

Session 12

## Arc Flash Standards - Australian Developments

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### ABSTRACT

Across the world, Arc Flash Hazard studies have emerged as a engineering service centred around two standards, IEEE 1584 and NFPA 70E. The first is the only available standard on arc hazard quantification but soon after publication was shown to be fundamentally incorrect through the research of Stokes & Sweeting (1). The second standard forms part of North America's equivalent to the Australian Wiring Rules. Neither standard is appropriate for the Australian workplace but in the absence of technical direction from the IEC, these documents have now become de-facto arc flash standards for Australian industry, particularly across the local operations of multinational companies. An array of arc flash software tools based around these standards has produced new opportunities for consulting engineers however it would seem even without considering the IEEE 1584 problems, basic power engineering principals have been overlooked. Namely: the relationship of switchgear segregation with arc propagation and identification of protection clearing location; the risk assessment process to match various activities with appropriate hazard controls; the treatment of multiple sources, staged protection clearing and motor contribution; the correct application of the hierarchy of controls; the roles of PPE.

### INTRODUCTION

Australian Industry is constantly searching for safer ways to manage the many hazards of business. In most cases, local and international standard organisations play a pivotal role in driving equipment selection, hazard quantification and risk management practices. In the electrical sector, Australian Standards, underpinned by harmonisation policy to IEC standards, provides pathways to achieve consistent outcomes in engineering. Other industry organisations, such as the ENA<sup>1</sup> also produce excellent standards through collaborative development from their membership.

Whenever a new processes or new technology is adopted without first establishing the appropriate standards, results can be expected to vary widely across end-users.

This is certainly the case for Arc Flash Hazard Studies whereby in the absence of any Australian Standards, the combination of IEEE 1584 and NFPA 70E have become the de facto local standard.

For Arc Flash Hazard Studies, the challenges for Australian end-users are:

- Understanding what the term 'Arc Flash Hazard Study' means
- Dealing with incompatibilities between foreign standards and the Australian workplace
- Proceeding without any applicable Australian Standards or IEC Standards
- Containment of the problems within IEEE 1584 and NPPA 70E.

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<sup>1</sup> Energy Networks Association

## **ARC FLASH HAZARDS**

It can be assumed that all asset owners and operators of electrical infrastructure would want to inform and protect their electrical workers against the many hazards of arc faults including.

- Electric shock.
- Burns Trauma from arc plasma, radiated heat, molten metal.
- Physical Trauma from flying debris and pressure waves.
- Respiratory Trauma from toxic gases.

In order to manage these hazards, they need to be understood by workers so the appropriate action and countermeasures can be applied.

### ***Electric Shock Hazard***

Electric shock is the most obvious hazard when working around electricity but once an arcing fault has initiated, the normal safe clearances no longer apply; given the worker may become engulfed in plasma and cannot be protected in the conventional way.

### ***Burn Trauma Hazard***

The burn hazard stems from the heat energy exposure to workers from arcing faults and can cause death or otherwise leave survivors with horrific and debilitating burn trauma. Quantifying the burn hazard dominates Arc Flash Hazard studies and then drives the introduction of various countermeasures into the workplace.

### ***Physical Trauma Hazard***

Arc Faults are associated with rapid increases in air pressure causing a pressure wave and flying-debris hazard. There are presently no readily available tools for electrical engineers to quantify pressure in a similar form to incident energy, however in the various countermeasures for burn hazards, particularly PPE, some protection is afforded. PPE is also considered effective up to incident energies of 40 cal/cm<sup>2</sup> (2), after which it is assumed that physical trauma becomes the dominant hazard.

### ***Respiratory Trauma from Toxic Gases***

The toxic gas hazard released during an arcing fault, whilst significant in terms of the long term trauma is also not considered the dominant hazard to electrical workers. Countermeasures available to deal with this hazard include externally venting IAC switchgear from a substation and the inherent protection provided by covered hoods associated with CAT3 and CAT4 PPE.

## **ARC FLASH HAZARD STUDY**

Manufacturers and users of switchgear participate in the development of switchgear standards that provide tangible performance outcomes through design, construction and type-testing of switchgear assemblies.

In terms of reducing the probability of arc-flash, switchgear can be made safer through shrouding of terminals, busbar insulation and segregation of functional units. To prevent burns to operators and electrical workers, arc fault containment testing is available for complete switchgear assemblies. For the fastest possible interception, arc fault protection relays are available monitoring pressure, light or heat.

Therefore for plants under design now or at any future point, it can be said the best technology and equipment available can be utilised to achieve the safest possible outcomes for electrical workers.

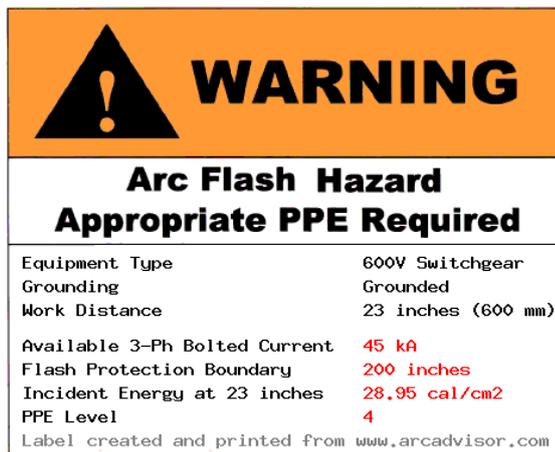
The reality however is that compared to the total population of installed equipment, very little additional industrial plant is commissioned each successive year. Therefore Arc Flash Hazard Studies on existing facilities will often deal with a wide range of equipment built at different times and to different standards.

***Understanding what ‘Arc Flash Hazard Study’ Means***

The intentions of an asset owner in commissioning an Arc Flash Hazard Study could be assumed as requiring information to mitigate the consequences for personnel from an arc-flash event on switchgear.

Putting aside the process for now, one major deliverable component of such a study has been the labelling of switchgear with arc incident energies, representing the equivalent thermal energy exposure at a given distance due to an arcing fault. That is, the incident energy is calculated at each location so electrical workers are informed of the extent of the hazard.

An example of a typical North American label is provided in Figure 1 below, however in the absence of direction from the USA standards, there are many variants of this. Such is the extent of difference there is not even consensus whether the label should carry a “WARNING” or “DANGER” status.



**Figure 1**-Example of North American Arc Flash Label (credits: www.arc advisor.com)

***Calculating Incident Energy***

It was established by Stokes and Sweeting (first in 2002 in Poland and again in 2006 in an IEEE Industry Applications (1) paper) that IEEE 1584 had fundamental errors in the determination of incident energy. Following extensive industry debate the IEEE and NFPA raised a new project and sought industry funding to undertake new testing to well-defined protocols and remodelling based on arc physics.

