the Workplace

## 2 Scope

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 practises to perform arc flash hazard calculations and assessment for HV and LV switchgear assemblies in AC power systems with faults involving three phases. This includes:

- HV and LV switchboards;
- Power equipment switchgear;
- Power factor correction equipment;
- Motor starters and variable speed drives;
- Harmonic filters; and
- Any other cubicle containing HV or LV power equipment.

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 for any changes to an installation that 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.

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

### 2.1 Approval to Deviate from This Standard

Approval may ultimately be granted by the SA Water Principal Electrical Engineer, to deviate from the requirements as stipulated in this Standard, if the functional requirements (e.g. asset life, ease of use, maintainability, etc.) for the asset differs from those stated in the Standard, but is assessed as still being acceptable. Any approval to deviate from the stated requirements of this Standard shall not be seen as creating a precedent for future like projects. Any request to deviate from this Standard must be carried out on a project by project basis, where each alternative proposal will be individually assessed on its own merit. No action should be taken until a written reply to such a request has been received.

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.

## 3 Design Criteria

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

### 1. Safety Considerations

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

### 2. 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.

### 3. Security of Operation

Designs should take into account 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.

### 4. 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.

### 5. Upgradability

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

### 6. 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.

### 7. 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.

### 8. 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 low voltage 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.

With regards to safety of personnel, assemblies rated above 250A per phase 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: 2016 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.

## 3.2 Design Expectations

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

1. Site investigations to gather all required information and data to develop a site power systems model in order to undertake arc flash assessment studies.
  - a. Where existing model 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.
  - b. Where model data does not exist, the Designer shall seek all data and develop a new model.
2. Perform and submit an arc flash assessment report in accordance with this Technical Standard, including calculations, arc flash category ratings, and any required protection setting changes (i.e. upstream) to reduce the arc flash risk to as low as is reasonably practicable.
3. Submit native data files of the power systems model developed and arc flash calculations carried out for future use (e.g. 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.
4. 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 (i.e. to reduce the arc flash risk), within the scope of the upgrade project.

## 4 Methodology

This section outlines the preferred methodology for the calculation of arc flash parameters for SA Water existing and proposed assets.

### 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 - 2014 National Guideline for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Arc Hazards*.

Current accepted practice in Australia is to apply the internationally accepted calculation methods provided in IEEE-1584 (*Guide for Performing Arc Flash Hazard Calculations*) to determine arc flash incident energy levels.

Once the incident energy levels are established, 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*.

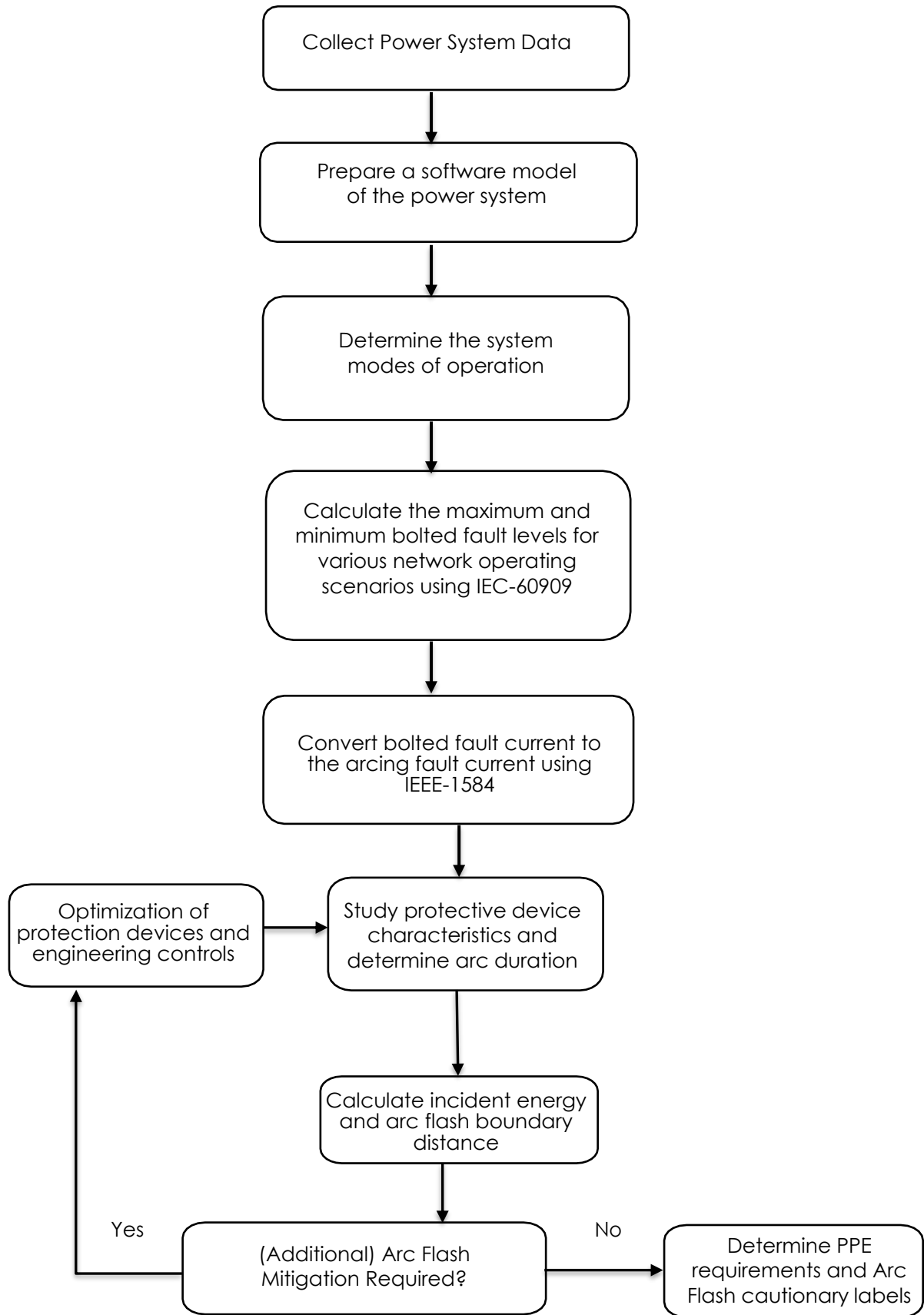
It is important to note that incident energy calculations and the resultant arc flash classification represents the worst-case situation. It represents the hazard present with equipment doors or panels open, and busbars or conductors exposed to personnel. It does not consider the reduction of risk when 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 a number of modelling software packages that are used to create power system models and perform arc flash hazard assessments. (e.g. SKM Power Tools for Windows (PTW), Electrical Transient and Analysis Program (ETAP), DigSILENT, PowerCAD and EasyPower.)

A high-level flowchart outlining the steps to be completed when performing an arc flash study is provided in Figure 4-1.



**Figure 4-1 - High-level flowchart for completing an Arc Flash Study**

## 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:

1. Maximum three phase symmetrical fault level and corresponding X/R ratio; and
2. Minimum three phase symmetrical fault level and corresponding X/R ratio.

### 4.3.1 Generators

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

1. Alternator kVA rating and power factor values from the nameplate;
2. Alternator impedance characteristics; and
3. Details of excitation system and field forcing; if applicable (e.g. AREP).

