# Technical Specification - Arc Flash

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# Revision details

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# Introduction

This Specification is for the analysis and mitigation of arc flash hazards on or near live electrical equipment for Sydney Water assets.

Sydney Water makes no warranties, express or implied, that compliance with the contents of this Specification shall be sufficient to ensure safe systems or work or operation.

It is the user's sole responsibility to ensure that the copy of the Specification is the current version as in use by Sydney Water.

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# Copyright

# Acronyms

| Acronym | Definition |
|---|---|
| AC | Alternating current |
| AS/ NZS | Australian Standard/ New Zealand Standard |
| AR | Arc rated |
| DB | Distribution Board |
| DC | Direct current |
| HV | Exceeding low voltage |
| IDMT | Inverse definite minimum time (protection) |
| IEC | International Electrotechnical Commission (Standard) |
| LV | Exceeding Extra-low voltage, but not exceeding 1000 V a.c. or 1500 V d.c. |
| MCC | Motor control centre |
| RMU | Ring main unit |
| SCA | Switchgear and control gear assembly |
| SCADA | Supervisory control and data acquisition |
| VSD | Variable speed drive |
| SKM PTW | SKM Power Tools for Windows Software |
| SLD | Single Line Diagram |
| SLG | Single Line to Ground |
| SC | Short Circuit |
| 3P | Three Phase |
| Z% | Transformer Impedance Percentage |

# General Terms & Definitions

| Term | Definition |
|---|---|
| Arc Blast | An arc blast is the force of plasma and fire from an electric arc. |
| Arc Flash | Is defined as a voltage breakdown of air gap resistance resulting in the formation of an arc of highly concentrated radiant thermal energy. |
| Arc Flash Analysis | A study to calculate the incident energy and PPE level |
| Arc Flash Assessment | The entire arc flash analysis and risk mitigation process from start to finish |
| Arc Flash Boundary | The safe working distance which, if crossed, will require use of appropriate PPE. The PPE Class depends on the category of the arc. |
| Arc Flash Exposure Consequence | The assessed potential for an arcing fault to harm people or to damage property in the event of an arc flash event occurring, and is derived from Arc Flash Incident Energy Calculations |
| Arc Flash Hazard | A dangerous condition associated with the possible release of energy caused by an electric arc |
| Arc Flash Hazard Assessment | A study to determine the severity of an Arc Flash and worker’s potential exposure to Arc Flash energy, conducted for the purpose of injury prevention and the determination of safe work practices, arc flash protection boundary, and the appropriate levels of PPE. |
| Arc Flash Incident Energy Calculations | Calculations based on the IEEE Std 1584 methodology to assess the approach distances, Incident Energy generated by an arcing fault, and hazard rating categories. The calculations are the mechanism for assessing the Arc Flash Exposure Consequences |
| Arc flash protection Boundary | An approach limit at a distance from live parts that are uninsulated or exposed within which a person could receive a second degree burn during an electrical arc event. |
| Arc Rated PPE | PPE that affords the wearer with protection from an electric arc up to an exposure level defined by the rating of the clothing |
| Arcing Fault Current | A fault current flowing through an electrical arc plasma. Also referred to as arc fault current or arc current |
| Backup Protection | 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 |
| Bolted Fault Current | A fault current flowing where there is close to zero resistance or impedance in the fault path |
| Contributing Branch | A connection to the switchboard through which a portion of the total arcing fault current originates |
| Design Life | Design Life of an asset is the life the asset is designed for operation |
| Distribution Board | General power distribution boards (typically up to 250A) are defined as single compartment electrical boards with MCB (miniature circuit breaker) outgoing circuits. |
| Hazard Risk Category | A rating factor used by NFPA70E to nominate the incident energy that may exist within the specified working distance due to an arcing fault |
| IEEE Std 1584 | U.S. guide for performing arc flash calculations. This standard is widely used in the absence of an equivalent IEC or Australian standard |
| Incident Energy | The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. In this report Incident Energy levels are calculated based on the concepts / formulas presented in IEEE Std 1584 |
| *N_box | Information detailed in SKM PTW Arc flash table “Notes (*N) Column”: Out of IEEE 1584 Box Range, Lee Equation Used. (Box width < 4 x Bus Gap. Based on IEEE 1584-2018) |
| Network Operator | The supply authority controlling the operation of the electrical supply network |

| Term | Definition |
|---|---|
| NFPA 70E | U.S. regulatory Standard for Electrical Safety in the Workplace. NFPA 70E references IEEE Std 1584 as one of a number of methods that can be used to assess arc flash hazards |
| PPE | Personal protective equipment |
| PPE Category | The rating of the PPE aligned to the incident energy intervals outlined in the Australian Energy Council – Arc Flash |
| Primary Protection | The fastest protection relay and circuit breaker combination to detect and clear an electrical fault. For an arcing fault occurring on a switchboard's main busbar this is typically the incomer protection |
| Remaining Life | The asset life remaining at a point in time before the asset is unusable |
| SKM Component Data State | Allow the SKM user to set the component data state to estimated or verified |
| Switchgear and Control gear Assembly | This covers the 400 V main switchboards, power distribution switchboards, motor control centres (MCCs) for indoor and outdoor application. These are generally known as switchgear and control gear assembly (SCA).<br>SCA does not include stand-alone motor starters, general power distribution board (DB), SCADA and IICATS panels, individual devices and self-contained components, such as starters, fuses, electronic equipment etc. which will comply with the relevant product standards. |
| Working Distance | The distance between the potential arc source and the face and chest of the worker performing the task. |

# 1. General

## 1.1 Scope

This specification defines the accepted Sydney Water practices for arc flash incident energy assessments, arc rated personal protective equipment, warning label requirements and design safety to reduce arc flash risk for HV and LV installations. The target arc flash hazard category must be as low as reasonably practicable and not above Cat.2 (8 $Cal/cm2$). This specification is intended to ensure that consistent arc flash analysis and mitigation outcomes are achieved across Sydney Water operations.

The arc flash hazard assessments detailed in this specification must be undertaken during the engineering design stage in accordance with Sydney Water Technical Specification – Electrical.

The standard applies to greenfield and brownfield sites, installation of new switchboards and for any alteration work to an installation affecting the arc flash incident energy levels of an existing switchboard e.g. changes to incomer protection, supply transformer, switchboard modification, alternative power supplies like permanent generator or renewable energy installations.

The following elements are included:

- Data Gathering – Collection of all required data through visual inspection and available plant documentation to be able to perform arc flash hazard calculations.
- System Modelling – Building/updating a system model based on the collected data that allows to perform arc flash incident energy calculations based on the methods presented in the IEEE Std 1584 to calculate incident energy levels, the arc flash boundary and the hazard rating category.
- Mitigation & Risk Assessment – Assessing the results of the arc flash incident energy calculations and conduct a risk assessment, equipment verification and field testing to be able to evaluate the most suitable control measures to apply to mitigate the present arc flash hazard levels.
- Outcome & Application – Applying the outcome of the arc flash assessment resulting in agreed control measures, procedures, arc rated PPE requirements taking into consideration the calculated incident energy levels, the switchboard design ratings/test certifications and operational activities and produce arc flash warning labels.
- Documentation – documenting the assessment results, deliverables, change controls and further outcomes.

Sydney Water's objective is that its assets will be designed so that they are safe, have a minimum long-term cost efficiency and with operability and maintainability considered.

This document sets out design specification and engineering practice which must be followed in respect of the analysis, mitigation and documentation of arc flash hazards on electrical equipment acquired by Sydney Water.

This includes but is not limited to:

- HV Switchboards/RMUs
- LV Switchboards
- Motor control centres
- Distribution Boards
- Motor starters

This specification cannot and does not address all issues that will need to be considered by the design party in respect to a particular arc flash hazard scenario including but not limited to temporary/construction works.

## 1.2 Proprietary items

Nomination of a proprietary item by Sydney Water does not imply preference or exclusivity for the item identified.

Alternatives that are equivalent to the nominated items can be submitted to Sydney Water for acceptance. The submission must include appropriate technical information, samples, calculations and the reasons for the proposed substitution, as appropriate.

# 2. Background

An arc flash is the uncontrolled release of energy (arc plasma) due to an electrical arcing fault through air (phase to phase or phase to earth). These faults produce intense heat, sound blasts and pressure waves, which can vaporize metal and initiate combustion in nearby materials, presenting risks of fire or explosion. Arc flash can result in significant harm, such as severe burns, hearing impairment, vision loss, respiratory damage, and in certain instances, it can tragically lead to fatalities.

An arc flash hazard is the danger of excessive heat exposure and serious burn injuries due to the arc plasma that is ejected at high speeds due to the associated pressure wave. The arc plasma itself is a superheated, ionized, conductive, magnetic gas which creates a severe burning hazard. Besides the potential human risk of injury or fatality due to an arc flash, other impacts may include treatment process disruption and other consequential damage as a result of the initial explosion.

The arc flash level is determined by the incident energy. The incident energy is defined as the amount of thermal energy impressed on a surface, a specific distance away from the source during an electrical arc event. Incident Energy is measured in joules per centimetre squared ($J/cm^2$) or in calories per centimetre squared ($Cal/cm^2$) and determines the arc flash hazard category level of switchgear, required PPE and boundary distance.

# 3. References

The majority of work and developments in arc flash have come from the U.S. where there are specific legislative requirements around the assessment of arc flash hazards, and the provision of AR PPE.

The most common methods of arc flash hazard assessment and resulting AR PPE specification used in the U.S. are:

- NFPA 70E (Standard for Electrical Safety in the Workplace, which includes tables providing generalised approximate (but conservative) PPE levels based on a hazard category associated with the type of work activity undertaken.
- IEEE Std 1584 (Guide for Performing Arc Flash Hazard Calculations), which provides techniques for designers to apply in determining the arc flash hazard distance and incident energy to which people could be exposed during their work on or near electrical equipment. The IEEE Std 1584 provides an empirically derived calculation model based on laboratory testing and subsequent statistical modelling and curve fitting and applies to systems fitting specified test range criteria.