Ultimately a better standard will be available from the IEEE and potentially, other standards organisations may get involved to produce alternative tools to IEEE 1584 to quantify the arc hazard.

In the meantime however, facility owners and operators still have a requirement to complete Arc Flash Hazard Studies. So even with the known problems of the IEEE 1584 calculation method they can justify the application of a process that quantifies the hazard, therein providing some relative ranking across assets.

Aside from invalid test data and empirical modelling, there are other deficiencies in the IEEE 1584 calculation approach. The staged clearing of protection devices and the effect of

motor contribution are not dealt with well and both are considered to be relevant factors in the determination of incident energy. Motor contribution can be overstated if the arc voltage is not taken into consideration in the calculation. It is not necessarily the case that overstating fault current is conservative because this may decrease the protection trip time and therefore reduce incident energy outcomes.

Additionally, in the determination of arc fault clearing time, the identification of the correct protection device is dependent on the level of switchgear segregation and/or whether the assembly is type-tested.

### ***Consideration of Risk***

Having labelled an item of switchgear, the electrical worker is informed of arc hazards. In many existing industrial installations, the incident energy is high, often resulting in PPE categories that necessitate a 'bomb suit' (i.e. CAT 3 and above).

Hazard quantification is intent of IEEE 1584 however it is appropriate that the Arc Flash Hazard Study' delivers additional information.

In reality, the electrical worker undertakes a wide variety of tasks and they vary in risk in terms of the likelihood of causing an arcing fault. Additionally, dependant on the task, the electrical worker has varying levels of exposure to an arc hazard. For example, if the task is switching a circuit breaker using an external handle or pushbutton, they may be afforded some protection by the closed door to the switchgear compartment. If however, the task is switching with the compartment door open, then irrespective of the arc-containment capabilities of the switchgear, they are fully exposed to the arc.

Overarching this example is the very low likelihood that any switching event will cause an arcing fault. Circuit breaker racking however is considered a higher risk.

It should be understood that the vast majority of arc faults involving electrical workers are directly related to the activities of the electrical worker. Once this is recognised, the components of risk analysis become obvious and the various work activities can be individually addressed in terms of the appropriate PPE countermeasures.

Having said that, PPE is the last countermeasure that should be applied and only as the last resort under the hierarchy of controls commonly used in Australia:

- 1) Elimination
- 2) Substitution
- 3) Engineering
- 4) Administration
- 5) PPE

The hierarchy is graphically represented in Figure 2.

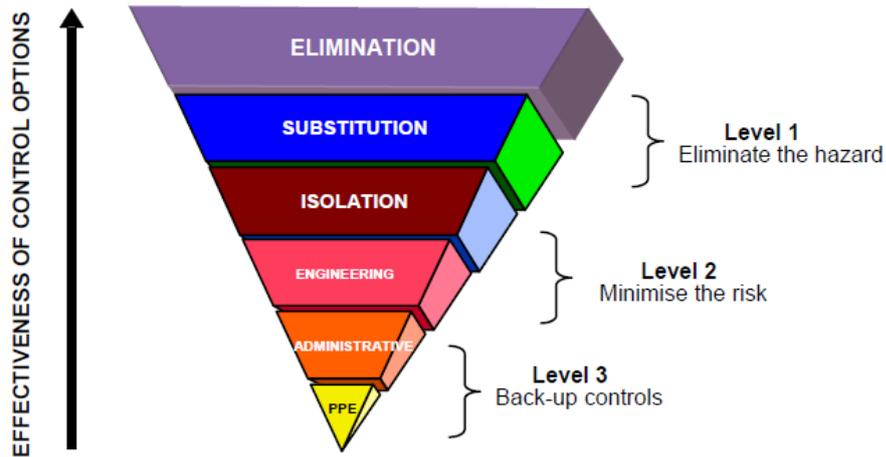


Figure 2 - Hierarchy of Controls (3)

**Arc Label for the Australian Workplace**

In conjunction with Rio Tinto Iron Ore, DlgSILENT has designed labels that addresses the need for compliant signage and applies risk analysis business rules for the correct selection of PPE against work activities.

The resultant label is shown in Figure 3 and this is placed, for example, on a HV cubicle or LV MCC incomer. The references to “Door OPENED” and “Door CLOSED” address the different requirements that apply for each case by recognising the burn reduction protections from a having a panel between the arc and the electrical worker. A blank cell indicates a particular activity is not relevant or otherwise not possible.

	<b>DANGER</b>		
	<b>ARC FLASH and SHOCK HAZARD</b>		
	0.415 kV	Shock Hazard when cover opened	
	1.1 m	Arc Flash Boundry	
	17.91 cal/cm <sup>2</sup>	Incident Energy	
ACME WIDGETS FACILITY XYZ		PPE Category	
Position : Main Incomer		ACTIVITY	Door OPENED
Equipment : 415V MCC			Door CLOSED
Location : Crusher Substation 3		SWITCHING	-
Arc Fault Level : 9.87kA for 1.793s		RACKING	-
Calc Ref : 4335		ELECTRICAL WORK	CAT 4
Date : 26/03/2010		VISUAL INSPECTION	CAT 2
Project : #1234		COVER REMOVAL	CAT 2
Company : DlgSILENT Pacific			
VALID UNTIL: 26/03/2015	No Group		

Figure 3 – “Australian-Compliant” Arc Flash Label Single Location

In the case of an LV MCC it is not appropriate that every outgoing cubicle has a label containing the same information. This is partly due to concerns with the negative effects of excessive labelling in desensitising the workforce to hazards but also due to space limitations on switchgear doors.

In this case, a group label is applied beneath the MCC main switch (refer Figure 4) and a reference label at the outgoing cubicles (refer Figure 5). The reference label carries the IEC electrical hazard icon that would otherwise be required on every cubicle door together with additional text to reference the appropriate group label.

In the situation that multiple incomers and bus-ties are present on the LV panel, the matching Group Label/Reference Labels are applied to the 'normal' switching configuration.