### 4.3.2 Transformers

The following information should be collected for transformers:

1. Primary and secondary voltage ratings;
2. Vector group;
3. kVA rating;
4. Tap position; and
5. 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:

1. Main cable from the utility connection up to site's main switchboard;
2. Cables used to provide alternate supply sources; e.g. generator cables; and
3. Cables supplying sub-distribution boards 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 for existing installations, data from site and protection relay datasheets.

### 4.3.5 Switching Points

All switching points in the electrical system which 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:

1. Secondary selective changeover arrangements;
2. Ring main switches; and
3. Contingency and backup supply arrangements; etc.

### 4.3.6 Loads

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

1. Large (>37kW rated) direct on-line and bypass soft-starter connected induction motors; and
2. Large motors connected through four quadrant (regenerative type) variable speed drives.

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:

1. Motor kW rating;
2. Motor power factor; and
3. Starting (locked rotor) current.

## 4.4 Prepare Software Model of the Power System

The power system simulation model should be prepared using an 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 switching scenarios (operating modes) of the switchboard 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; this includes:

1. Sites with more than one electrical utility supply;
2. Secondary selective switchboards (Main-tie-main arrangements);
3. Embedded generation that may be operated islanded from the electrical utility;
4. 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.



### 4.5 Calculate Maximum and Minimum Bolted Fault Currents

In order 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:

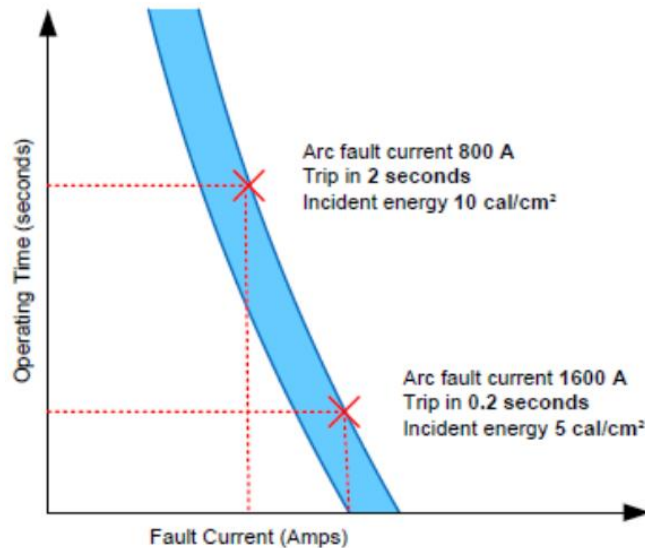


Figure 4-2 - Typical LV Fuse Curve

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

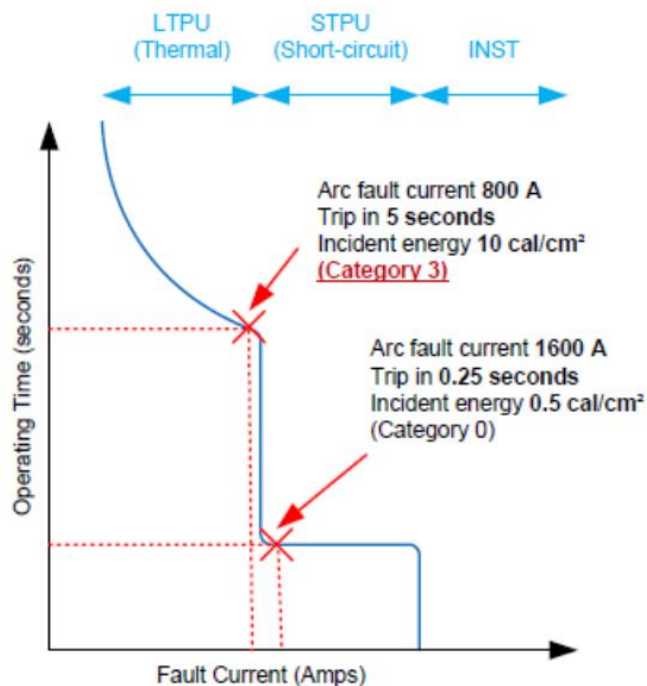


Figure 4-3 - Typical LV Circuit Breaker Curve

A small reduction in fault current causes fault to be cleared on LTPU in 5 s rather than STPU in 250ms.

The fault current calculations should therefore consider:

1. All possible operating scenarios of the system;
2. Maximum and minimum pre-fault voltage factors (c-factors) as per IEC 60909; and
3. Fault current levels with and without motor 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 0.208kV and 15kV, IEEE 1584 provides equations to estimate the arcing current, depending upon several factors, including:

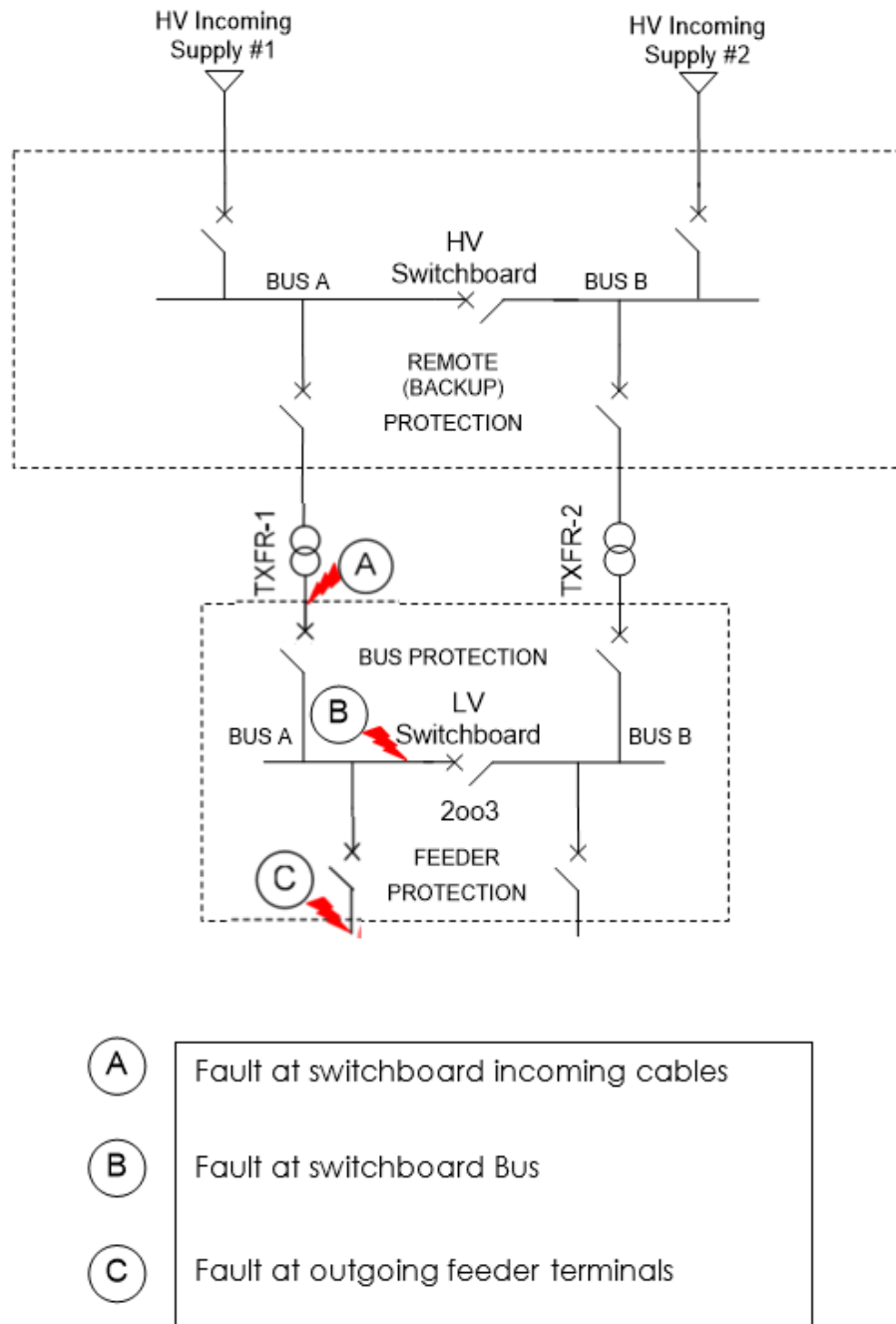
1. The prospective three phase bolted fault current.
2. The nominal voltage of the equipment.
3. The bus-gap (i.e. the gap between adjacent phases at a possible arcing point).
4. An adjustment factor "K", which depends upon the location of arcing (enclosed vs. unenclosed space).