Although a U.S standard, IEEE Std 1584 has become the most widely used method to evaluate switchboard arc flash hazards in Australia largely due to lack of official authoritative Australian Standards or guidelines.

However, the Australian Energy Council and Australian Energy Networks Association, ENA NENS-09, provides an approach of interpretation of the U.S. standards for the Australian industry.

AS/NZS4836 is a legislated Standard for Australia where arc flash has been identified as a hazard for low voltage installations. This specification provides the detail for calculating incident energy and evaluating the risks associated with arc flashes to comply to the requirements in AS/NZS4836.

## 3.1 Guidelines and Design Manuals

| | |
|---|---|
| Sydney Water | Technical Specification – Electrical |
| Sydney Water | Sydney Water Conditional Assessment Standard DOC0002014 |
| Australian Energy Council | Electrical Arc Flash Hazard Management Guideline |
| Energy Networks Association | ENA NENS-09 National Guidelines for the Selection, Use and Maintenance of Personal Protective Equipment for Electrical Hazards |

## 3.2 Australian Standards

| | |
|---|---|
| AS/NZS 3000 | Electrical Installations – ‘Wiring Rules’ |
| AS/NZS 3008.1.1 | Electrical Installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1 kV |
| AS/NZS 2067 | Substations and High Voltage Installations |
| AS/NZS 3851 | The calculation of short-circuit currents in three phase A.C. systems |
| AS/NZS 62271 series | High-voltage switchgear and control gear - A.C. metal-enclosed switchgear and control gear for rated voltages above 1kV |
| AS/NZS 4836 | Safe working on or near low voltage electrical installations and equipment. |

| | |
|---|---|
| AS/NZS 61439 series | Low-voltage switchgear and control gear assemblies |

## 3.3 Legislation & Act

| | |
|---|---|
| Legislation | Work Health and Safety Act 2011 |
| Legislation | Work Health and Safety Regulation 2017 |

## 3.4 International Standards

| | |
|---|---|
| IEEE Std 1584 | IEEE Guide for Performing Arc Flash Hazard Calculations |
| NFPA 70E | Standard for Electrical Safety in the Workplace |

# 4. Arc Flash Assessment Overview

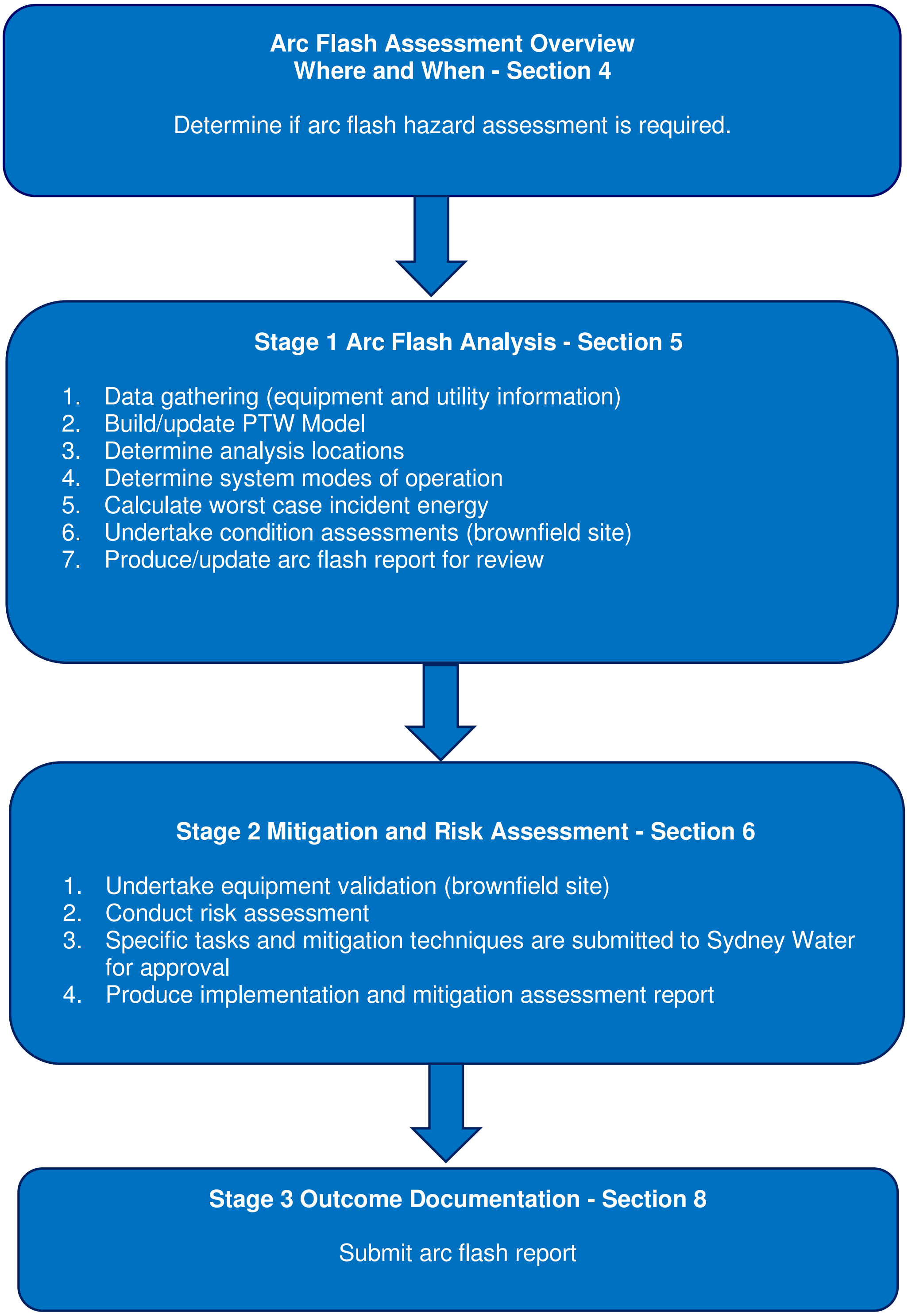



Figure 1- Arc Flash Assessment Overview

## 4.1 Where and when to perform arc flash calculations

Arc flash assessment (calculation of the arc flash incident energy level and hazard category) must be conducted on all switchboards, SCA's, MCC's, standalone motor starter panels and DB's based on the latest IEEE 1584 and NFPA 70E standards through modelling. The contributions of arc flash model must consider energy sources including but not limited to:

i. Alternative supply sources
ii. Co-gen, hydro-gen and biomethane-gen systems
iii. Diesel generator/s (permanent and/or mobile generators)
iv. Solar PV systems (above 2kA bolted fault current requires DC arc flash calculation)
v. Motor contributions must consider all single motor load equal to or greater than 37.5kW
vi. Normal and abnormal switching scenarios.

Greenfield sites are to follow the full arc flash calculation and assessment process. If a PTW Model and report has been produced (as part of the design development) all inputs are to be re-validated and updated based on the final as-selected equipment.

Brownfield sites that require limited arc flash assessment that have an existing PTW model and arc flash report are not required to complete the full arc flash assessment process. The arc flash assessment is to be carried out on the impacted parts of the site.

Arc flash assessment must be carried out for DB's, sub-distribution panels, standalone motor starter panels, control, instrumentation, and SCADA cubicles that meet at least one of the conditions below:

a. Maximum prospective fault level is above 10kA; or
b. The rating of the upstream protection device is 400A or higher; or
c. The rating of the upstream circuit breaker is 100A, or 160A, or 250A rated current with an instantaneous (magnetic release) trip setting above 8x nominal CB rated current.

Note: Under most circumstances the instantaneous settings on 250A, 160A or 100A CBs should not be more than 8x.

# 5. Arc Flash Analysis

Arc Flash Hazard assessments must be carried out during engineering design stage in accordance with the requirement in Sydney Water Technical Specification – Electrical.

For Arc Flash Hazard assessments of Sydney Water's HV and LV switchboards, the IEEE Std 1584 method of arc flash calculation must be utilised, as outlined in Section 4.2 of IEEE 1584. However, if the equipment or system parameters fall outside the defined range specified in Section 4.2, the Ralph Lee equation should be employed instead.

The arc flash analysis must be produced based on the Normal and Abnormal operating scenario the system could practically generate.

For switchboards (HV and LV), SCA's and MCC's the target arc flash hazard category must be as low as reasonably practicable and not above Cat.2 (8 $Cal/cm^2$). The arc flash analysis report must provide mitigation through engineering options to reduce the arc flash hazard category to Cat.2 or below.

Where an arc flash incident energy level is greater than Cat.2, the final design must have prior agreement from SWC, and the hazard mitigation strategy must have prior acceptance from SWC before procuring equipment and the implementation of the mitigation work.

For DB's and standalone motor starter panels the target arc flash hazard category must be as low as reasonably practicable and not above Cat.1. Mitigation measures must be provided to reduce the arc flash hazard category to Cat.1 or below and can include reduction of upstream protection fault clearance times and/or provision of upstream fault current limiters.

The specific outcomes and requirements for performing arc flash assessments are described in following sections.

## 5.1 IEEE Std 1584 arc flash analysis method

The outcomes of an IEEE Std 1584 arc flash analysis method are as follows:

### 5.1.1 Incident energy at the working distance

The incident energy is the amount of energy a surface (or a person's face and chest) exposed to an arc flash will experience at a set distance (known as the working distance) from an arc. The incident energy reduces exponentially as the distance between the person and the arc source increases.

### 5.1.2 Arc flash boundary

The arc flash boundary is the distance from live parts within which a person without Arc Rated PPE could receive a second-degree burn. Outside of the arc flash boundary the assessed energy levels are below 1.2 cal/cm2 (i.e. within the arc flash boundary the energy levels are 1.2 cal/cm2 or above). The software evaluation tool automatically determines the arc flash boundary.