ACME WIDGETS FACILITY XYZ		PPE Category	
Position : Main Incomer	Equipment : 415V MCC	ACTIVITY	Door OPENED
Location : Crusher Substation 3	Arc Fault Level : 9.87kA for 1.793s	SWITCHING	Door CLOSED
Calc Ref : 4335	Date : 26/03/2010	RACKING	-
Project : #1234	Company : DigSILENT Pacific	ELECTRICAL WORK	CAT 4
VALID UNTIL: 26/03/2015	No Group	VISUAL INSPECTION	CAT 2
		COVER REMOVAL	CAT 2

Figure 4 – “Australian-Compliant” Arc Flash Label Multiple Location (i.e. Group Label)

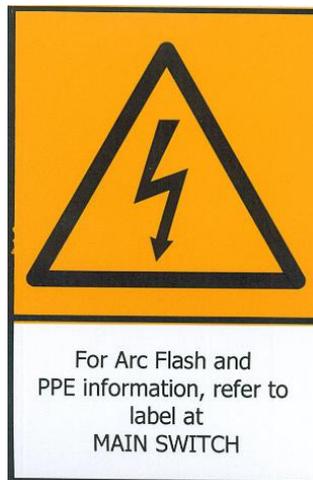


Figure 5 - Arc Flash Group Reference Location (i.e. outgoing cubicles of MCC)

## **INCOMPATIBILITIES BETWEEN THE USA STANDARDS AND AUSTRALIAN WORKPLACE**

### ***North Americans Standards Framework***

For arc flash hazards, the US Department of Labor OSHA<sup>2</sup> Code of Federal Regulations has generic arc flash warning requirements which have been interpreted by industry to mandate NFPA 70E (2).

Similarly, the IEEE 1584 (4) published by the Institute of Electrical and Electronic Engineers has only an implied mandate with respect to OSHA codes, whereby either the NFPA 70E or IEEE 1584 methods of calculation are taken to be equally valid despite vastly differing results between these two methods.

On first review, these contradictions between industry practice and actual legislative requirements are of major concern, however, when reviewing OSHA standard interpretations, it is clear the documents are treated as guidelines where facility owners are required to address the inherent risk by an 'appropriate method'.

Therefore, it seems the precedent from the USA with respect to standards NFPA 70E and IEEE 1584 is to decide on a single method, then execute arc flash studies in a consistent and transparent manner without weighing heavily on the anomalies within those standards.

### ***Incompatibilities***

There may be misconceptions surrounding the direct application of NFPA 70E and IEEE 1584 into the Australian Workplace.

NFPA 70E is a document produced by USA organisation the National Fire Protection Association. The NFPA<sup>3</sup> is the standards organisation that publishes the National Electrical Code, being the USA's equivalent standard to Australia's *The Wiring Rules AS/NZS 3000*. NFPA 70E is an extension to NFPA 70 covering electrical requirements for employee workplaces. The history of its existence relates to OSHA requirements for electrical standards aimed at employers and facility operators instead of electrical professionals and within this document, are the specific sections dealing with the issue of arc hazards.

NFPA 70E sets out requirements for electrical work practices and in the case of arc flash hazards mandates various ANSI<sup>4</sup> and ASTM<sup>5</sup> standards for different types of PPE<sup>6</sup>.

Importantly, it must be understood that USA-specific requirements for electrical work practices are intrinsic to the standard. An example of this are the terms, *Restricted*, *Limited* and *Prohibited* that relate to boundary distances from live parts that qualified and unqualified persons can approach for a given system voltage. This is illustrated in Figure 6.

Whilst these terms have been carried into some North American arc flash label templates, this is because they have wider meaning for general electrical work.

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<sup>2</sup> OSHA – Occupational Safety and Health Administration

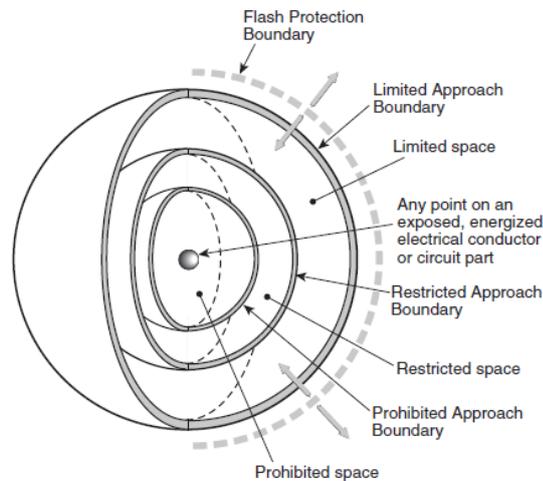
<sup>3</sup> NFPA-National Fire Protection Association

<sup>4</sup> ANSI-American National Standard Institute

<sup>5</sup> ASTM-American Society for Testing and Materials

<sup>6</sup> PPE - Personnel Protective Equipment

It is inappropriate for Arc Flash Hazard Studies in Australia to produce labels carrying North American approach boundaries given these contradict other mandated standards declaring safe clearances in Australia.



**Figure 6 – NFPA Concept "Limits of Approach " (1)**

As the USA standards dealing with arc flash hazards are integrated with USA work practices and license classes for electrical workers it does not seem appropriate, given the differences, to apply these standards locally in Australia.

On a much simpler level, the Australian workplace is aligned to the IEC for safety signage and symbols. It is fundamental to all safety outcomes that the correct use of icons and colours is applied across labelling and signage. It is inappropriate therefore to apply the USA Orange-on-black "WARNING" and White on Red "DANGER" label stock or USA safety icons anywhere in the Australian workplace.

## **DISCUSSION: IEC AND AUSTRALIAN SWITCHGEAR STANDARDS**

### ***Arc Containment Standards***

For decades IEC and Australian Standards have provided voluntary certifications for LV and HV switchgear assemblies to internal arcing faults and for personal protection.

### ***High Voltage Switchgear***

For High Voltage switchgear assemblies (1kV-52kV), IEC 62271-200 Appendix A provides five criteria that must be fully fulfilled for IAC classification:

- 1) Covers and doors remain closed
- 2) No fragmentation of the enclosure and no projection of small parts above 60g
- 3) No holes in the accessible sides up to a height of 2m
- 4) Horizontal and vertical indicators do not ignite due to the effect of hot gases
- 5) The enclosure remains connected to its earthing parts.

Such IAC assemblies offer a tested level of protection to persons in the vicinity of equipment in normal operating conditions and with the switchgear and controlgear in normal service position. In the event on an internal arc, with all doors and covers correctly closed and providing technical limits are not exceeded, IAC switchboards will not expose electrical workers to a burn hazard or projectile hazard.

### ***Low Voltage Switchgear***

AS/NZS 3439.1:2002 Annex ZD sets out test procedures and guidelines for internal arc containment of LV switchgear assemblies. The location of the initiating arc fault for the testing however is a decision between Vendor and supplier and it should be clearly understood whether the resulting type-test is limited when apply arc-contained classification in the outcomes.