For accurate arcing current calculations, the bus gap should be obtained from the switchboard manufacturer, however, in the absence of 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 used for incident energy calculations will depend on a number of factors, including:

1. The tripping characteristics of the protective device that would interrupt the fault.
2. 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 4-4 - Arc Fault Locations vs. Protection Device Selection.



**Figure 4-4 - 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 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

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.

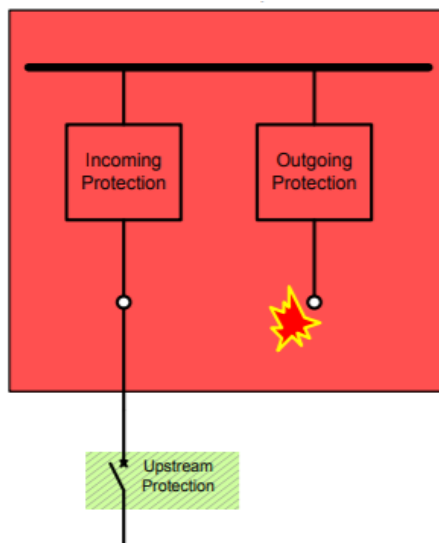


Figure 4-5 - Arc Fault Propagation for Form 1 Switchboards

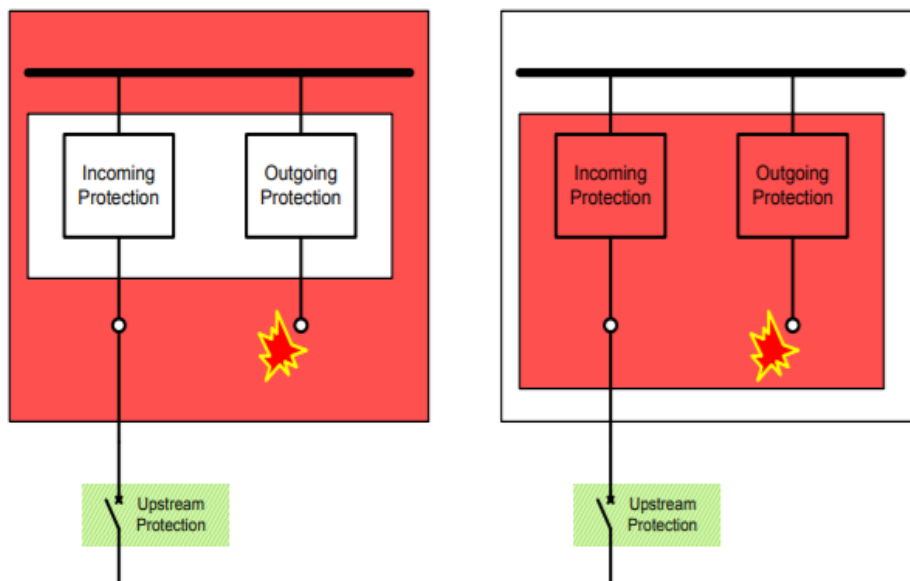


Figure 4-6 - Arc Fault Propagation for Form 2a (left) and Form 2b (right) Switchboards

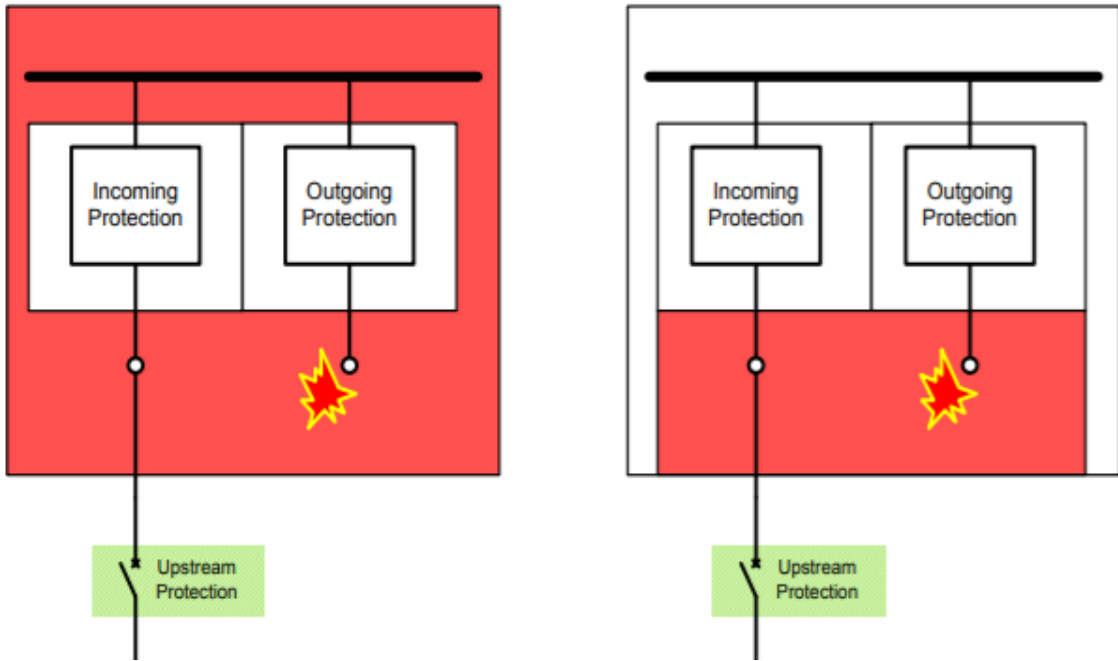


Figure 4-7 - Arc Fault Propagation for Form 3a (left) and Form 3b (right) Switchboards