### 5.1.3 Hazard rating category

Once the incident energy has been assessed a Hazard Rating Category can be assigned. The Australian Energy Council defines five Hazard Rating Categories (Category 0 – 4), according to specified ranges of incident energy (refer to Section 5.14 Arc rated PPE Selection for PPE requirements).

## 5.2 Arc flash analysis locations

The below figure illustrates the three possible locations on a switchboard where an arc flash could occur.

The arc flash incident energy is different at each location due to different protection devices (with a different operating time) acting to interrupt the arc. Arc flash calculations must be undertaken at locations 1, 2 and 3. Refer to Section 0

Determining 'worst case' incident energy.

1. Location 1 – Incomer terminals on the line side of the incomer protection
2. Location 2 – Terminals, main busbars and droppers located between the main incoming protection and the outgoing feeder protection
3. Location 3 – Feeder terminals on the load side of the outgoing distribution feeder protection

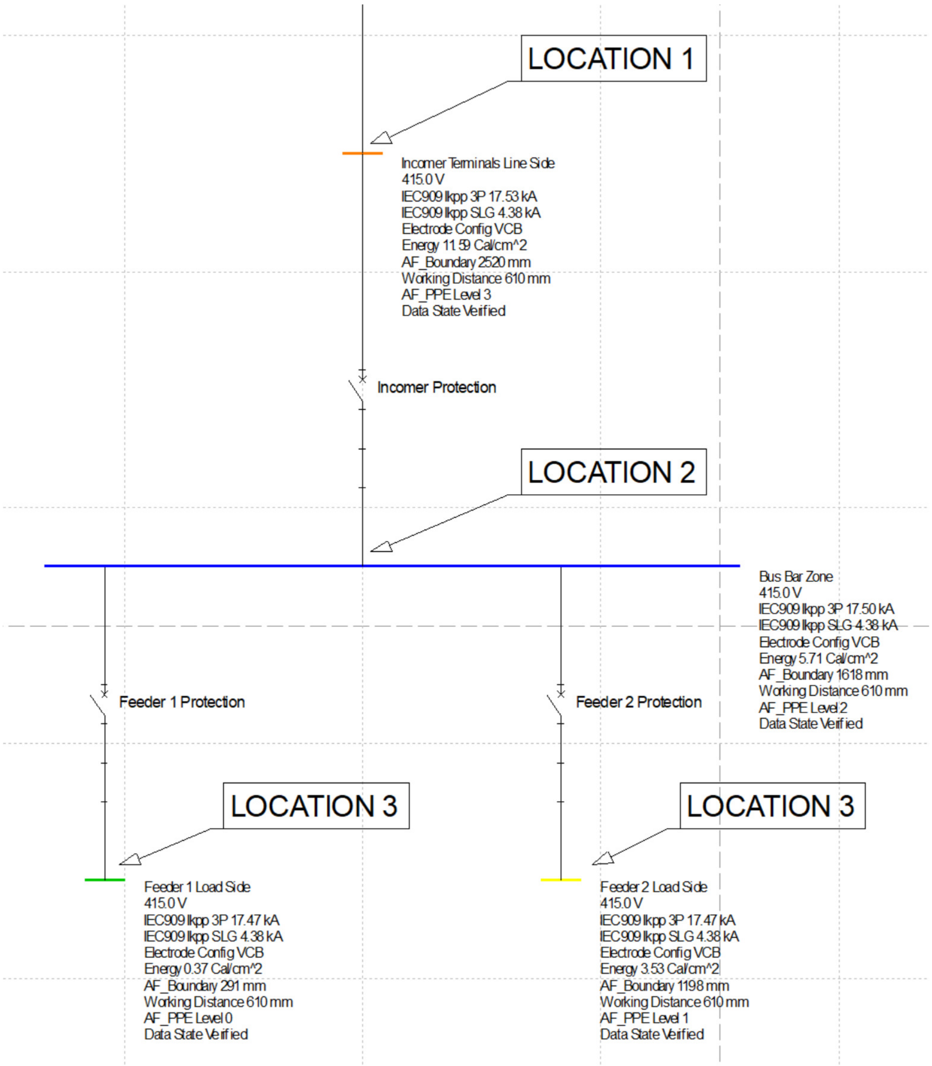



Figure 2- Switchboard Locations

For standalone motor starter panels and DBs the arc flash analysis must be conducted at the incomer cable terminal as the worst-case scenario (e.g. line side of DB/local isolator incomer circuit breaker/switch).

## 5.3 Arc flash calculations steps

The following steps must be completed when performing an arc flash analysis:

- Collect the system and installation data
- Prepare a software model of the electrical system
- Assess the duration of the arcing fault
- Identify working distances
- Determine the normal and abnormal operating scenarios
- Calculate the incident energy
- Determine the arc flash boundary
- Produce arc flash report

### 5.3.1 Brownfield Sites

For brownfield sites that require limited arc flash analysis the existing PTW model and arc flash report, where available, must be updated to include parts of the electrical installation that are impacted by renewals, upgrades, alterations, or modifications. Where no existing PTW model or arc flash report is available a full arc flash assessment is required.

Brownfield sites require equipment validation to be carried out as part of the arc flash analysis. Impacted parts of the site must be subject to protection testing (for HV CBs and LV CBs with electronic trip units) and switchboard condition assessments if not previously completed. Validation is to be carried out on the full protection (tripping) chain. Results are to be detailed in the updated arc flash risk assessment to inform the arc flash risk event ‘likelihood’.

For brownfield sites, motors less than 37.5kW may be lumped together into a single motor to calculate the fault current contribution for arc flash. A schedule of all lumped motor loads must be provided with all individual motors listed in the arc flash report.

## 5.4 Data Gathering

For each electrical equipment or plant area under assessment the data that is required for modelling of the electrical system in order to carry out arc flash incident energy level assessments is detailed in the following sections which includes:

- Utility protection and fault level details at PCC
- Transformer, mobile and permanent generator data
- Cable data
- Switchboard types e.g. arc rated, form 3b, AFLR
- Cubical / Panel dimensions
- Protection device details and settings
- Bus gaps
- Switching points
- Electrode configurations
- All loads and motor data

All assumptions must be detailed in the report.

### 5.4.1 Utility Protection Details and Fault Contribution

The utility power supply protection device details and settings are to be requested and supplied by Sydney Water, where information is not available it must be requested and supplied by the utility.

The fault current contribution is to be modelled as follows:

- Maximum three phase initial symmetrical fault level (or equivalent impedance)
- Minimum three phase initial symmetrical fault level (or equivalent impedance)
- X/R ratio of the supply network impedance, for both the maximum and minimum fault level cases

### 5.4.2 Permanent and Mobile Generators

The following information must be modelled for generators:

- Rated voltage
- kVA rating
- Rated power factor
- D-Axis sub-transient reactance (Xd")
- Stator resistance (Rg)
- NER details

***Note:***

For installations with facility for connection of a mobile generator, the arc flash assessment must consist of a minimum generator rating (with typical sub-transient and resistance parameters) that satisfies the performance requirements of the installation.

### 5.4.3 Transformers

The following name plate information must be modelled for transformers:

- Voltage ratings
- Winding connections
- kVA rating
- Tap position
- Positive sequence transformer impedance (%Z)
- Positive sequence X/R ratio

***Note:***

As an alternative to %Z and X/R ratio, the %X and %R values can be modelled.

The following assumptions are acceptable where information is not available, all assumptions must be detailed in the arc flash report:

- Nominal tap position (position '0' in PTW)
- Transformer X/R ratio of 10 for transformers rated below 10 MVA (as per AS 3851)
- Primary transformer winding: Delta
- Secondary Winding: Star

- Impedance, transformers using standard values from PTW

### 5.4.4 Cables

All cables of the electrical distribution system from the utility point of supply up to the bus bars of the switchboards under assessment, as well as any other sources of fault current including generators and induction motors that would contribute fault current in the event of an arcing fault, including induction motors downstream of the board under assessment must be modelled.

The following information must be modelled for cables:

- Conductor size
- Conductor resistance and reactance values
- Number of conductors in parallel
- Conductor length

For LV cables the resistance and reactance values of cables can be obtained from the manufacturer technical catalogues or AS/NZS 3008.1.1.

### 5.4.5 Cubical / Panel dimensions

Cubical / Panel dimensions are to be modelled at the required arc flash analysis locations using actual dimensions.

### 5.4.6 Protection Device Characteristics

Protection device settings must include:

- The time current characteristic settings of the protection device
- The upper and lower operating time tolerance bands of the time current tripping characteristic
- Both the detection time and the circuit breaker opening time must be included in the model. Where a protection device is a circuit breaker with integral trip unit, the time current characteristic provided by the manufacturer typically represents the combined detection and opening time. Where the protection relay and circuit breaker are separate devices, the circuit breaker opening time must be specified as a separate modelling parameter

***Note:***

- Based on the ‘worst-case’ assumption that arcing faults quickly escalate into three phase balanced faults, earth fault protection cannot be relied upon to clear an arcing fault. Thus, modelling of earth fault protection devices is not a requirement for arc flash assessment.
- For some facilities the backup protection is provided by the upstream utility protection device, requiring liaison with the power utility
- If/when the tested circuit breaker tripping time is shorter (better) than standard tripping time from the manufacture manual, the standard tripping time must be used as the input for the system modelling.
- If/when the tested circuit breaker tripping time is longer (worse) than the standard tripping time from the manufacture manual, the worst-case tested tripping time must be used as the input for the system modelling.

### 5.4.7 Bus Gaps

Bus gap dimensions are to be modelled at the required arc flash analysis locations, refer to section 5.7 for further information on determining bus gaps.

### 5.4.8 Switching Points

The model must include all switching points which could affect the fault current levels, within the site distribution boundary. This includes HV and LV switching points such as:

- Isolation switches
- Bus-ties
- Isolation points for contingency supply arrangements (i.e. 'emergency feeder')

### 5.4.9 Electrode configuration

Electrode configurations are to be modelled at the required arc flash analysis locations, refer to section 5.8 for further information.

### 5.4.10 Loads

The system model, as a minimum, must include all loads on the site that may contribute to the overall fault levels including motors. Motor contributions must consider all single motor load equal to or greater than 37.5kW.

The following information must be modelled for motors:

- Motor kW rating
- Motor efficiency
- Power factor
- Locked rotor current

The following assumptions are acceptable where information is not available for brownfield sites, all assumptions must be detailed in the arc flash report:

- Power factor: 0.9
- Motor efficiency: 0.9
- Locked rotor current: 7 × FLA

### 5.4.11 System Buses

The nominal operating voltage must be included in the model for all busses and terminals. For switchboards, the bus labels in the system model must be using Maximo asset tag number with numeric extension representing different bus section (e.g. For ST0001SCA1234, if it has three bus sections, then they will be labelled as SCA 1234-1, SCA 1234-2 and SCA 1234-3). For nodes representing the line side or load side terminal of a protective device, equipment label_line or equipment label_load as the node label must be used.

## 5.5 Software Model of the Electrical System

### 5.5.1 Software Requirement

The SKM Power*Tool for Windows (PTW) modelling software package must be used to create and/or update power system models and perform the arc flash analysis. The software version must be compatible with the Sydney Water's master library file software version.

The use of PTW provides:

- Consistency of approach and output
- Accurate modelling
- Common basis for the future electrical installation modifications/assessment.

The PTW model with all associated library files must be provided to Sydney Water.

### 5.5.2 Software Model Limits

The terminal points for modelling must include the components of the electrical distribution system from the utility point of supply up to the bus bars of the switchboards under assessment, as well as any other sources of fault current including generators and induction motors that would contribute fault current in the event of an arcing fault, including induction motors downstream of the board under assessment.

Once the model has been accurately setup in PTW the arc flash tool can be used to automatically calculate the incident energy, arc flash boundary and hazard rating categories.

Where new switchboards are being installed at an existing facility, Sydney Water must be consulted to obtain the existing model of the facility's electrical system, where available. In some cases, the existing model may not be current and must be developed and updated by the designer prior to its use for Arc Flash Hazard Assessments.

### 5.5.3 SKM Power tools single line diagram

Arc flash analysis SLD scenario is to be detailed using colour "Toggle Arc Flash Category Colour" which will allow easy viewing to highlight PPE categories. Figure 3 depicts the colour assignments for the appropriate arc flash incident energy. Only required buses are to be detailed in the SLD as per Section 4.

| Incident Energy From (cal/cm^2) | Incident Energy To (cal/cm^2) | Required Minimum Arc Rating of PPE (cal/cm^2) | Category Background Colour | Category Background Colour Code |
|---|---|---|---|---|
| 0.0 | 1.2 | N/A | | RGB (0,223,0) |
| 1.2 | 4.0 | 4 | | RGB (0,0,255) |
| 4.0 | 8.0 | 8 | | RGB (255,255,0) |
| 8.0 | 25.0 | 25 | | RGB (255,150,40) |
| 25.0 | 40.0 | 40 | | RGB (255,0,0) |
| 40.0 | 999.0 | N/A | | RGB (128,0,128) |

Figure 3 - Arc Flash Category Colour

The data block attributes for equipment are to be shown on the PTW SLD are detailed in Table 1. Refer to Section 9 for examples.

Table 1 - PTW SLD Data Block Format

| PTW SLD Data Block Displayed Attributes | | | |
|---|---|---|---|
| **Utility** | **Generator** | **Transformer** | **Cable** |
| Rated Voltage | Rated kVA | Nominal kVA | Cable Size |
| SC Contribution 3P | Data State | Pri Rated Voltage | Qty Per Phase |
| SC Contribution SLG | | Sec Rated Voltage | Conductor Desc |
| X/R 3P | | Pri Tap | Conductor Type |
| X/R SLG | | Z% | Length |
| Data State | | Data State | Data State |
| **Bus** | **Protection Device** | **Motor** | |
| Description | Manufacturer | Rated kW | |
| System Nominal Voltage | Frame/Model | Data State | |
| Ikpp 3P | CT Ratio | | |
| Ikpp SLG | Sensor Trip | | |
| Electrode Config | Plug | | |
| Incident Energy | Settings | | |
| Boundary | Data State | | |
| Working Distance | | | |
| PPE Level | | | |
| Data State | | | |

Note: The Data State attribute is to indicate if the equipment has been verified or assumed.

## 5.6 Determining the System Modes of Operation

The system operating modes impact on the prospective short circuit current and incident energy at a switchboard.

The Normal operating mode is the base case operating arrangement for the site (i.e. the system state that is used to run the plant for most production cycles or phases). An Abnormal mode is anything other than the Normal case, including temporary switching arrangements and alternative operating modes.

Where a switchboard is supplied via a single radial utility feed, there is only a single mode of operation that needs to be considered. However, it is not uncommon to have switchboards supplied by distribution systems with more than one possible mode of operation, for example:

- Sites with two utility points of supply (typically associated with large sites such as wastewater treatment plants)
- Embedded generators that can operate islanded or in parallel with the utility supply
- Sites which have an emergency/mobile backup generator facility for supply in the event of a mains failure
- Dual feeds to switchboards providing either single or parallel supplies.
- Bus-sectionalises which can be opened or closed

## 5.7 Determining Bus Gaps

The bus gap is defined as the distance between adjacent phases at a potential arc point. When performing arc flash assessments, the actual bus gap information must be included in the SKM model. If the actual bus gap for existing equipment cannot be obtained, the typical bus gap dimensions specified in IEEE Std 1584 (as shown in Table 2 below) may be used as an alternative. However, this substitution must be accompanied by a clear and documented justification explaining why the actual bus gap could not be determined, supported by valid reasons. When typical bus gap dimensions are used, the affected bus must be explicitly listed as an assumption in both the arc flash report and the SKM model.

Provisions must be made to accommodate a reassessment if requested by Sydney Water. This documentation must be finalised and approved prior to completing the arc flash analysis.

Table 2- Bus gap dimensions (IEEE1584 typical)

| Class of Equipment | Bus Gap |
|---|---|
| 11kV Switchgear (up to 15 kV) | 152 mm |
| 3.3kV and 6.6kV Switchgear | 104 mm |
| LV switchgear and motor control centres, Form 3b/4 | 32 mm |
| LV starter cubicles, Form 1 switchboards, distribution boards | 25 mm |

For any location where,

a) the incident energy calculation results in an "*N-box" designation in the SKM model arc flash table, Notes (*N) Column (as depicted in Figure 4.), and

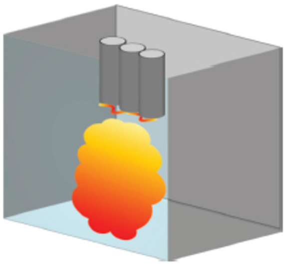
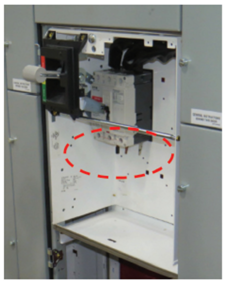
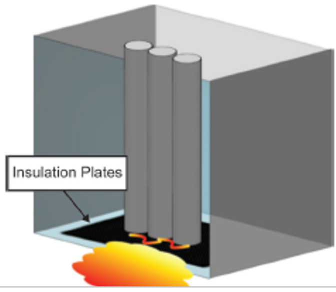
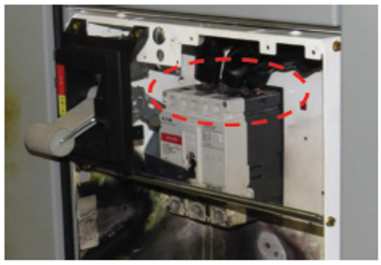
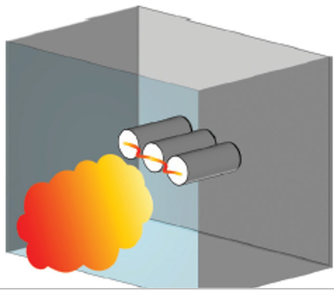
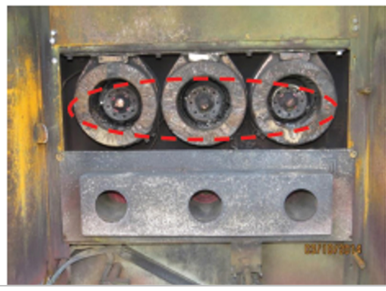
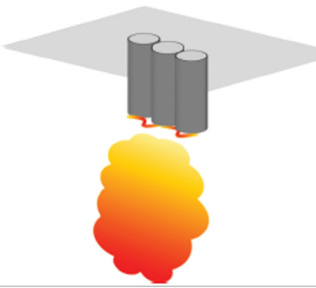
b) the incident energy exceeds 8 $Cal/cm^2$ (Cat.2) must be documented. This documentation indicate that the Ralph Lee method is employed, and the mitigation process outlined in section 6 must be followed.

| Bus Name | Protective Device Name | Bus kV | Bus Bolted Fault (kA) | Bus Arcing Fault (kA) | Prot Dev Bolted Fault (kA) | Prot Dev Arcing Fault (kA) | Trip/ Delay Time (sec.) | Breaker Opening Time/ Tol (sec.) | Equip Type | Electrode Config | Box Width (mm) | Box Height (mm) | Box Depth (mm) | Gap (mm) | Arc Flash Boundary (mm) | Working Distance (mm) | Incident Energy (cal/ cm2) | PPE Level / Notes (*N) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CBH51392 CABLE SIDE | CBH51392 | 11.00 | 7.12 | 7.12 | 7.12 | 7.12 | 0.4520 | 0.1000 | SWG | HCB | 600 | 1143 | 762 | 152 | 4283 | 914 | 26.2 | Level 4 (*N_box) |
| | | | | | | | | | | | | | | | | | #Level 4 = 1 | (*N_box) - Out of IEEE 1584 Box Range. Lee Equation Used. Consider NESC/EPRI method to compare |

Figure 4 -*N_box example

## 5.8 Determining the Electrode Configuration

Each required bus bar is to be assigned the electrode configuration as below (excerpt from IEEE1584).

| | Electrode Configuration | Electrode Configuration Example |
|---|---|---|
| **VCB** |  |  |
| **VCCB** |  |  |
| **HCB** |  |  |
| **VOA** |  |  |

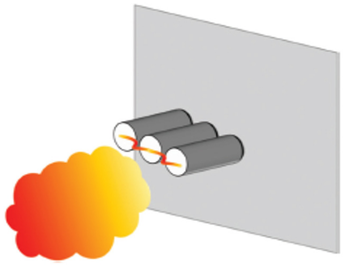
| | | |
|---|---|---|
| **HOA** |  |  |

Figure 5 - Electrode Configuration

## 5.9 Assessing the Duration of the Arcing Fault

The duration of the arcing fault is determined by assessing the clearance time of protection devices under arcing fault conditions.

Where the time-current trip characteristic of a protection device includes an upper and lower tripping tolerance, the worst-case trip time must be used.

For unit protection schemes, such as an arc flash detection system, the trip time must be determined using the manufacturer datasheets.

The arcing duration must include both the relay detection time and the circuit breaker opening time.

## 5.10 Determining Working Distances

The working distance is defined as the distance between the closest possible arc point and the head and body of a person conducting work. The IEEE Std 1584 defines generalised working distances for different classes of equipment. The working distances defined in the table below must be used (varied working distances for specific task-based activities or asset classes may be considered on Sydney Water approval).

Table 3 - Working Distances

| Class of Equipment | Working Distance |
|---|---|
| HV Switchboards (>1000V) | 910 mm |
| Main LV Switchboards typically Form 3b/4 construction | 610 mm |
| All LV switchboards, SCAs, standalone motor starter panels, distribution boards, that do not fall into the category above. | 455 mm |

## 5.11 Determining 'Worst Case' Incident Energy

A lower arcing fault current can lead to higher incident energy levels. Thus, to determine the 'worst case' incident energy at each assessment location four calculations must be undertaken considering different possible arcing fault currents levels.

The process is shown in the below figure, the incident energy must be calculated at 100% and 85% of the assessed arcing fault current, for both the maximum and minimum bolted fault current. The 'worst case' incident energy result is the highest incident energy result from the four calculations.

The worst-case incident energy must be determined from both Normal and Abnormal operating scenarios.

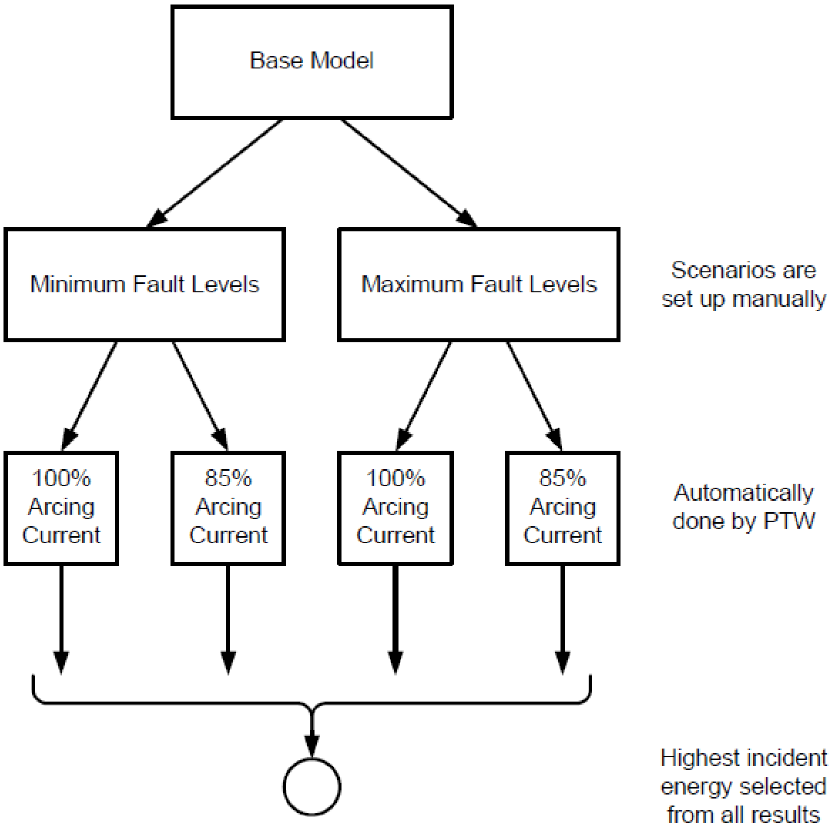



Figure 6 - Process to Determine the 'Worst Case' Incident Energy

***Note:***

- The maximum and minimum bolted fault scenarios are not handled automatically by the PTW Arc Flash Evaluation Tool and must be setup as separate study cases prior to using the evaluation tool to calculate the incident energy for both the maximum and minimum cases.
- If the authorities only provide one fault level, then separate maximum and minimum scenarios are to be extrapolated using the C Factor 1.1 for maximum and 0.9 C Factor for minimum fault current calculation.

## 5.12 DC Calculations

PTW software utilizes the Maximum Power Method (as per NFPA 70E) to calculate DC arc flash up to 1000Vdc.

For solar PV installations the arc flash analysis must include the combiner boxes (or any other isolation point) and the inverter. DC arc flash analysis to be conducted when the bolted fault current exceeds 2kA.

## 5.13 Determining the required PPE level

Arc rated PPE is an effective method of protecting personnel from burn injuries due to arc flash incidents. However, PPE must be used as a 'last line of defence' against potential exposure and does not replace the requirement to implement mitigation measures to reduce exposure levels.

## 5.14 Arc Rated PPE Selection

The Australian Energy Council defines Arc Rated PPE categories, which can be used to protect personnel against direct exposure to an arc corresponding to intervals of incident energy as defined in the table below.

PPE requirements for each work task should be assessed based on the arc flash hazard category rating and assessment of the arc flash risk 'likelihood' as part of the activity-based risk assessment.

Table 4 - Assessed Arc Rated PPE Categories

| Arc Rated PPE Category | Incident Energy Cal/cm$^2$ | Minimum PPE Arc Rating Requirement Cal/cm$^2$ | Minimum PPE Requirement |
|---|---|---|---|
| Cat 0 | Less than 1.2 | Rating not required | Protective Clothing, Non-melting or Untreated Natural Fibre. (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials)<br>Shirt (long sleeve) + Pants (long)<br>Safety glasses or safety goggles, Hearing protection (ear canal inserts) Heavy Duty Leather or CAT0 Rated & Above Gloves. |
| Cat 1 | 1.2 to 4 | 4 | Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm$^2$<br>Arc-rated long-sleeve shirt + long pants or arc-rated coverall<br>Arc-rated face shield or arc flash suit hood<br>Hard hat, Safety glasses or safety goggles<br>Hearing protection (ear canal inserts)<br>Heavy Duty Leather or CAT1 Rated & Above Gloves.<br>Leather work shoes |
| Cat 2 | 4 to 8 | 8 | Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm$^2$<br>Arc-rated long-sleeve shirt + long pants or arc-rated coverall<br>Arc-rated flash suit hood or arc-rated face shield with chin guard + arc-rated balaclava<br>Hard hat, Safety glasses or safety goggles<br>Hearing protection (ear canal inserts)<br>Heavy Duty Leather or CAT2 Rated & Above Gloves.<br>Leather work shoes |
| Cat 3 | 8 to 25 | 25 | Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm$^2$<br>Arc Flash Suit Hood Rated At 25 cal/cm$^2$ or greater<br>Arc Flash Suit Jacket Rated At 25 cal/cm$^2$ or greater<br>Arc Flash Suit Leggings Rated At 25 cal/cm$^2$ or greater<br>Hard Hat, Safety glasses or safety goggles<br>Hearing protection (ear canal inserts)<br>CAT3 or Above Rated Gloves.<br>Leather work shoes |

| | | | |
|---|---|---|---|
| Cat 4 | 25 to 40 | 40 | Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm$^2$<br>Arc Flash Suit Hood Rated At 40 cal/cm$^2$ or greater<br>Arc Flash Suit Jacket Rated At 40 cal/cm$^2$ or greater<br>Arc Flash Suit Pants Rated At 40 cal/cm$^2$ or greater<br>Hard Hat, Safety glasses or safety goggles<br>Hearing protection (ear canal inserts)<br>CAT4 or Above Rated Gloves.<br>Leather work shoes |
| Dangerous | >40 | N/A | PPE is not rated for above 40 cal/cm$^2$ |

# 6. Arc Flash Hazard and Mitigation Assessment

For both new and existing installations the target arc flash hazard category is as low as reasonably practicable and not above Cat.2 (8 $Cal/cm^2$). The engineering methods below are recommendations to reduce the arc flash risk event 'consequence' rating.

## 6.1 Risk Assessment

The risk assessment is required to inform any immediate actions (whether temporary or permanent) to reduce the arc flash risk to an acceptable level. Arc flash risk mitigation must be implemented for all installations with an arc flash hazard rating of above 8 $Cal/cm^2$ (Cat.2), or locations as deemed necessary as an outcome of the risk assessment (all installations with a risk assessment rating above Low-6 must be provided with additional risk control measure/s). The risk assessment is to be conducted by qualified personnel as per the engineering competency table.

An arc flash risk assessment should be performed prior to work on or near an equipment with arc flash hazard. The arc flash risk assessment constitutes three key steps:

1. To identify the arc flash hazards and its severity. The engineering way of quantifying the consequence rating of an arc flash event is by incident energy level (Cal/$cm^2$).
2. To estimate the likelihood of occurrence rating of an arc flash event based on the work activities on or near the equipment of concern and the condition of the equipment refer to Sydney Water Arc Flash Operational Procedure.
3. To determine if additional protective measures, operational practices, or mitigation controls are required to carry out the work on or near the equipment of concern, including the use of Arc Rated PPE.

## 6.2 Risk Assessment Controls

The below control measures outline a systematic approach to reduce arc flash incident energy and the required PPE level. Control measures are to be detailed in the risk assessment. The list of control measures below is not exhaustive and mitigation comprising a combination of control measures or other control measures not listed below may be presented for Sydney Water review and acceptance prior to implementation.

Control measures shown in order of assessment preference:

1. Engineering control – Review and optimisation of any assumptions
2. Engineering control – Adjust protection settings *
3. Isolation – Remote operation, equipment and worker segregation
4. Engineering control – Install arc flash detection *
5. Engineering control – Arc fault current limiting *
6. Engineering control – Maintenance mode *
7. Engineering control – IEC61850 zone selective interlocking *
8. Substitution – Switchboard renewal with AFLR rated switchboard
9. Engineering control – Arc Quenching *
10. Elimination – System redesign, reduce arc energy (fault current)
11. Administrative – Training, safe work policies and procedures.

* *(Note: For line side of main incomers where the protective device is controlled by the DNSP, control measures may require prior evaluation and approval from DNSP before implementation.)*

## 6.3 Review Assumptions

Review all assumed data gathered and update model information with actual information where possible e.g. cable lengths, enclosure dimensions and bus gap dimensions. Where assumptions are used reassessment may be required per section 5.7.

## 6.4 Protection Device Selection and Setting Optimisation (Engineering Control)

Arc flash incident energy can be greatly reduced by selecting appropriate protection devices and protection settings.

Setting optimisation is achieved by reducing the protection settings as much as possible, while maintaining time and current coordination between protection devices and still avoiding risk of nuisance tripping.

For LV switchboards the incoming protection for Form 3b/4 switchboards can only be relied upon to achieve the desired category rating where line side terminals are fully insulated or phase barriered. Otherwise, the arc flash hazard category must be based on the next upstream protection device.

Note: New LV switchboards are required to have line side insulation. On existing boards being modified, if practical, fully insulating the line side terminals must be included within the scope of work, allowing the incomer protection to be relied upon.

For HV transformer feeder protection the H2 Harmonic Restraint function can be used to reduce the instantaneous trip time setting of a relay after a transformer has energised.

## 6.5 High Risk Arc Flash Mitigation (Engineering Control)

For installations that return a high-risk arc flash assessment, including installations that return a 'Dangerous' arc flash hazard category, the option of sacrificing protection discrimination grading (whether completely or partially) to temporarily reduce the arc flash risk to an acceptable level, until a long-term mitigation strategy is implemented, may be considered with prior consultation with Sydney Water.

Note: a load flow analysis may be required where mal-grading may occur before a solution can be adopted.

## 6.6 Remote Operation (Isolation)

Remote operation means operating switchgear outside the arc flash boundary which the switchboard is located, using a designated remote switching panel or via an HMI. Location of the remote switching panel is to take into consideration the pressure wave if an arc blast was to occur. Remote switching via plant SCADA maybe permitted with prior approval from Sydney Water OT team.

HMI or hard-wired remote operation panel can be used for isolating and energising equipment, removing the operators from potential exposure to high incident energy levels.

## 6.7 Arc Flash Detection (Engineering Control)

Arc flash detection schemes must be installed for new HV switchboards and all LV switchboards that are directly supplied by Sydney Water transformers (pad mounted and/or kiosk type).

Arc flash detection systems that utilise light sensors must also be provided with a current check scheme to detect an arcing fault.

Arc flash detection current transformers (CTs) must be located on the line side of the incomer protection device.

Arc light sensors must be accessible for maintenance and installed as per the manufacture's requirements.

## 6.8 Arc Fault Current Reduction (Elimination)

Either current limiting fuses or moulded case circuit breakers can be used. The design must ensure that the protection device specified will operate in its fault current limiting range under minimum arcing fault current conditions.

The performance of fuses for limiting the peak value of prospective bolted fault current is generally better than that of fault current limiting circuit breakers.

If current limiting fuses are chosen for mitigation, additional labelling stating fuse type and ratings are required on the switchboard to clearly designate the use of current limiting fuses. The design will need to show all calculations to ensure the fault limiting fuses are carrying out there intended use. The design is to be submitted to Sydney Water for approval.

The alternate option of limiting the arc fault current by using lower kVA rated transformers to reduce the available short circuit current on the secondary winding can also be considered.

## 6.9 Maintenance Mode (Engineering Control)

Maintenance Mode schemes can be used for HV and LV protection devices to reduce the incident energy during activities where staff can be in the arc flash boundary or working distance. A key switch, or similar, remotely activates the "Maintenance Mode" on the protection device, reducing the instantaneous current and delay time, whilst raising an alarm to annunciate the activation of the protection "maintenance mode" in IICATS/SCADA system.

## 6.10 IEC61850 - Zone Selective Interlocking (Engineering Control)

Zone selective interlocking between backup, primary and outgoing feeder protection is an alternative to installing an arc flash detection scheme to reduce incident energy levels.

Zone selective interlocking uses blocking signals which are sent between downstream and upstream protection devices, allowing protection to trip quickly without a protection grading trade off.

Adopting the IEC61850 Communication protocol standard can be used when equipment does not discriminate with other protection devices.

Example using IEC 61850 protocol for a simple blocking scheme allowing for better discrimination shown in the below figure 7 Blocking Scheme.

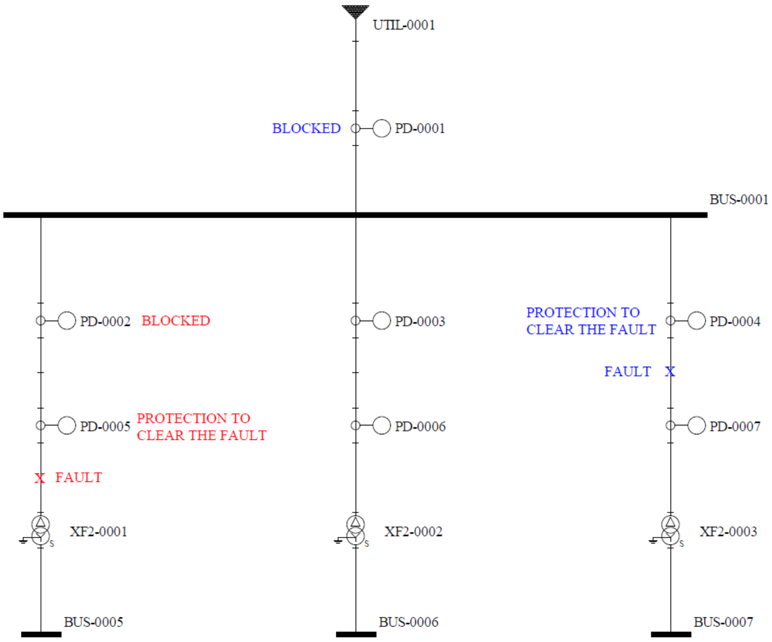



Figure 7 - Blocking Scheme

## 6.11 Arc Quenching (Engineering Control)

Arc quenching devices can only be used with prior approval from Sydney Water.

To 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 causing 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 fuse or circuit breaker.

Arc quenching devices are available for both HV and LV switchboards. For LV switchboards the available quenching devices are relatively compact and can be incorporated into the switchboard being protected, if the bolted fault withstand rating of the board is adequate. If the board cannot safely sustain a bolted fault, then the quenching point can be installed upstream of the board.

Typically, HV quenching systems need to be installed within a separate standalone cubicle.

An arc quenching device must be provided with integrated self-monitoring of system as well as healthy status monitoring in IICATS/SCADA system.

## 6.12 Switchboard Renewal (Substitution)

The option to renew an existing switchboard to mitigate/reduce the arc flash risk assessment ‘likelihood’ rating in an attempt to reduce the overall risk rating can be considered subject to the outcome of the installation condition assessment and other site requirements.

***Note:***

- The arc flash risk assessment ‘consequence’ rating is irrespective of the age or condition of the installation and that renewal of a switchboard only enables mitigation/reduction of the risk ‘likelihood’ rating.
- A switchboard that is ‘aged’ (e.g. passed its Design Life however with Remaining Life before the asset is unusable), and non-compliant to the current standards should not be used as the sole justification for renewal of an existing switchboard.

# 7. Signage & Labels

Upon acceptance of the final arc flash assessment results, labels must be fitted to the switchgear indicating relevant PPE level, appropriate working distance and incident energy, arc flash hazard category, and arc flash boundary.

## 7.1 Warning Labels

An adhesive standard arc flash warning label located on the front of the switchboard must be produced for each switchboard to inform workers of potential arc flash incident energy level and the required PPE when working on various part of the switchboard.

There should only be one label for each switchboard, it is preferred the label is installed near the incomer(s). The arc flash warning label is showing the worst-case arc flash consequence at various location of the switchboard irrespective of the work activities.

For installations with facility for a mobile generator connection, a separate warning label must be provided at the generator connection point and switchboard generator circuit breaker panel highlighting the basis for sizing the mobile generator alongside the resultant arc flash hazard rating associated with the mobile generator operation.

The information required for the arc flash label must comply with Australian Energy Council Arc flash guideline requirements and Sydney Water Labelling Specification. The following information must be included on the arc flash warning label:

- Hazard danger warning symbol in accordance with AS 1319
- Electrical shock risk symbol in accordance with AS 1319
- Site name
- Maximo Location number and Location description of the switchboard
- Nominal voltage of the switchboard
- Date of the Arc Flash assessment
- Asset tag of the protection control device.
- Incident energy level at working distances ($Cal/cm2$)
- Arc Flash boundary (mm)
- Minimum safe working distance
- PPE requirements (Category Number) for every work activity

**WARNING**

**ARC FLASH HAZARD**

| | | | | |
|---|---|---|---|---|
| Site - | ST00XX - XXX WasteWater Treatment Plant | | | |
| Location - | SCAxxxx - Dewatering switchboard | | | |
| Voltage Level | 400V | Date of assessment | | 2/05/2020 |
| **Incomers Circuits** | | | | |
| Switchgear Panel | Incident Energy (cal/cm2) | Arc Flash Boundary (mm) | Minimum Safe Work distance (mm) | Minimum PPE Category |
| CBL 1234 | | | | Category 3 |
| CBL 1235 | | | | Category 4 |
| **Non-Incomers Circuits** | | | | |
| Switchgear Panel | Incident Energy (cal/cm2) | Arc Flash Boundary (mm) | Minimum Safe Work distance (mm) | Minimum PPE Category |
| CBL 1236 | | | | Category 1 |
| CBL 1237 | | | | Category 2 |
| CBL 1238 | | | | Category 0 |
| **Busbar** | | | | |
| Busbar | Incident Energy (cal/cm2) | Arc Flash Boundary (mm) | Minimum Safe Work distance (mm) | Minimum PPE Category |
| SWB 1902 | | | | Category 1 |
| SWB 1901 | | | | Category 1 |

Figure 8 - Arc Flash Labels

# 8. Documentation Requirement

All documentation listed in this section must be submitted as two hardcopies and one electronic copy.

## 8.1 8.1. System study reports

System study reports must be provided for each stage detailing as a minimum the information listed below. For brownfield sites the existing PTW model and arc flash report, where available, must be updated to include any new/altered component as well as any other existing component within the system that may be impacted by the new/altered component.

Stage 1 – Arc flash assessment

- Build/update PTW Model
- Produce/update Fault current report
- Equipment validation testing report (brownfield site)
- Condition assessment report (brownfield site)
- Produce/update Arc flash report (for review)

Stage 2 – Mitigation & Risk Assessment

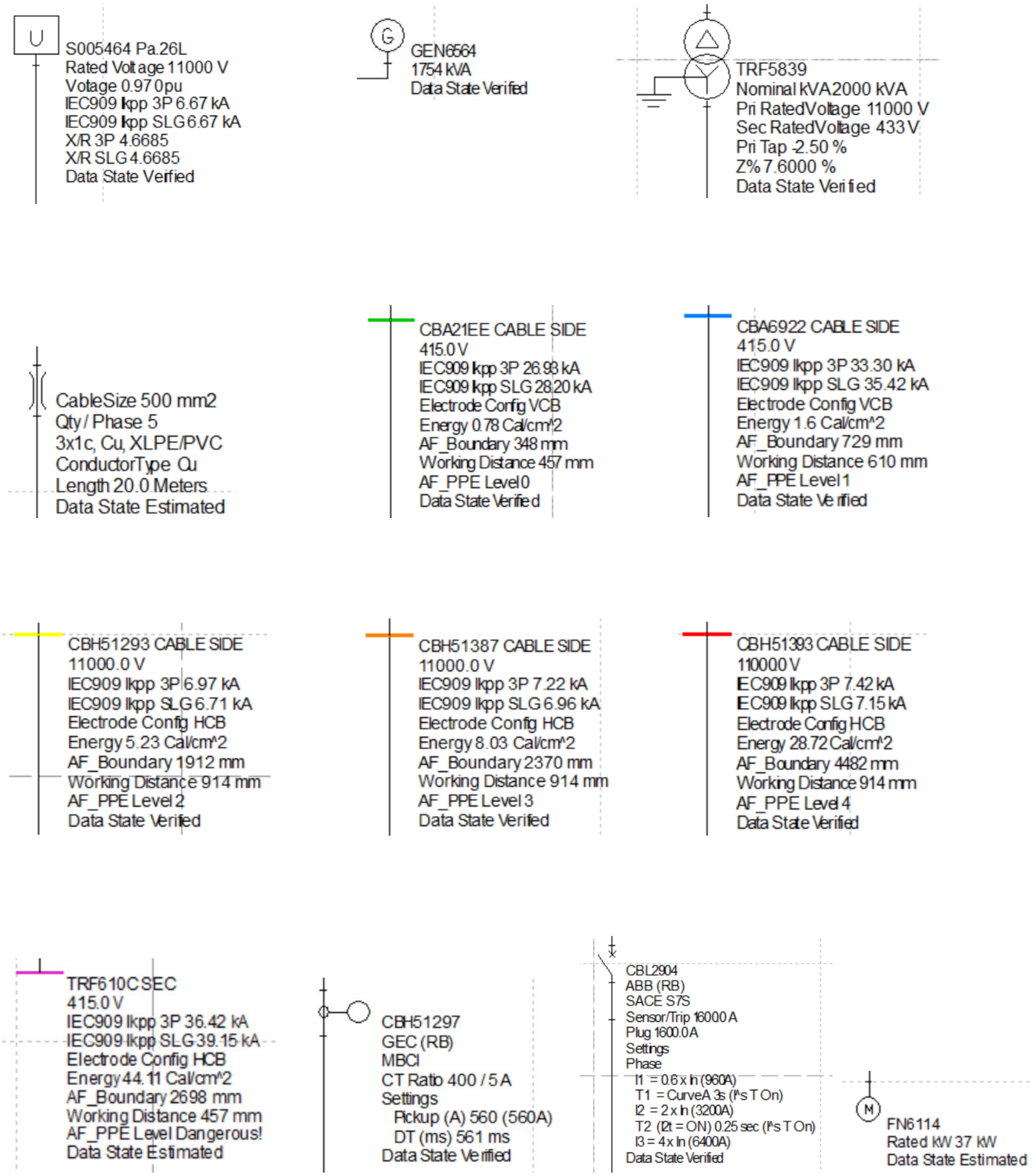
- Risk assessment
- Specific task and mitigation techniques submitted to Sydney Water for approval
- Mitigation assessment report, including pre and post mitigation model and SLDs

Stage 3 – Outcome

- Signage, labels and application of arc flash boundary line colours
- General Arrangement drawings in DWG and PDF format for each switchboard, SCA and MCC showing the arc flash PPE boundaries. Refer Section 0 for an example.
- Arc flash SLDs and TCCs. Refer Section 9.2.
- Submit arc flash report
- Test reports to validate the performance of any mitigation implemented

# 9. Examples

## 9.1 PTW Data block attributes



## 9.2 Arc Flash SLD and TCC (Time Current Curves)

Arc Flash Single Line Diagram must be provided showing the electrical reticulation system with incident energy level colour coded at each bus in accordance with the colour selection from the Arc Flash labelling.

For large distribution networks including treatment plant sites, an overall arc flash SLD must be provided (with colour coded busbars in accordance with arc flash label categories) showing the utility supply down to the LV SCA immediately downstream of Sydney Water transformer (refer example in Figure 9). For downstream LV SCAs, a TCC of the SCA of concern including both upstream and downstream protection curves, must be provided alongside the arc flash SLD showing the upstream and downstream system on a combined single sheet (refer example in Figure 10, with TCC on the left hand side, and arc flash SLD on the right hand side of the sheet).

For small sites, such as pump stations, an overall arc flash SLD and TCC must be provided on a single sheet (TCC on the left hand side, and arc flash SLD on the right hand side of the sheet).

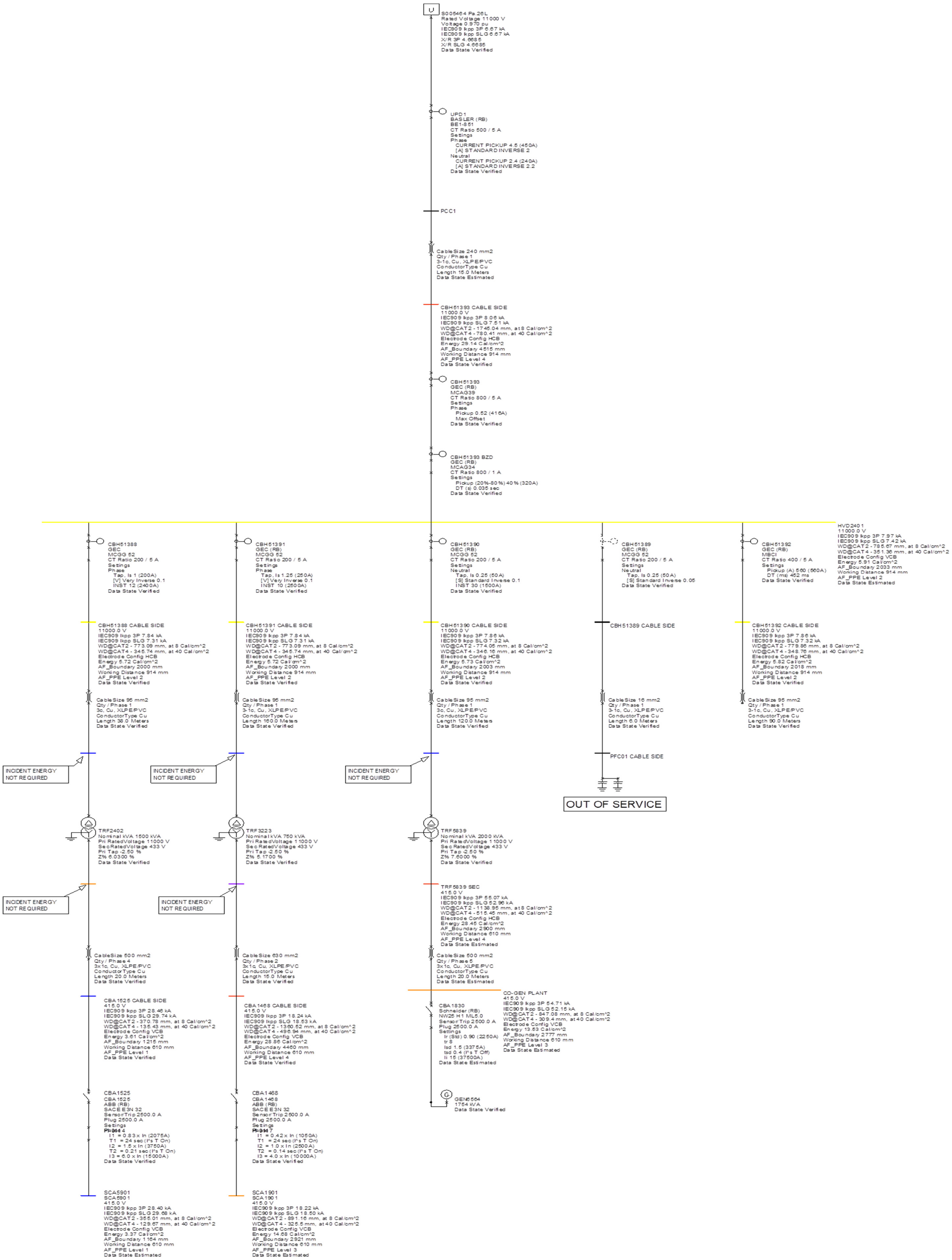


Figure 9 - Overall Arc Flash Single Line Diagram Example

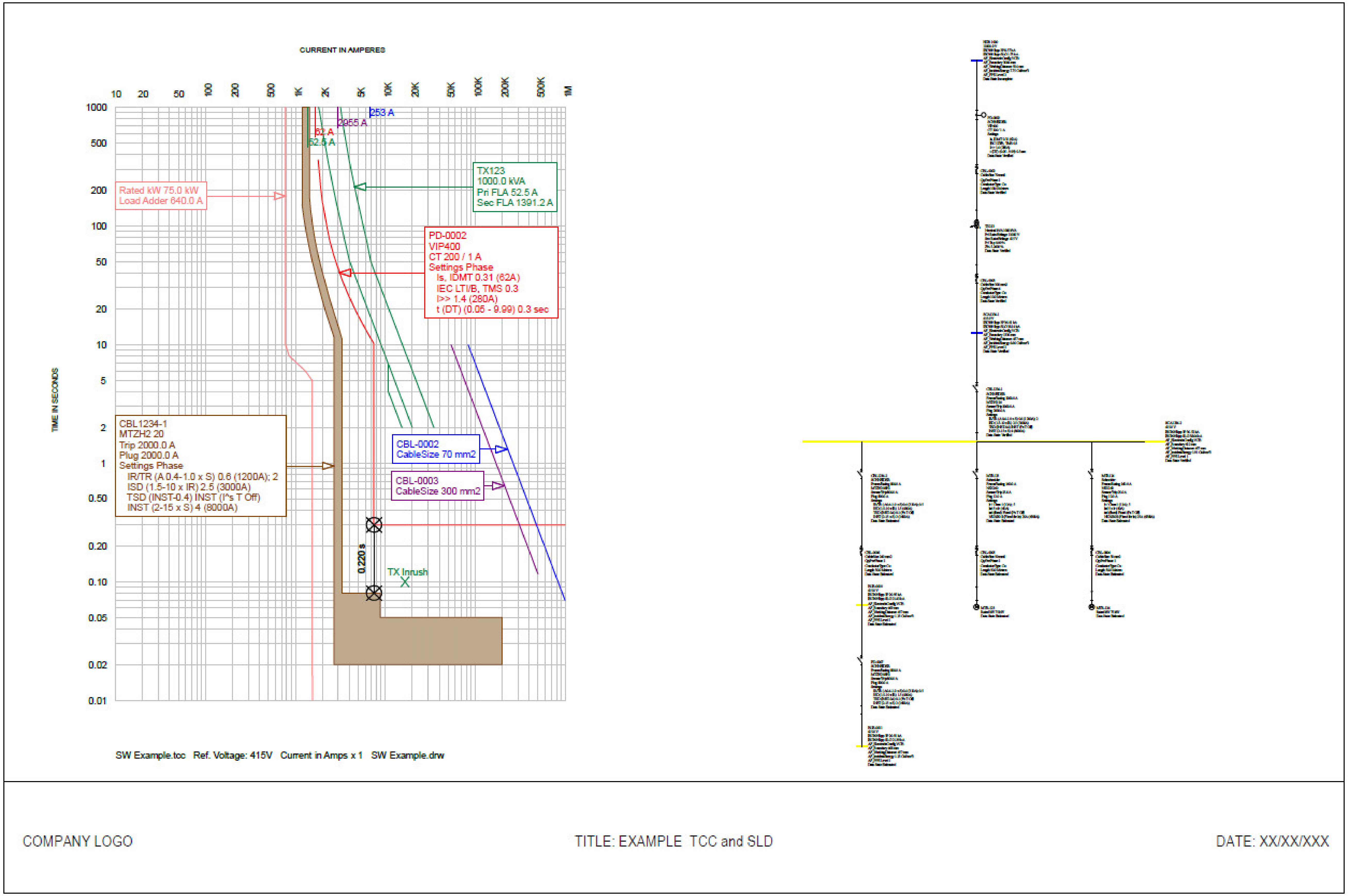



Figure 10 - Combined TCC and Arc Flash SLD Example

## 9.3 Arc flash boundary floor marking

General Arrangement drawings in DWG and PDF format for each switchboard, SCA and MCC showing the Cat.2 and Cat.4 arc flash PPE boundaries must be provided following the below criteria:

- Switchboard with less the Cat.2 rating: no floor marking required.
- Switchboard with Cat.2 rating: only one (yellow) line to be show at the Cat.2 arc flash PPE boundary.
- Switchboard with Cat.3 or Cat.4 rating: one (yellow) line to be show at the Cat.2 arc flash PPE boundary and second line (red) to be shown at the Cat.3 arc flash PPE boundary (this is to designate the boundary at which Cat.2 no longer suffices and Cat.4 PPE must be worn).
- Switchboard with Dangerous rating: one (yellow) line to be show at the Cat.2 arc flash PPE boundary, second line (red) to be shown at the Cat.3 arc flash PPE boundary and third (purple) line to be shown at the Dangerous arc flash boundary.

Arc flash boundary general arrangement floor plan must be provided for switchrooms (Figure 11), or if the switchboard is not in a switchroom, the general arrangement area plan is to show arc flash boundary for the assets of concern.

The application of the arc flash boundary line colours must be carried out on completion of the arc flash assessment for the switchboards of concern with the colour of the lines on the ground in accordance with above.

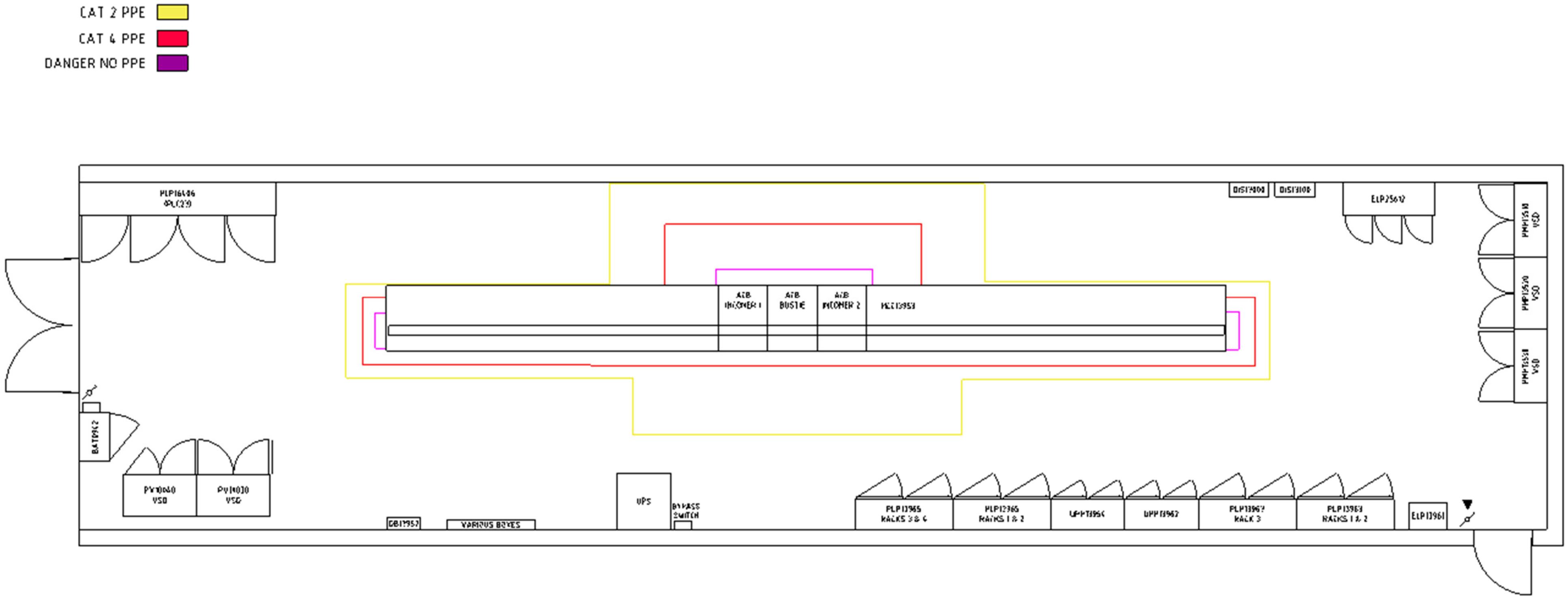



Figure 11 - Switchroom Floor Marking Example (switchboard with Dangerous rating)

# Ownership

## Ownership

| Role | Title |
|---|---|
| **Group** | Water and Environment Services – Engineering Modernisation |
| **Owner** | Engineering Manager |
| **Author** | Technical Director – Electrical Engineering |
| **BMIS Number** | D0002263 |

## Change history

| Version No. | Prepared by | Date | Approved by | Issue date |
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| 1 | Paul Zhou/ Hedi Mahdavi Aghdam | 09/09/2023 | Norbert Schaeper | 10/09/2023 |
| 2 | Paul Zhou/ Hedi Mahdavi Aghdam | 24/02/2025 | Norbert Schaeper | 28/02/2025 |