### ***Identification of Clearing Device***

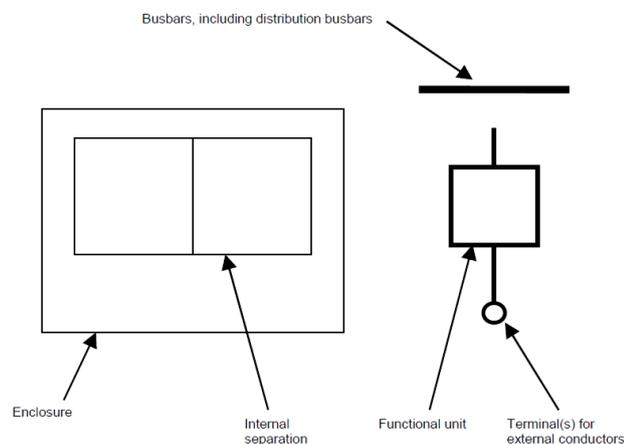
For fixed conditions of installation, the most dominant factor influencing incident energy is protection clearing time.

In completing an Arc Hazard Study, the correct identification of the fault clearing device is as critical to the outcome as correctly understanding protection clearing time.

AS/NZS 3439.1:2002 and IEC 61439-2 Edition 1.0 2009-01 outline the forms of segregation for switchgear assemblies. Primarily, these forms describe the varying configurations for separation of functional units of switchgear from each other. Whilst the voluntary LV arc containment type-tests should drive responsible practices in purchase of new switchboards, for existing switchgear assemblies the identification of arc-fault clearing location is tied to the issue of arc propagation. It is not the case that the physical barriers in the forms of separation are necessarily effective in arresting arc propagation and where designed to do so, this must be verified by type-testing.

Nevertheless, it is relevant to review and discuss how segregation can relate to fault clearing.

In Figure 7, the diagrammatic representation adopted by the IEC is explained for the delineation between Forms of Segregation for LV switchgear assemblies.



**Figure 7-Understanding diagrams for Forms of Segregation of LV switchgear assemblies**

The diagrams from Figure 8 to Figure 11 illustrate various arcing fault locations, whereby the solid shaded area (in red) illustrates the extent of possible arc propagation. The protection device identified to clear the arcing fault is then shaded with diagonal hatching (in green).

Form 1:  
No internal separation

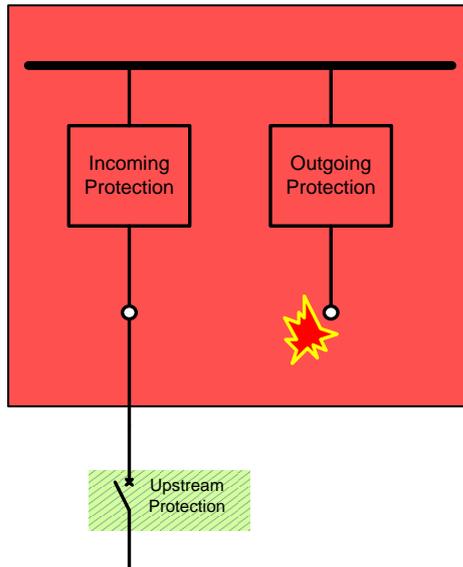
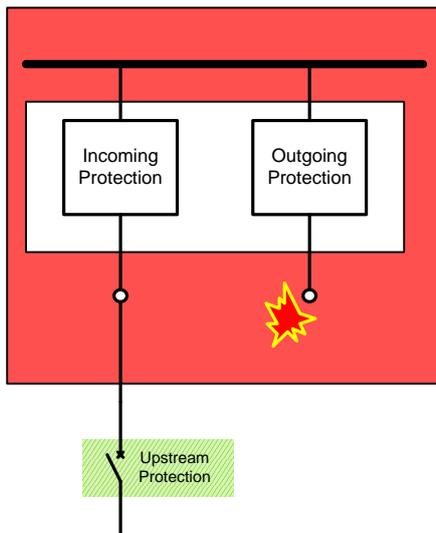


Figure 8-Arc Fault in Form 1 Enclosure

Form 2a:  
Terminals not separated from busbars



Form 2b:  
Terminals separated from busbars

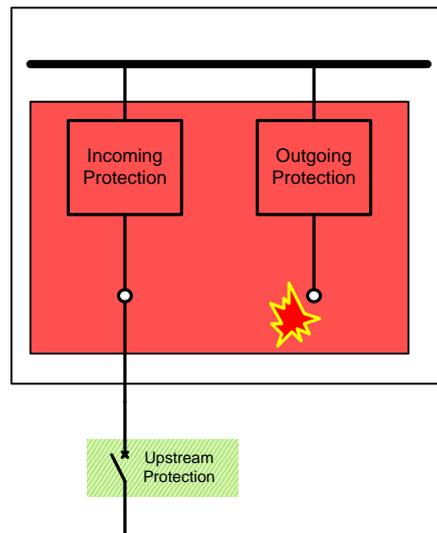
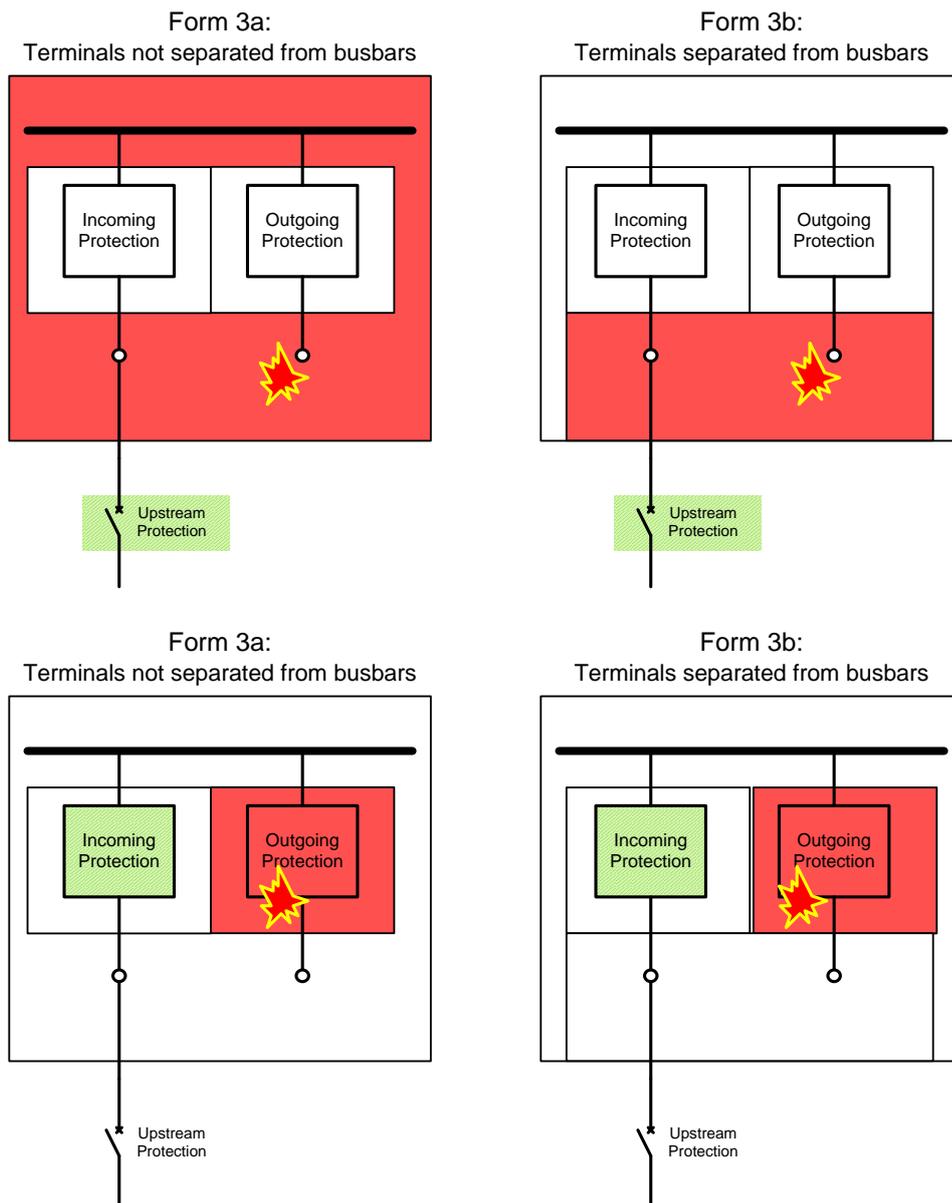