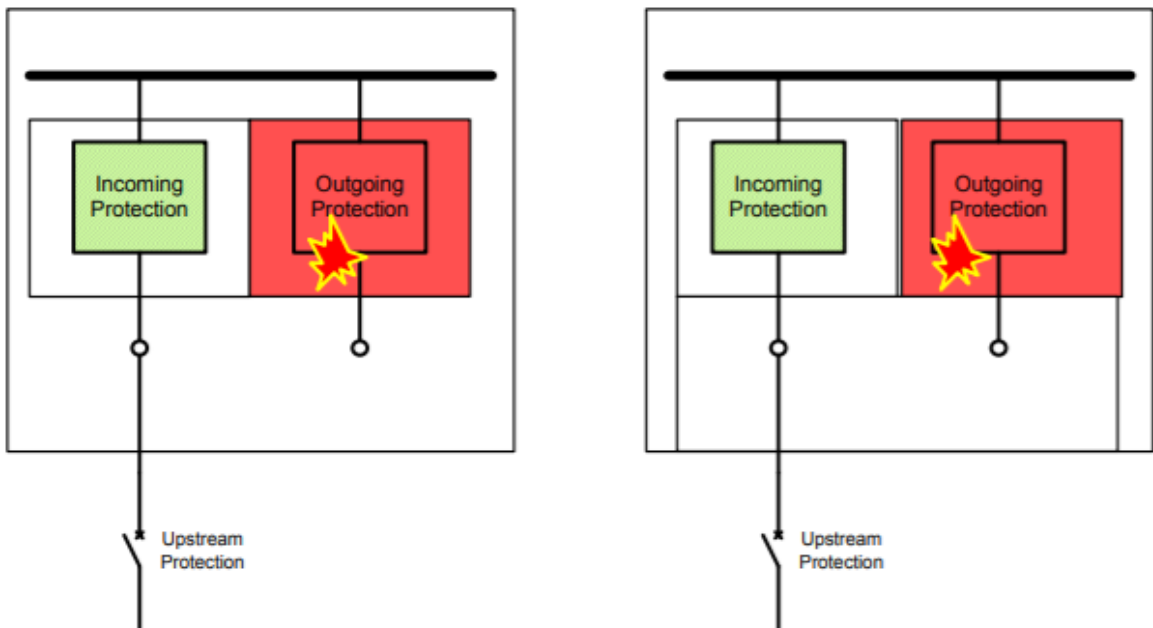
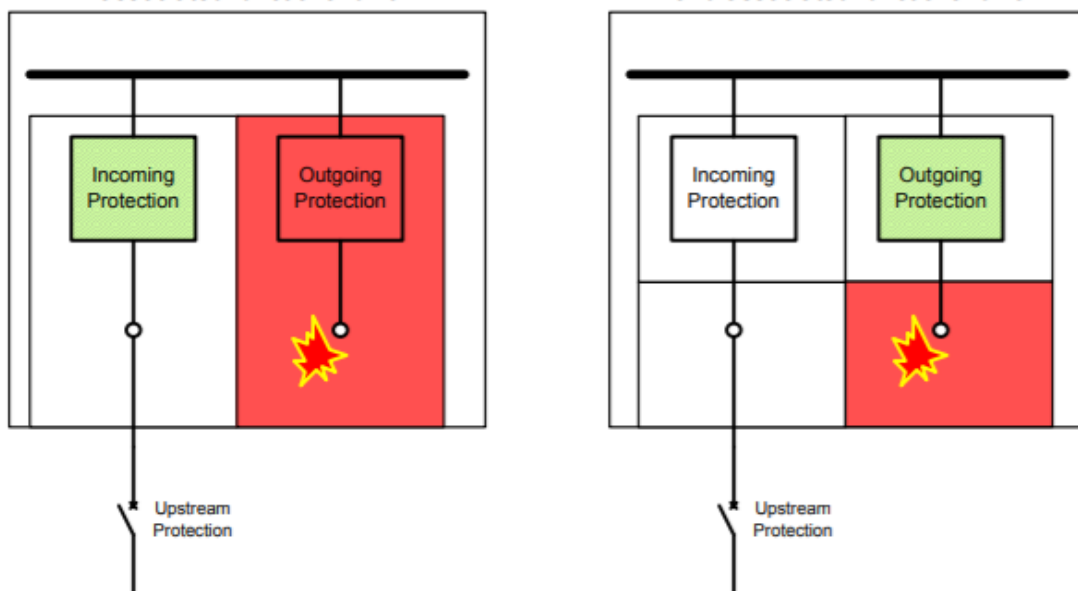


Figure 4-8 - Arc fault propagation for Form 3a (left) and Form 3b (right) switchboards



**Figure 4-9 - 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 utilizes low voltage switchboards of form 3b 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 the calculation of incident energy is the determination of 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. Generalized 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:

1. The equipment operating voltage;
2. Working distance associated with the operating voltage;
3. Calculated arcing current (maximum and minimum); and
4. Arcing time (i.e. 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 as 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<sup>2</sup>, 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 (2018) reproduced in Appendix A.

**Table 4-1 - SA Water Arc Flash Classifications**

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

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 i.e. switchboard panel doors open 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 personnel 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 type-test certification 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. Note that 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 Optimized protection settings

Arc fault incident energy can be greatly reduced by selecting appropriate protection devices and protection settings. Setting optimization 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 particular 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 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

Various other technologies are available, such as **zone selective interlocking and bus differential protection schemes**, which can be applied to reduce the incident energy levels. Zone selective interlocking provides protection between backup, primary and outgoing feeder protection that uses blocking signals between the devices, allowing protection to trip more quickly without a protection grading trade-off. A bus differential protection scheme, when implemented, provides a faster tripping time during a fault condition, within a given zone of protection.

Where the mitigation methods described above do not reduce incident energy levels to Category 1 or below, then **remote switching** 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 operation (remote tripping, closing or spring charging) at a safe distance from the switchboard. A label shall be installed adjacent to the device to indicate remote switching 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. Excerpts from NFPA 70(E) Table 130.5(C) are provided in Appendix A of this document. 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, examination of insulated cables without manipulation	Any	No
Electrical (energized) work, racking of circuit breakers, examination and manipulation of insulated cables, 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 and Appendix A, 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 the PPE requirements for each activity separately.

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

**Table 5-2 – Task-Specific Basis of PPE**

Activity Descriptor	Switchboard is internally Arc Rated		Switchboard is not internally Arc Rated	
	Doors Closed	Doors Open	Doors Closed	Doors Open
Operating non-switching Controls	Minimum PPE for site	Based on Location B or Location A incident energy	Minimum PPE for site	Based on Location B or Location A incident energy
Visual Inspection	Minimum PPE for site	Based on Location A and B incident energy	Minimum PPE for site	Based on Location A and B incident energy
Electrical Work	N/A		N/A	
Switching	Minimum PPE for site	Based on Location B or Location A incident energy	Based on Location B or Location A incident energy	Based on Location A incident energy
Racking	Minimum PPE for site	Based on Location B or Location A incident energy	Based on Location B or Location A incident energy	Based on Location A incident energy

Note: Locations (A,B) relate to Figure 4-4 - 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**

ACTIVITY	Task Specific PPE Category	
	Doors Closed	Doors Open
<b>Incomer and Non-Incomer circuits</b>		
Operating controls	Cat x or blank	Cat x or blank
Visual inspection	Cat x or blank	Cat x or blank
Electrical Work	Cat x or blank	
Switching	Cat x or blank	Cat x or blank
Racking	Cat x or blank	Cat x or blank

### 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:

1. Personnel (Operators and Tradespeople) interacting with control or monitoring devices mounted on the front panel or escutcheon of a switchboard or control panel.
2. Only locations on a switchboard or control panel that are designed to be accessed by non-electrically qualified personnel.
3. Opening hinged doors to access escutcheon devices.
4. 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 is not compromising the arc flash category that deems it safe to conduct this task, the likelihood of occurrence of an arc fault impacting on 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 upon the condition of the switchboard under assessment, a higher category 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:

1. Personnel reading panel meters (provided that all doors are closed).
2. Personnel 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.
3. 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

1. Visual inspection with doors closed is always deemed a low risk activity. However, depending upon the condition of the switchboard under assessment, a higher category 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.
2. 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:
  - a. If the line side busbars and terminals are fully insulated or phase barriered, select PPE category based on Location B (busbar) incident energy assessment.
  - b. If the line side busbars and terminals are not fully insulated or phase barriered, select PPE based on Location A (line side) incident energy assessment.

### 5.2.5 Electrical Work Definition

Electrical work refers to:

1. Connecting / disconnecting electricity supply to electrical equipment or installation;
2. Installing, removing, adding, testing, replacing, altering electrical equipment or an electrical installation, including testing for dead circuit; and/or
3. Cover removal or opening hinged doors on equipment that could contain exposed energized 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 persons. 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 i.e.:

1. Test for dead circuit.
2. Lock/unlock cubicle using interlock key.
3. Operation of an isolator, fuse switch, contactor or circuit breaker.
4. Fuse removal / insertion.
5. Manual spring charging.
6. Operating earthing mechanisms.
7. Install/remove equipment service tags.

### 5.2.8 Switching Explanation

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

1. For switchboards which have been verified for internal arc containment, switching activities with the doors closed require minimum level "standard" PPE.
2. For non-internal arc rated boards, recognizing 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:
  - a. If the line side busbars and terminals are fully insulated or phase barriered – select PPE Category based on Location B (busbar) incident energy assessment.
  - b. If the line side busbars and terminals are not fully insulated or phase barriered - select 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

1. For switchboards which have been verified for internal arc containment, racking in/out of the functional units do not require special PPE. The selection of PPE to be used during racking with doors open should be based on the following criteria:

- a. 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 PPE category based on Location B (busbar) incident energy assessment.
  - b. 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 PPE category based on Location A (line side) incident energy assessment.
  - c. 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 PPE category based on Location B (busbar) incident energy assessment.
2. For switchboards which have not been verified for internal arc containment, PPE selection for racking with doors open is a high-risk activity and the PPE should be selected 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:

- a. 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 PPE category based on Location B (busbar) incident energy assessment.
- b. 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 PPE category based on Location A (line side) incident energy assessment.
- c. 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 PPE category based on Location B (busbar) incident energy assessment.

## 6 Arc Flash Cautionary Labels

An adhesive arc flash cautionary label shall be produced for each switchboard or equipment item requiring such labelling to inform personnel 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 <sup>2</sup> )	0.84
11	Arc Flash Boundary (closest approach distance) (m)	0.36
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 <sup>2</sup> - follow risk assessment
15	A table of minimum arc rated PPE requirements against operational activities with doors open and doors closed.	<i>(Refer Figure 6-1 and Figure 6-2 for examples)</i>

It is important that the arc flash labels are posted in appropriate locations and be visible, securely attached, and maintained in legible condition. The bottom of the label should be placed 1.5m from ground level. A 'warning' label shall be applied for arc flash ratings that do not exceed Category 1. A 'danger' label will 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.