Figure 9-Arc Fault in Form 2a and 2b Enclosures



**Figure 10-Arc Fault in Form 3a and 3b Enclosures**

Only in the case of Form 3a and Form 3b segregation, where the arcing fault is within the outgoing unit compartment, is the fault cleared by the incomer device. This statement is made on the assumption that the arcing fault may propagate to the line side of the switchgear but not beyond the compartment itself.

For Form 4a and Form 4b, it can be assumed that the incomer protection will clear faults on the outgoing compartments on the basis of the same assumption.

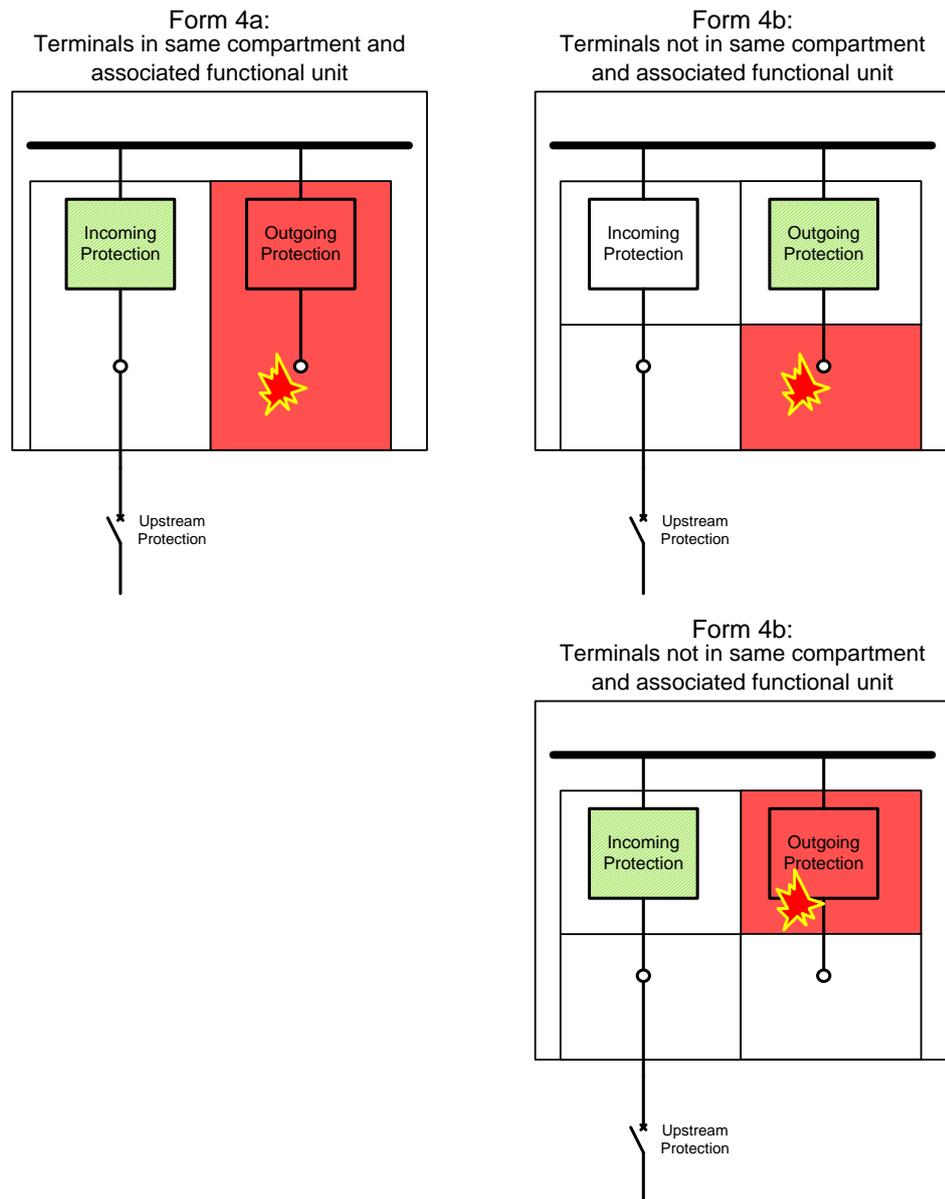


Figure 11-Arc Fault in Form 4a and 4b Enclosures

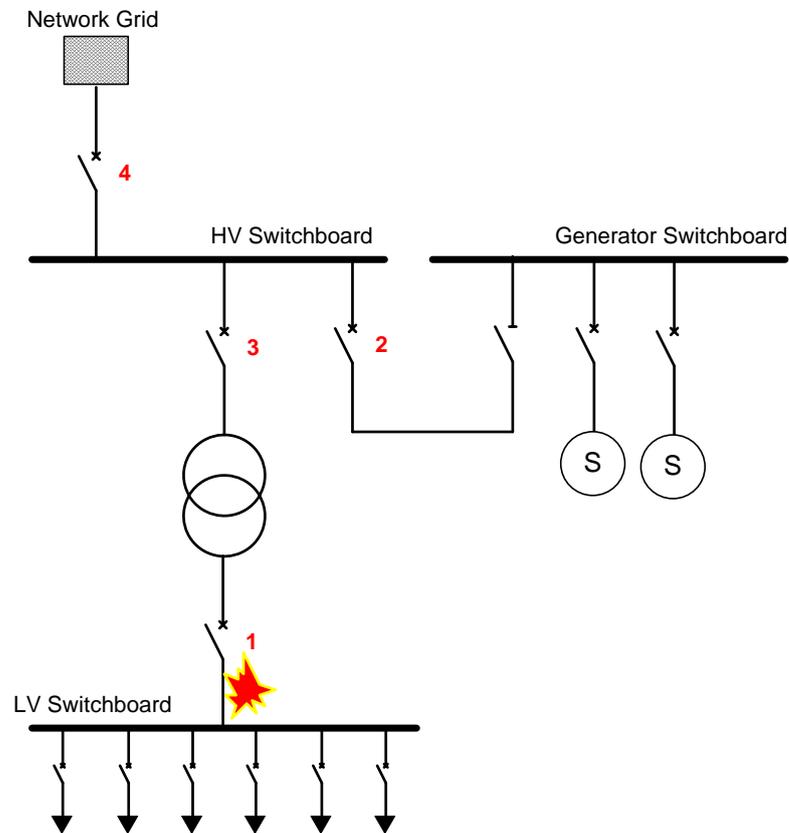
**Effect of Mal-grading**

Arc Flash Hazard studies are usually completed on existing facilities and the study scope does not often include any protection regrading. Rather, the arc flash outcomes are quantified across a site then violations are ranked and prioritised for rework. Even if protection adjustment is part of the initial scope, in the determination of existing performance it is necessary that the calculation process can deal with multiple trip clearing sequences.

In Figure 12, the assessable location is the incomer cubicle and therefore the HV transformer feeder is the closest upstream clearing position. Due to mal-grading however the HV incomer from the generator switchboard (device #2) opens first in time of  $t_1$ . The incident energy at the working distance associated with this first clearing stage timing is then calculated as  $E_{\text{Stage1}}\{I_1, t_1\}$ .

At this point, the system topology has changed and the prospective fault level is lower due to generator disconnection.

The arc current is recalculated based on this system change and the next device to trip is determined to be the HV Incomer from the supply authority (device #4). Again, the incident energy from this stage is calculated as  $E_{\text{Stage2}}\{I_2, (t_2-t_1)\}$ .



**Figure 12 Example of mal-graded system with multiple trip sequences**

The total incident energy for the fault then becomes:

$$E_{\text{Total}} = E_{\text{Motor}} + E_{\text{Stage1}} + E_{\text{Stage2}}$$

, whereby  $E_{\text{Motor}}$  is the portion of incident energy due to motor contribution for  $t_m$  cycles.

## **DIGSILENT APPROACH - ARC FLASH HAZARD STUDY**

The approach adopted for Arc Flash Hazard Studies by DlgSILENT Pacific involves the following steps.

### ***Site Inspections & Assessments***

Site inspections are required to identify the switchgear types in service, retrieve protection relay details and all other information required to build a detailed power system model.

For existing switchgear assemblies, attention is paid to any manufacturer identification of type-tested or IAC assemblies and whether the panel fixings are intact. Additionally, where Form 3x or Form 4x designs have been applied, consideration is given to the probability of arc propagation within function units (i.e. cubicles) from the load-side to the line-side of protective devices.

In the absence of an arc fault type-test, only outgoing compartments with protective devices having insulated line-side terminals or rear connected spouts are considered to be non-propagating terms of load-side arcing faults. It is otherwise too conservative to assume all non-type tested assemblies arc propagating but ultimately such decisions should come from the facility owner/operator.