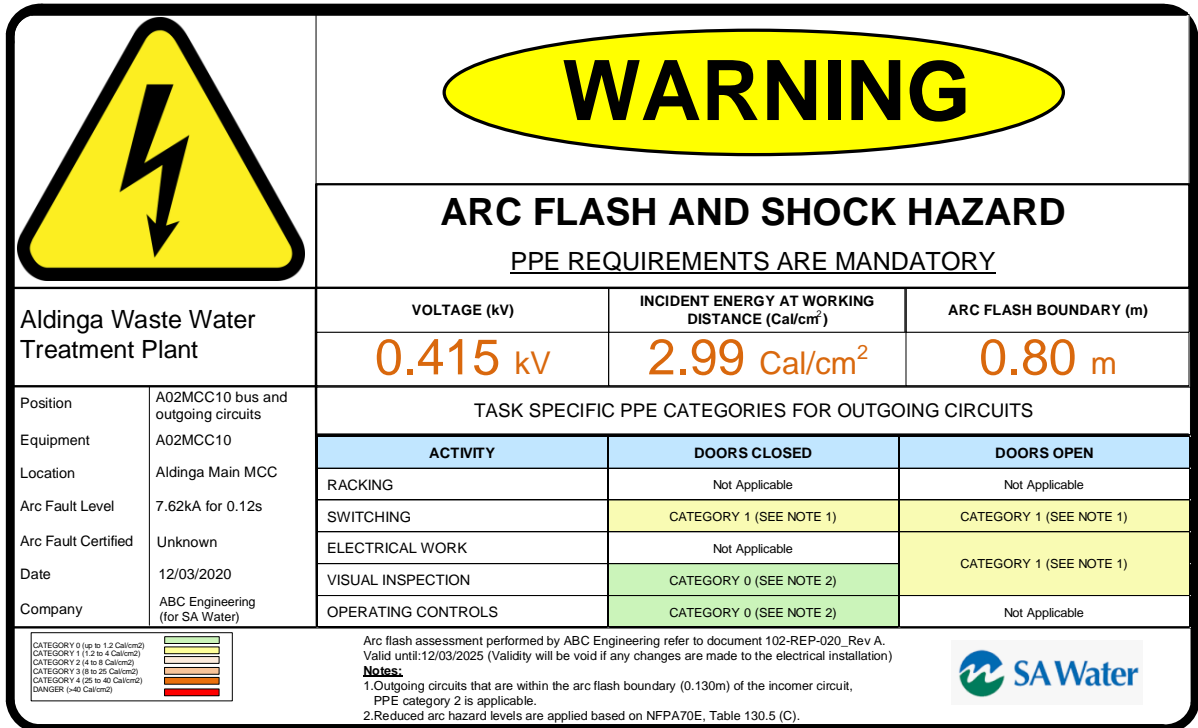


Figure 6-1 - Arc Flash 'Warning' Label Example

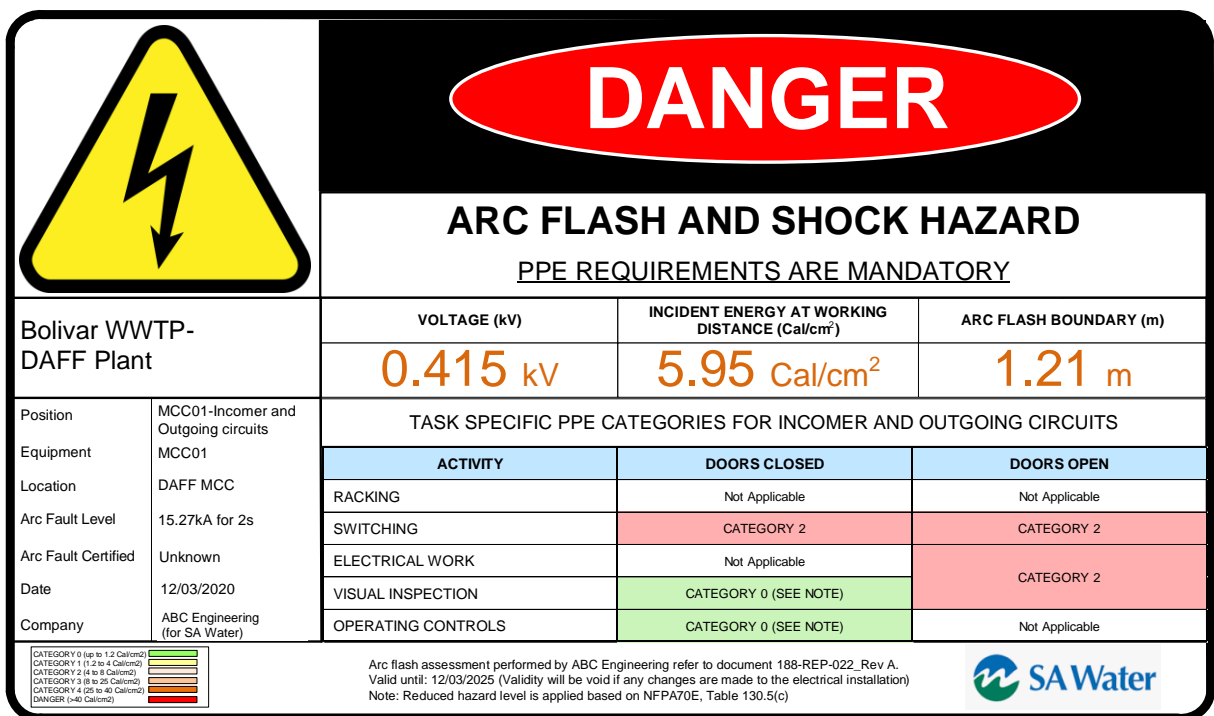


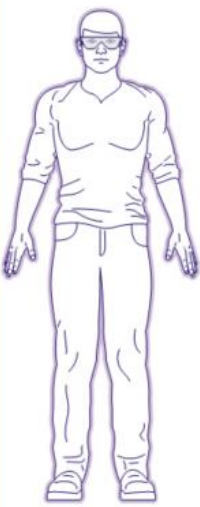



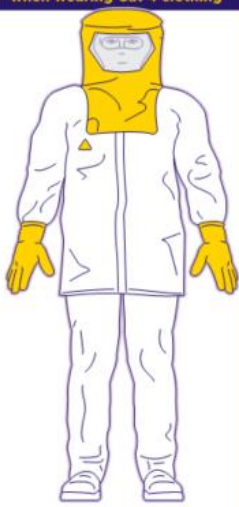
Figure 6-2 - Arc Flash 'Danger' Label Example

In addition to the above warning/danger labels, a general PPE label similar to that of Figure 6-3, which contains protective clothing details that needs 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 is to be provided on a suitably formatted sign made using fit-for-purpose material, separate to the Arc Flash rating signs, and located in a prominent and relevant position.

<h2 style="text-align: center;">ARC FLASH CATEGORIES - PPE REQUIREMENTS</h2> <p style="text-align: center;">APPLY PPE CATEGORIES LISTED BELOW AS SPECIFIED BY INDIVIDUAL EQUIPMENT SIGNS ON THIS SITE</p>				
PPE CATEGORY <b>0</b>	PPE CATEGORY <b>1</b>	PPE CATEGORY <b>2</b>	PPE CATEGORY <b>3</b>	PPE CATEGORY <b>4</b>
				<div style="background-color: #000080; color: white; padding: 2px; font-size: small;">HAZARD - Be aware of heat stress when wearing Cat 4 clothing</div> 
Incident Energy below 1.2 cal/cm <sup>2</sup>	Incident Energy 1.2 to < 4 cal/cm <sup>2</sup>	Incident Energy 4 to < 8 cal/cm <sup>2</sup>	Incident Energy 8 to < 25 cal/cm <sup>2</sup>	Incident Energy 25 to < 40 cal/cm <sup>2</sup>
<b>MINIMUM PPE FOR SITE</b>  (Specified on a per-site basis.)   This is a suggested minimum:	Arc-Rated Clothing - Minimum Arc Rating of 4 cal/cm <sup>2</sup> (16.75 J/cm <sup>2</sup> ): <b>Arc-rated long-sleeve shirt and pants or arc-rated overall</b>	Arc-Rated Clothing - Minimum Arc Rating of 8 cal/cm <sup>2</sup> (33.5 J/cm <sup>2</sup> ): <b>Arc-rated long-sleeve shirt and pants or arc-rated overall</b>	Arc-Rated Clothing - Minimum Arc Rating of 25 cal/cm <sup>2</sup> (104.7 J/cm <sup>2</sup> ): <b>Appropriate clothing system to meet the minimum arc rating</b>	Arc-Rated Clothing - Minimum Arc Rating of 40 cal/cm <sup>2</sup> (167.5 J/cm <sup>2</sup> ): <b>Appropriate clothing system to meet the minimum arc rating</b>
	<b>Arc-rated face shield</b>	<b>Arc-rated arc flash suit hood or arc-rated face shield and arc-rated balaclava</b>	<b>Arc-rated arc flash suit hood</b>	<b>Arc-rated arc flash suit hood</b>
<b>Sturdy covered footwear</b>	<b>Industrial work boots</b>	<b>Industrial work boots</b>	<b>Industrial work boots</b>	<b>Industrial work boots</b>
<b>Long sleeve shirt and pants</b>	<b>Safety glasses or safety goggles</b>	<b>Safety glasses or safety goggles</b>	<b>Safety glasses or safety goggles</b>	<b>Safety glasses or safety goggles</b>
Safety glasses or safety goggles – if specified.	<b>Hearing protection (ear plugs)</b>	<b>Hearing protection (ear plugs)</b>	<b>Hearing protection (ear plugs)</b>	<b>Hearing protection (ear plugs)</b>
	<b>Heavy duty leather gloves</b>	<b>Heavy duty leather gloves</b>	<b>Arc Rated Gloves</b>	<b>Arc Rated Gloves</b>
	<b>Hard Hat</b>	<b>Hard Hat</b>	<b>Hard Hat</b>	<b>Hard Hat</b>

**Figure 6-3 - General PPE Information Label Example**





**Figure 6-4 - Example Label to be Used Where Space is Limited**

All equipment rated Category 3 and above shall have the arc flash boundary suitably identified on the ground.

## 7 Assessment Outcome and Control

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

1. Different operational scenarios considered in the study,
2. 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,
3. A summary of arc flash PPE categories,
4. All applicable arc flash cautionary labels,
5. Arc flash mitigation measures and recommendations as applicable, and
6. 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 arc flash incident energy levels. 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 around the following power reticulation configuration and switchboard design principles outlined in this section.

### 8.1 LV Power Reticulation Philosophy

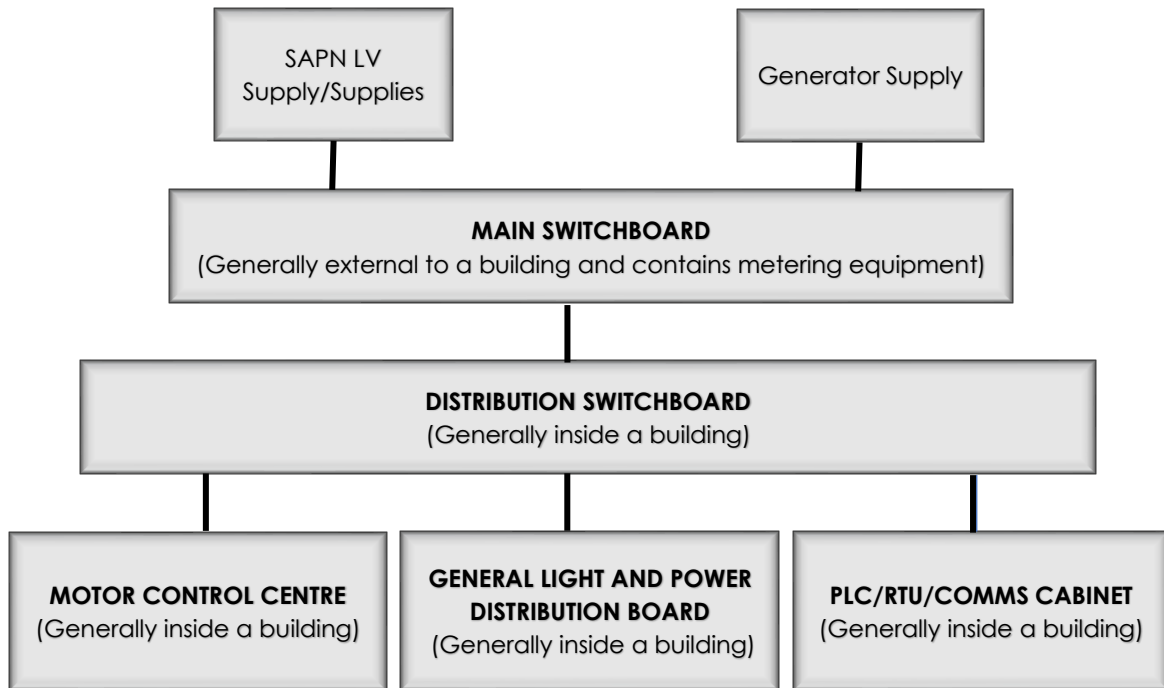


Figure 8-1 - LV Power Reticulation Philosophy

Table 8-1 - Switchboard Configuration Approach

Description	Arc Fault Containment Required to AS61439 (Appendix ZD <sup>(1)</sup> )	Maximum Permitted Arc Flash Category Rating (with Doors Open) – refer to Note 2	Maximum Permitted Arc Flash Category Rating (with Doors Closed) – refer to Note 2
Main Switchboard	Yes	2 <sup>(2b)</sup>	0
Distribution Switchboard	Dependent on arc flash assessment	1 <sup>(2c)</sup>	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
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.

## 8.2 General Design Requirements for Switchboards

All switchboards rated above 250 Amps shall be verified to provide arc flash energy containment. The arc flash energy containment 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 such that arcing exhaust gases are evacuated to the exterior of the switchboard/building in such a way that does not present a hazard to personnel.
- 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 containment to other sections, cable ways between the sections shall not compromise the arc fault containment 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, e.g. 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 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.

## 8.3 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 arc fault contained, with an absolute maximum arc flash energy rating of less than 40 cal/cm<sup>2</sup> (i.e. maximum of Category 4), but preferably an arc flash energy rating of less than 8 cal/cm<sup>2</sup> (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 Contractor shall liaise with the relevant electrical utility provider in an effort to modify/replace the upstream protective device, to reduce the associated risks.

## 8.4 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.

The need for arc fault containment 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  $< 4 \text{ cal/cm}^2$  (Category 1).

A Distribution Switchboard will typically supply the following loads:

1. Other local power distribution switchboards
2. Local motor control centres
3. Local control panels
4. General light and small power distribution boards
5. Proprietary standalone process equipment packages
6. Power conditioning equipment
7. UPS systems, etc.

## 8.5 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 (i.e. circuit breakers, contactors, relays, overloads, soft starters, etc.) and suitable interfaces to the wider control system i.e. segregated PLC/RTU section or facilities to interface to a separate PLC/RTU panel.

The need for arc fault containment 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  $< 4 \text{ cal/cm}^2$  (Category 1).

Consideration should also be given to the location of any Variable Speed Drives. Where space and installation environment/methodology allow, VSDs shall be IP54, mounted external to the switchboard i.e. mounted on the switchroom building internal wall.

Multiple Motor Control Centres shall be considered for areas where:

1. Category 1 arc flash energy ratings cannot be achieved through the use of one switchboard.
2. The required maximum demand is greater than 800 Amps.
3. The board length introduces supply, transportation, construction or installation issues.
4. There are benefits in providing electrical redundancy in the system.
5. There are benefits when carrying out future board replacement programs.

## 8.6 Distribution Boards or Sections Rated $\leq 250\text{A}$

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

All low voltage distribution boards and control panels for this purpose shall have a maximum current rating of  $\leq 250\text{A}$ . 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:

1. Maximum rating of 250 Amps and protected by a maximum 250 Amp adjustable circuit breaker located within the upstream switchboard (i.e. within the Distribution Switchboard or Motor Control Centre).
2. Arc flash energy rating of < 1.2 Cals/cm<sup>2</sup> (i.e. Category 0). This will allow acceptable safe access to Operators in appropriate standard PPE (i.e. clothing with typically > 80% natural fibre and standard safety glasses).
3. 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. e.g. installation of multiple, lower-rated distribution boards.
4. If it is not possible to demonstrate Category 0 attainment through calculation, providing distribution boards with upstream protection limited to 63A or less, will be an acceptable mitigation outcome.
5. For boards or sections which are accessible to personnel without an electrical license (e.g. PLC cabinet, telemetry section, etc.), a minimum degree of protection of IPXXC (i.e. 2.5mm diameter holes at least 100mm distant from live parts) shall be provided in addition to ensuring that at the position of operation or inspection, arc flash energy exposure is 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.

## 8.7 Arc Detection Systems

Arc fault detection devices using optical technology, in combination with current measurement sensors, or similar mitigation devices, are recommended for LV switchboards rated **800A or more**. The arc detection system can be used to trigger the operation of circuit breakers well in advance of the normal trip caused by arc fault current alone.

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

- At the point of switchboard connection to the incoming supply;
- In the incoming circuit breaker compartment;
- Along the main busbar, (unless this is fully insulated);
- Along the distribution busbar, (unless this is fully insulated);
- In outgoing circuit breaker compartments; and
- 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, of 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 1500mm from floor level.

# Appendix A – Excerpts from NFPA 70E

## A1 Table 130.5 (C)

130.6 ARTICLE 130 — WORK INVOLVING ELECTRICAL HAZARDS

Table 130.5(C) Estimate of the Likelihood of Occurrence of an Arc Flash Incident for ac and dc Systems

Task	Equipment Condition	Likelihood of Occurrence*
Reading a panel meter while operating a meter switch.	Any	No
Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening of doors or covers.		
Working on control circuits with exposed energized electrical conductors and circuit parts, nominal 125 volts ac or dc, or below without any other exposed energized equipment over nominal 125 volts ac or dc, including opening of hinged covers to gain access.		
Examination of insulated cable with no manipulation of cable.		
For dc systems, insertion or removal of individual cells or multi-cell units of a battery system in an open rack.	Any	Yes
For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack.		
For ac systems, work on energized electrical conductors and circuit parts, including voltage testing.		
For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing.		
Removal or installation of CBs or switches.		
Opening hinged door(s) or cover(s) or removal of bolted covers (to expose bare, energized electrical conductors and circuit parts). For dc systems, this includes bolted covers, such as battery terminal covers.		
Application of temporary protective grounding equipment, after voltage test.		
Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts.		
Insertion or removal of individual starter buckets from motor control center (MCC).		
Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed.		
Insertion or removal of plug-in devices into or from busways.		
Examination of insulated cable with manipulation of cable.		
Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center.		
Insertion or removal of revenue meters (kW-hour, at primary voltage and current).		
Removal of battery conductive intercell connector covers.		
For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by a dc source.		
Opening voltage transformer or control power transformer compartments.		
Operation of outdoor disconnect switch (hookstick operated) at 1 kV through 15 kV.		
Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV.	Normal	No
Operation of a CB, switch, contactor, or starter.		
Voltage testing on individual battery cells or individual multi-cell units.		
Removal or installation of covers for equipment such as wireways, junction boxes, and cable trays that does not expose bare, energized electrical conductors and circuit parts.		
Opening a panelboard hinged door or cover to access dead front overcurrent devices.	Abnormal	Yes
Removal of battery nonconductive intercell connector covers.		
Maintenance and testing on individual battery cells or individual multi-cell units in an open rack		
Insertion or removal of individual cells or multi-cell units of a battery system in an open rack.		
Arc-resistant switchgear Type 1 or 2 (for clearing times of less than 0.5 sec with a prospective fault current not to exceed the arc-resistant rating of the equipment) and metal enclosed interrupter switchgear, fused or unfused of arc resistant type construction, 1 kV through 15 kV.		
Insertion or removal (racking) of CBs from cubicles;		
Insertion or removal (racking) of ground and test device; or		
Insertion or removal (racking) of voltage transformers on or off the bus.		