### ***Assessable Locations***

In simple terms an assessable location is an operating point requiring an arc hazard label. The work activities are then determined for each assessable location.

### ***Work Activities***

Work activities are a concise list of defined tasks relevant to a particular assessable location that requires PPE based on the prevailing incident energy and evaluated risk.

### ***Calculation of Incident Energy Developed***

The calculation of arc incident energy is determined in accordance with IEEE 1584 by the following steps:

- 1) Calculate the prospective 3-phase fault level
- 2) Together with switchgear voltage, busbar gap and IEEE 1584 factors, calculate the arc fault current.
- 3) Apply the arc fault current and determine incident energy from motor contribution and identify the first protection device(s) to respond from all relays simulated.
- 4) Open this first protection device(s) and recalculate to determine if the fault has been cleared. If not, recalculate arc current based on modified system topology, then determine next protection device trip and continue process until the fault is cleared.
- 5) If total trip time exceeds 2 secs, then cap incident energy at this level.
- 6) Add incident energy from each protection clearing step.

### ***Production of Label***

By merging the assessable location data and the arc energy calculation result, a unique label is produced and printed using an industrial label printer.

Labels are valid for 5-years or until the protection settings change or the electrical network changes in some other way to invalid the original calculation results. With the switchgear assessments stored within a database, new labels can be merged with updated calculation results and labels provided efficiently as an ongoing service. This is in contrast to the campaign approach common with engineering consults.

### ***Reports***

From the database, a detailed report is produced for every label substantiating the incident energy calculations and the assigned activity list. The report details the staged fault clearing, circuit breaker opening time and motor contribution components. For each clearing step, both the 100%.Ia and 85%.Ia cases are considered, together with protection clearing curves.

An example of the report is contained overpage. In this case, the system is 33kV so Lee's equations are applied. Additional, the client business rules dedicated that irrespective of how low the CAT rating may be, a minimum of CAT2 PPE is required for HV switching.

### ***Label Placement Forms***

Every label is delivered with a form detailed the placement location. Once the label is placed, the form is signed and returned with a photograph for the database to be updated. In the event that of any label errors, there may be some subsequent actions as indicated by the label status (i.e. installed, installed by requires reassessment, cancelled etc).

## Arc Flash Hazard: Assessible Location Report



**ID:** 4337

**Client:**

**Site:**



**Location:**

**Equipment:** 33kV RMU-V1

**Supplied from:** Pole VL65 - 40A DOF

**Classification:** No Group

**SLD:** W133-E-1093

**Assessment date:** 23/03/2010

**Assessed by:** JRH

**Label status:** Pending

### Switchgear Information

**Assessible loc. no.:** 1

**Name:** RMU-V1

**Location:** Village

### Equipment Information

Screws intact?

Louvres/vents present?

Withdrawable to isolate?

IAC assembly?

No. of group labels:

No. of reference labels:

### PowerFactory Summary Information

**Output date:** 26/03/2010

**Version:** NA

**Operation scenario:** NA

**Expansion stage:** NA

**Study case:** Site Visit

**Assessment ID:** 1182-1

**Voltage (kV):** 33

**Configuration:** Unknown

**Equipment type:** Unknown

**Bus gap, G (mm):** NA

**Working distance, D (mm):** 910

**K:** NA

**K1:** NA

**K2:** NA

**Cf:** NA

**x:** NA

**Bolted fault current (kA):** 2.233

**Arcing current (kA):** 2.233

**Arcing time (s):** 0.049

**Incident energy (cal/cm<sup>2</sup>):** 2.885

**Motor Contribution (cal/cm<sup>2</sup>):** 0.984

**Boundary distance (mm):** 1413.922

### Assessible Location Picture



### PPE Classification Information

Activity List:	Door Open	Door Closed
SWITCHING	-	CAT 2
RACKING	-	-
ELECTRICAL WORK	CAT 2	-
VISUAL INSPECTION	CAT 0	-
COVER REMOVAL	CAT 2	-

### Arc Fault Clearing Sequences

Sequence number:	1		
Relay:	RMU-V1 (40A Fuse)		
Cubicle:	RMU-V1 Incoming-OHL		
Switchboard:	VL65 Interconnection 33kV		
Bolted fault current (kA):	2.233	Accumulated energy (cal/cm2):	1.901
Arcing current, $I_a$ (kA):	0.000	Arc energy contribution (cal/cm2):	1.901
Tripping time (s):	0.049	Contribution time (s):	0.049
CB opening time (s):	NA	Sequence end time (s):	0.049
CB Open Dissipation Factor:	NA		

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### Motor Contribution Details

Accumulated energy without motor (cal/cm2):	1.901	Motor contribution time (s):	0.100
Bolted fault current with motor (kA):	2.715	Energy with motor (cal/cm2):	5.540
Bolted fault current without motor (kA):	2.233	Energy without motor (cal/cm2):	4.556
Arcing current with motor (kA):	2.715	Motor contribution (cal/cm2):	0.984
Arcing current without motor (kA):	2.233		

**Calculation Details of Sequence : 1**

**List of Relays Considered in the Calculations (100% Ia)**

Relay:	Cubicle:	Switchboard:	Arcing time (s):
RMU-V1 (40A Fuse)	RMU-V1 Incoming-OHL	VL65 Interconnection 33	0.040
6612 FDR	T601 Outgoing(unknown siz	T601 MV	0.173
6611 FDR	T601	T601 MV	0.220
Incomer	TF28	SB21_load 0.415kV	0.320
T1-F5051H/Y	T601	220 kV to Juna Downs	0.694
TF28 (25A Fuse)	Cub_2	VL64 Interconnection 33	1.132
Incomer	SB21 Bustie	SB21_gen 0.415kV	1.713
DA01 Incomer	DA01	SB21_gen 0.415kV	2.719
DA05 Incomer	DA05	SB21_gen 0.415kV	3.315
GN01	LC01/GN01-P1	LC01 6.6kV	6.682
GN02	LC01/GN02-P1	LC01 6.6kV	6.682
GN03	LC01/GN03-P1	LC01 6.6kV	6.682
GN04	LC01/GN04-P1	LC01 6.6kV	6.682
GN05	LC01/GN05-P1	LC01 6.6kV	6.682

**List of Relays Considered in the Calculations (85% Ia)**

Relay:	Cubicle:	Switchboard:	Arcing time (s):
RMU-V1 (40A Fuse)	RMU-V1 Incoming-OHL	VL65 Interconnection 33	0.049
6612 FDR	T601 Outgoing(unknown siz	T601 MV	0.209
6611 FDR	T601	T601 MV	0.220
Incomer	TF28	SB21_load 0.415kV	0.413
T1-F5051H/Y	T601	220 kV to Juna Downs	0.902
TF28 (25A Fuse)	Cub_2	VL64 Interconnection 33	1.630
Incomer	SB21 Bustie	SB21_gen 0.415kV	2.345
DA01 Incomer	DA01	SB21_gen 0.415kV	3.877
DA05 Incomer	DA05	SB21_gen 0.415kV	4.877
GN01	LC01/GN01-P1	LC01 6.6kV	8.921
GN02	LC01/GN02-P1	LC01 6.6kV	8.921
GN03	LC01/GN03-P1	LC01 6.6kV	8.921
GN04	LC01/GN04-P1	LC01 6.6kV	8.921
GN05	LC01/GN05-P1	LC01 6.6kV	8.921

**Switch Activation List**

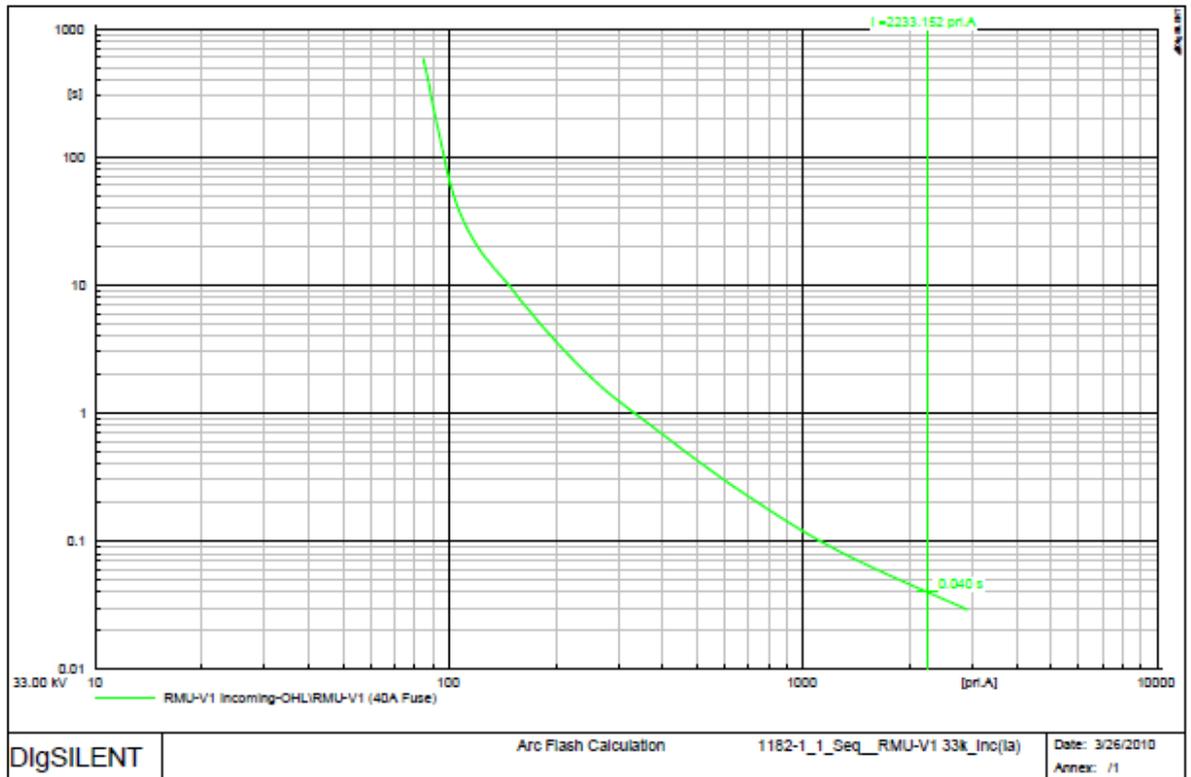
Switch:	Location:
Switch	RMU-V1 Incoming-OHL

**Calculation Details of Sequence : 1**

**Summary of 100% Ia**

Relay:	RMU-V1 (40A Fuse)
Cubicle:	RMU-V1 Incoming-OHL
Switchboard:	VL65 Interconnection 33kV
Bolted fault current (kA):	2.233
Arcing current, Ia (kA):	2.233
Tripping time (s):	0.040
CB opening time (s):	NA
CB Open Dissipation Factor:	NA
Arc energy contribution (cal/cm2):	1.832
Contribution time (s):	0.040
Assigned to incident energy result?	<input type="checkbox"/>

**Time Over Current Plots (100% Ia)**

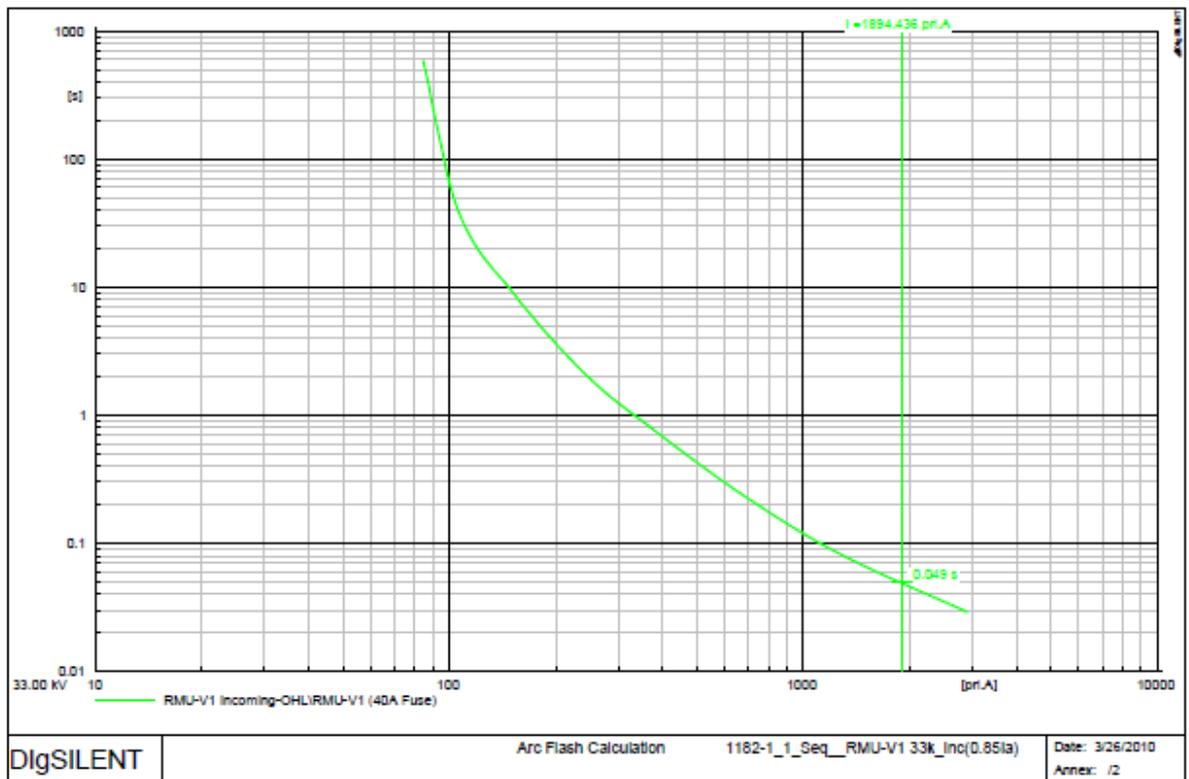


**Calculation Details of Sequence : 1**

**Summary of 85% Ia**

Relay:	RMU-V1 (40A Fuse)
Cubicle:	RMU-V1 Incoming-OHL
Switchboard:	VL65 Interconnection 33kV
Bolted fault current (kA):	2.233
Arcing current, Ia (kA):	1.898
Tripping time (s):	0.049
CB opening time (s):	NA
CB Open Dissipation Factor:	NA
Arc energy contribution (cal/cm2):	1.901
Contribution time (s):	0.049
Assigned to incident energy result?	<input checked="" type="checkbox"/>

**Time Over Current Plots (85% Ia)**



## Arc Flash Hazard: Label Installation



**ID:** 4337  
**Client:** RIO TINTO IRON ORE  
**Site:** WEST ANGELAS  
**Location:**   
**Equipment:**   
**Supplied from:**   
**Classification:** No Group  
**Label status:** Pending

### PowerFactory Information

**Assessment ID:** 1182-1  
**Voltage (kV):** 33  
**Arcing current (kA):** 2.233  
**Arcing time (s):** 0.049  
**Motor contribution (cal/cm2):** 0.984  
**Incident energy (cal/cm2):** 2.885  
**Boundary distance (mm):** 1413.922

### Switchgear Information

**Assessible loc. no.:** 1  
**Name:** RMU-V1  
**Location:** Village

### Assessible Location Picture



### Equipment Information

**No. of reference labels:**  
**No. of group labels:**

### Placement Record

**Label fitted?**  **Date:**   
**Photographed?**  **Ref.:**   
**By:**

### PPE Classification Information

<u>Activity List:</u>	<u>Door Open</u>	<u>Door Closed</u>
SWITCHING	-	CAT 2
RACKING	-	-
ELECTRICAL WORK	CAT 2	-
VISUAL INSPECTION	CAT 0	-
COVER REMOVAL	CAT 2	-

### Notes:

**Office Use:** Database Updated?  **By:**  **Date:**

## **REFERENCES**

- (1). *Electrical arcing burn hazards*. **Stokes, A.D. Sweeting, D.K.** Issue 1, s.l. : IEEE, 2006, Vol. 42. IEEE Transactions on Industry Applications,.
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- (3). **J. Spence, D.Stevens, P. Willis,**. *RTIO Arc Flash Guidelines*. Perth : RTIO, 2009.
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- (5). **IEC**. *High-voltage switchgear and controlgear – Part 200:AC metal-enclosed switchgear and controlgear*. s.l. : IEC, 2003. IEC 62271-200.