(continues)



Table 130.5(C) Continued

Task	Equipment Condition	Likelihood of Occurrence*
Equipment condition considered to be "normal" if all of the following circumstances apply:		
<ul style="list-style-type: none"> <li>(1) The equipment is properly installed in accordance with the manufacturer's recommendations and applicable industry codes and standards.</li> <li>(2) The equipment is properly maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards.</li> <li>(3) The equipment is used in accordance with instructions included in the listing and labeling and in accordance with manufacturer's instructions.</li> <li>(4) Equipment doors are closed and secured.</li> <li>(5) Equipment covers are in place and secured.</li> <li>(6) There is no evidence of impending failure such as arcing, overheating, loose or bound equipment parts, visible damage, or deterioration.</li> </ul>		
*As defined in this standard, the two components of risk are the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard. Risk assessment is an overall process that involves estimating both the likelihood of occurrence and severity to determine if additional protective measures are required. The estimate of the likelihood of occurrence contained in this table does not cover every possible condition or situation, nor does it address severity of injury or damage to health. Where this table identifies "No" as an estimate of likelihood of occurrence, it means that an arc flash incident is not likely to occur. Where this table identifies "Yes" as an estimate of likelihood of occurrence, it means that additional protective measures are required to be selected and implemented according to the hierarchy of risk control identified in 110.1(H).		
Informational Note No. 1: An example of a standard that provides information for arc-resistant switchgear referred to in Table 130.5(C) is IEEE C57.20.7, <i>Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults</i> .		
Informational Note No. 2: Improper or inadequate maintenance can result in increased fault clearing time of the overcurrent protective device, thus increasing the incident energy. Where equipment is not properly installed or maintained, PPE selection based on incident energy analysis or the PPE category method might not provide adequate protection from arc flash hazards.		
Informational Note No. 3: Both larger and smaller available fault currents could result in higher incident energy. If the available fault current increases without a decrease in the fault clearing time of the overcurrent protective device, the incident energy will increase. If the available fault current decreases, resulting in a longer fault clearing time for the overcurrent protective device, incident energy could also increase.		
Informational Note No. 4: The occurrence of an arcing fault inside an enclosure produces a variety of physical phenomena very different from a bolted fault. For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating. Equipment and design practices are available to minimize the energy levels and the number of procedures that could expose an employee to high levels of incident energy. Proven designs such as arc-resistant switchgear, remote racking (insertion or removal), remote opening and closing of switching devices, high-resistance grounding of low-voltage and 5000-volt (nominal) systems, current limitation, and specification of covered bus or covered conductors within equipment are available to reduce the risk associated with an arc flash incident. See Informative O for safety-related design requirements.		
Informational Note No. 5: For additional direction for performing maintenance on overcurrent protective devices, see Chapter 2, Safety-Related Maintenance Requirements.		
Informational Note No. 6: See IEEE 1584, <i>Guide for Performing Arc Flash Calculations</i> , for more information regarding incident energy and the arc flash boundary for three-phase systems.		
(3) <b>Changes in Scope.</b> Employees shall be instructed to be alert for changes in the job or task that could lead the person outside of the electrically safe work condition or expose the person to additional hazards that were not part of the original plan.	(C) <b>Illumination.</b>	
(B) <b>Blind Reaching.</b> Employees shall be instructed not to reach blindly into areas that might contain exposed energized electrical conductors or circuit parts where an electrical hazard exists.	(1) <b>General.</b> Employees shall not enter spaces where electrical hazards exist unless illumination is provided that enables the employees to perform the work safely.	
	(2) <b>Obstructed View of Work Area.</b> Where lack of illumination or an obstruction precludes observation of the work to be performed, employees shall not perform any task within the limited approach boundary of energized electrical conductors or circuit parts operating at voltages equal to or greater than 50 volts or where an electrical hazard exists.	

Shaded text - Revisions. Δ - Text deletions and figure/table revisions. \* - Section deletions. N - New material.



## A2 Table 130.7 (C)

Table 8-2 - NFPA 70E Table 130.7 (C)

Arc-Flash PPE Category	PPE
1	<p>Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm<sup>2</sup> (16.75 J/cm<sup>2</sup>)<sup>a</sup> Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield<sup>b</sup> or arc flash suit hood</p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AN)</p> <p><b>Protective Equipment</b></p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)<sup>c</sup></p> <p>Heavy-duty leather gloves<sup>d</sup> Leather footwear (AN)</p>
2	<p>Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm<sup>2</sup> (33.5 J/cm<sup>2</sup>)<sup>a</sup> Arc-rated long-sleeve shirt and pants or arc-rated coverall</p> <p>Arc-rated flash suit hood or arc-rated face shield<sup>b</sup> and arc-rated balaclava Arc-rated jacket, parka, rainwear, or hard hat liner (AN) <b>Protective Equipment</b></p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)<sup>c</sup></p> <p>Heavy-duty leather gloves<sup>d</sup> Leather footwear</p>
3	<p>Arc-Rated Clothing Selected so that the System Arc Rating Meets the required Minimum Arc Rating of 25 cal/cm<sup>2</sup> (104.7 J/cm<sup>2</sup>)<sup>a</sup></p> <p>Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood</p> <p>Arc-rated gloves<sup>d</sup></p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AN)</p> <p><b>Protective Equipment</b></p> <p>Hard hat</p> <p>Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)<sup>c</sup></p> <p>Leather footwear</p>
4	<p>Arc-Rated Clothing Selected so that the System Arc Rating meets the required Minimum Arc Rating of 40 cal/cm<sup>2</sup> (167.5 J/cm<sup>2</sup>)<sup>a</sup></p> <p>Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR)</p> <p>Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood</p> <p>Arc-rated gloves<sup>c</sup></p> <p>Arc-rated jacket, parka, rainwear, or hard hat liner (AN)</p> <p><b>Protective Equipment</b></p> <p>Hard hat</p>

Arc-Flash PPE Category	PPE
	Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts) <sup>c</sup> Leather footwear

AN: As needed (optional). AR: As required. SR: Selection required.

<sup>a</sup> Arc rating is defined in Article 100.

<sup>b</sup> Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

<sup>c</sup> Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

<sup>d</sup> If rubber insulating gloves with leather protectors are used, additional leather or arc-rated gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement.