

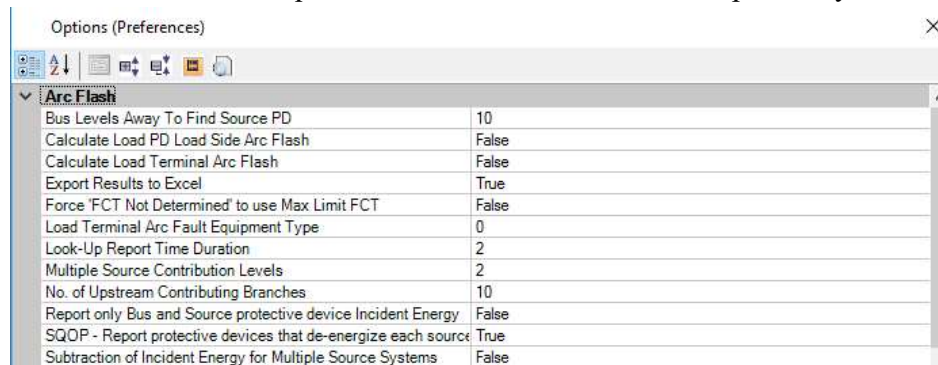
ETAP Workshop Notes



Arc Flash Analysis

Purpose and Description

The purpose of this exercise is to introduce Arc Flash interface by using the system modelled as part of the Relay Coordination example and thereby calculating the arc flash incident energy, flash protection boundary and recommended PPE along with protection clearing time and arcing current as per IEEE 1584 for all source PD and loads/Bus PD at every switchgear bus. Before running ETAP, it is necessary to check the Tools->Options (Preferences)->Arc Flash which by ETAP default is as below. The requirements to be entered are self-explanatory.

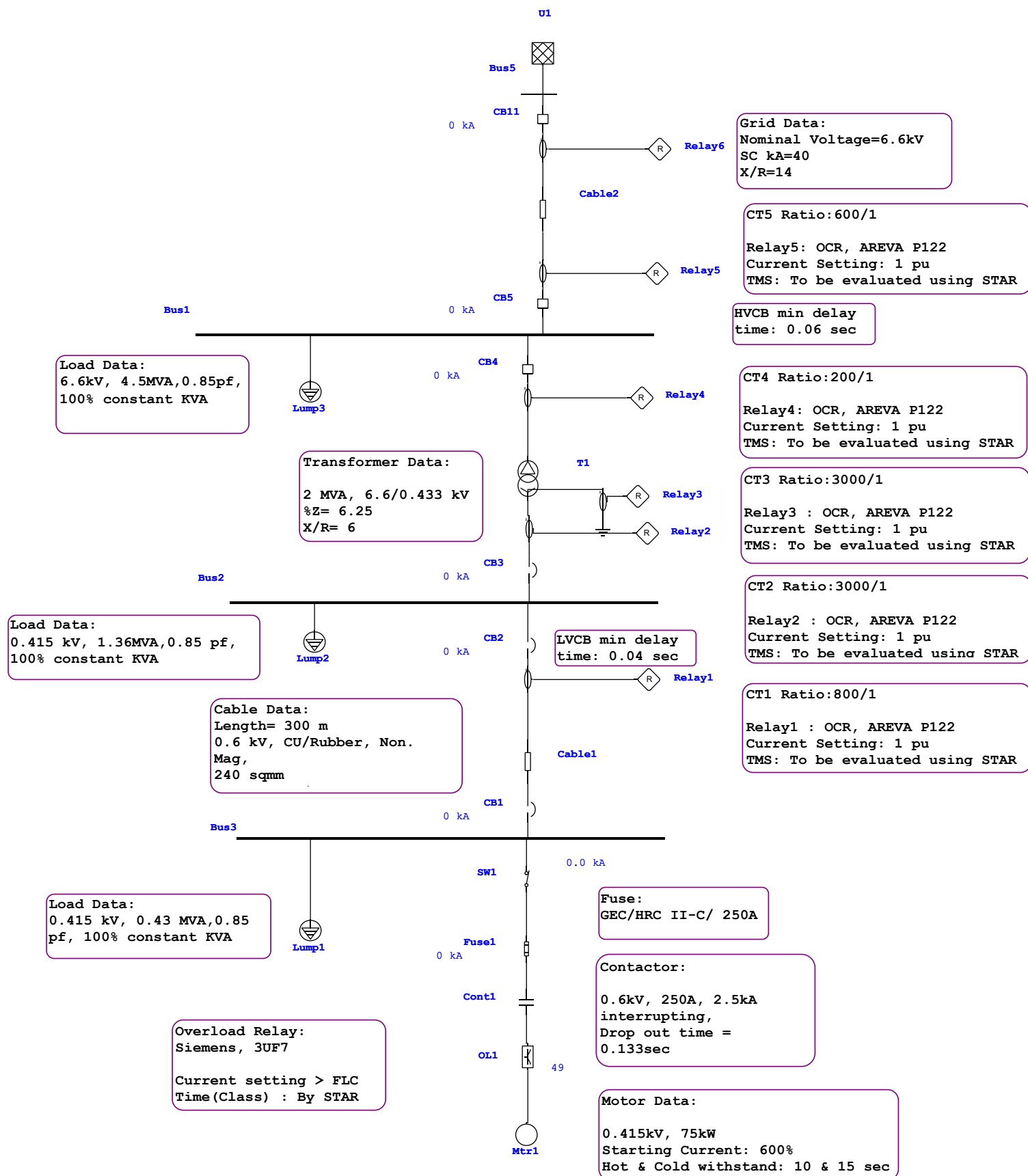


Options (Preferences)	
Arc Flash	
Bus Levels Away To Find Source PD	10
Calculate Load PD Load Side Arc Flash	False
Calculate Load Terminal Arc Flash	False
Export Results to Excel	True
Force 'FCT Not Determined' to use Max Limit FCT	False
Load Terminal Arc Fault Equipment Type	0
Look-Up Report Time Duration	2
Multiple Source Contribution Levels	2
No. of Upstream Contributing Branches	10
Report only Bus and Source protective device Incident Energy	False
SQOP - Report protective devices that de-energize each source	True
Subtraction of Incident Energy for Multiple Source Systems	False

Procedure

1. Open the Relay Coordination OTI example carried out as part of the relay coordination exercise. The OLV attached in the following page reflects the settings provided for all the relays for the user's reference.

One-Line Diagram - OLV1 (Arc Flash)

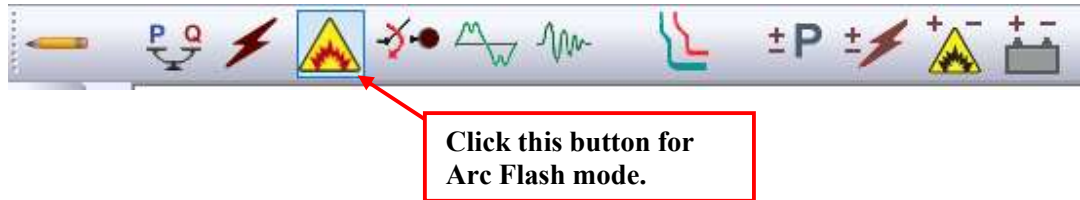


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- Click on “Arc Flash Module” in Mode toolbar as shown.



- As part of this exercise, we will carry out arc flash analysis calculations at Bus 11 and Bus 12 as shown in below OLV.

In Bus 12, bus 'Rating' page, select "Switchgear" which will have typical gap length as per IEEE 1584. (As per IEEE, the following options are available -> Switchgear, Switchboard, MCC, Panelboard, Open Air, Cable Bus.) In the Bus 12, bus 'Arc Flash' page note the working distance as per V 1584 for the 6.6kv voltage level.

The left screenshot shows the 'Bus Editor - Bus12' window, 'Rating' tab. The 'Type' dropdown is set to 'Switchgear'. The 'Enclosure Isolation' checkbox is checked. The 'Gap Between Conductors / Buses' is 153 mm. The 'Distance X Factor' is 0.973. The 'Orientation' is 'Vertical'. The 'Termination' is 'Open Tips'. The 'Conductor Type' is 'Copper'. The 'Shock Protection' section shows 'Limited Approach Boundary' selected. The 'Insulating Glove Class' is 1. The 'V-Rating' is 7500 VAC. The 'Shock Hazard when' is 'covers removed'. The 'Automatically Update Arc Flash and Shock Protection Data' checkbox is checked.

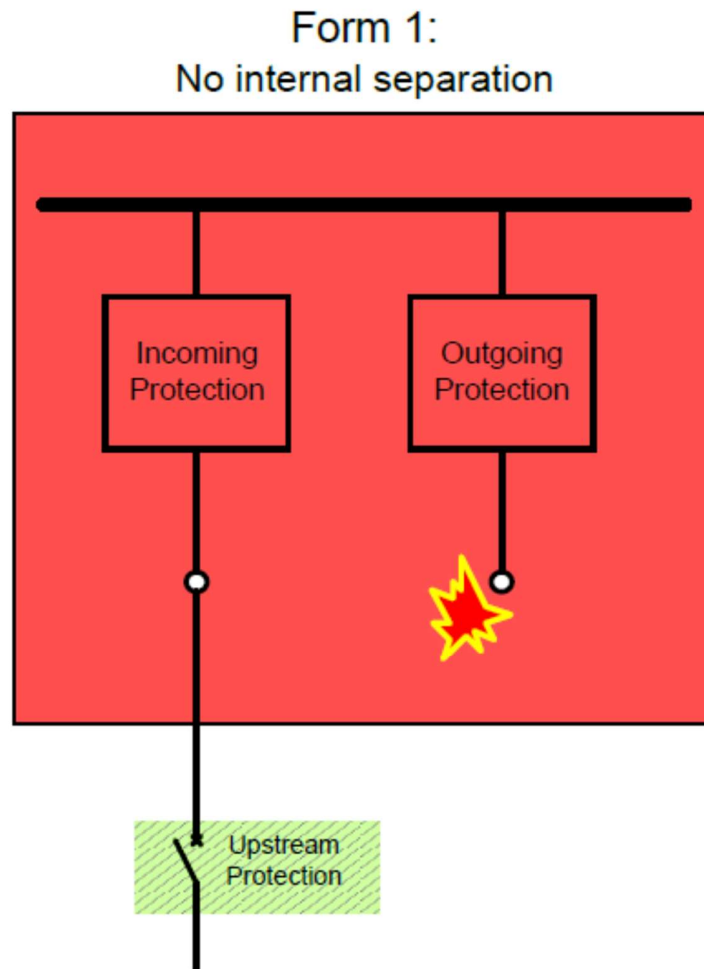
The right screenshot shows the 'Bus Editor - Bus12' window, 'Arc Flash' tab. The 'Calculated' section shows: Bus Fault Current (30.9 kA), Bus Arcing Current (29.42 kA), Source PD (CB16), Source PD Arcing Current (25.95 kA), Fault Clearing Time (FCT) (0.344 Sec), Grounding (Grounded), Incident Energy (14.215 cal/cm²), Arc Flash Boundary (11.599 m), Working Distance (91.4 cm). The 'User-Defined' section shows: Bus Fault Current (0 kA), Bus Arcing Current (0 kA), Source PD (CB16), Source PD Arcing Current (25.95 kA), Fault Clearing Time (FCT) (0.1 Sec), Grounding (Grounded), Incident Energy (0 cal/cm²), Arc Flash Boundary (0 m), Working Distance (91.44 cm). The 'Alerts' section shows: Allowable Energy (0 cal/cm²), Energy Level (0 kA). The 'TCC Plot Energy' section shows: Ibf (Selected), la (Selected), Calculated (Selected), User-Defined (Selected). The 'TCC Plot Arcing Current' section shows: Calculated kV (Selected), User-Defined (Selected), Calculated/UD Source PD (Selected), Allowable Energy (0 kA), All Energy Categories (Selected).

Similarly, for Bus 11, in bus 'Rating' page, select "Switchboard" which will have typical gap length as per IEEE 1584. In the 'Arc Flash' page note the working distance as per IEEE 1584 for the 0.415kV voltage level.

It should be noted that against MCC there is an ‘Enclosure Isolation’ to be checked ON or OFF for “Main PD” which refers to incomer PD. Depending on MCC enclosure form (Form 1, 2, 3, 4) installed, the main PD isolation may be blocked by keeping this option unchecked. ‘Main PD Not Isolated’ means remote source end PD has to be relied upon for bus and load side fault clearance. Typically for Form 3 and above, this option may

Arc Flash Analysis

be kept as checked ON. In this respect, the details of the forms of enclosure from an arc flash point of view are as below –

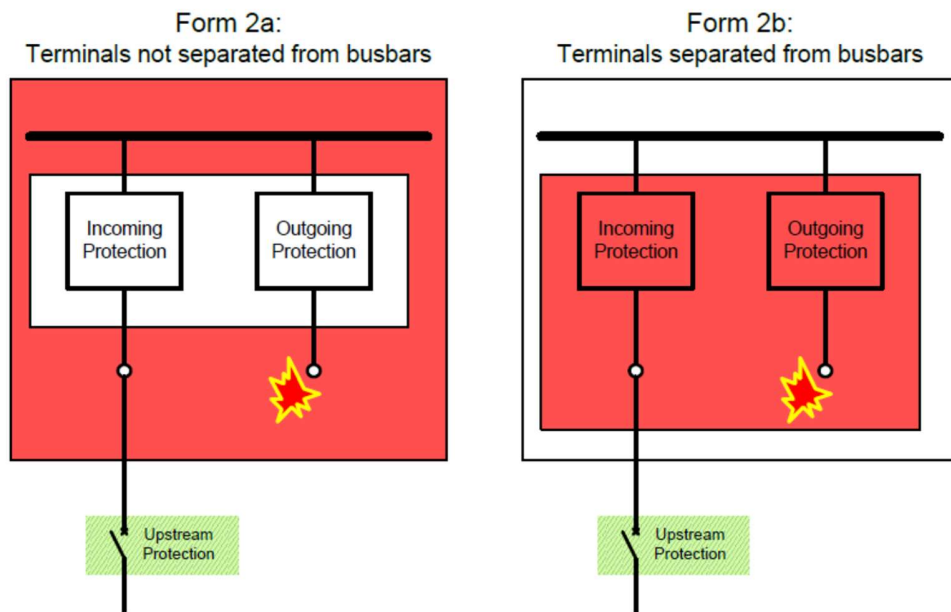


Arc Fault in Form 1 Enclosure

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Arc Flash Analysis

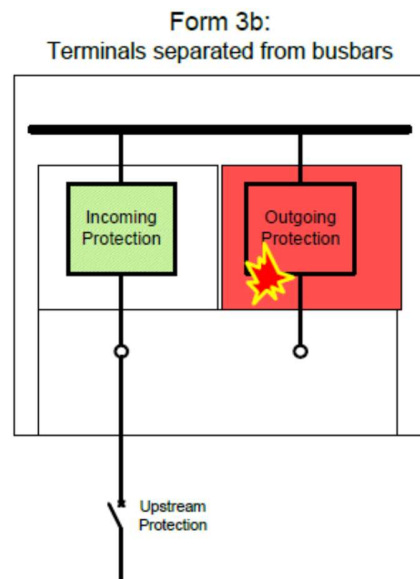
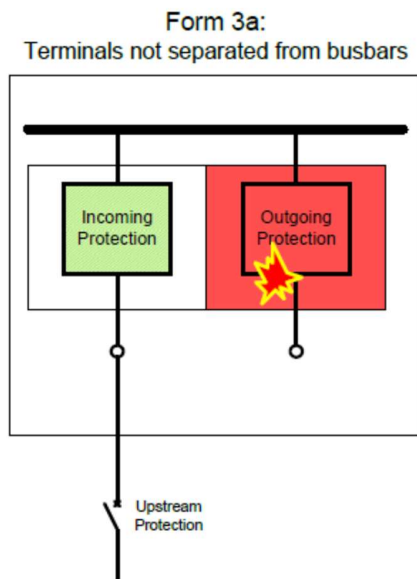
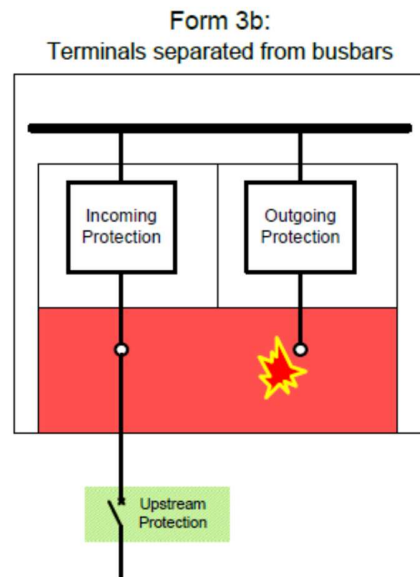
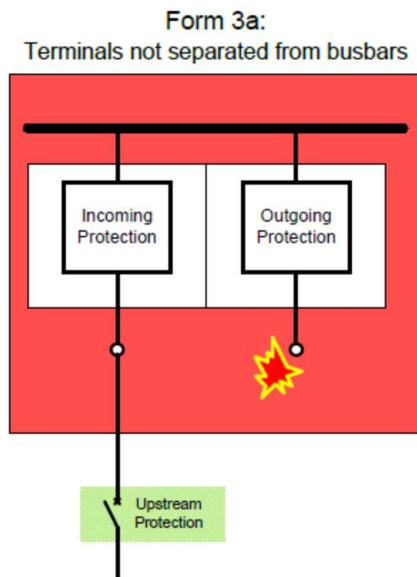


Arc Fault in Form 2a & 2b Enclosure

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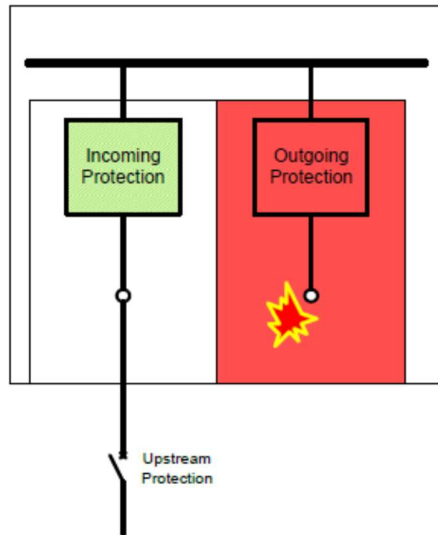


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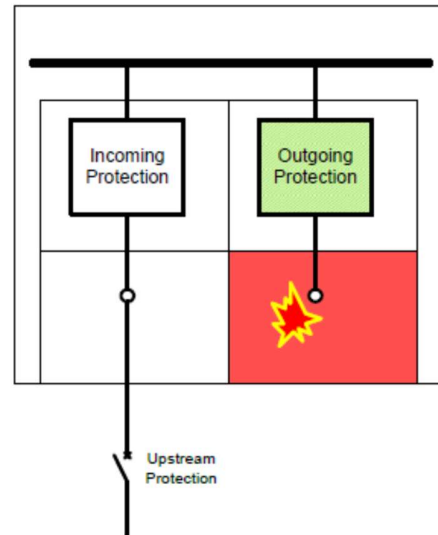


Arc Flash Analysis

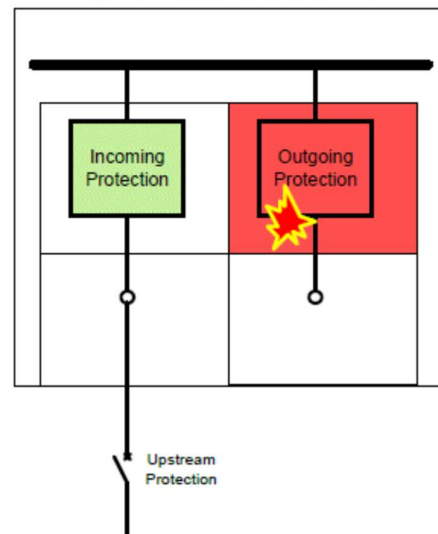
Form 4a:
Terminals in same compartment and
associated functional unit



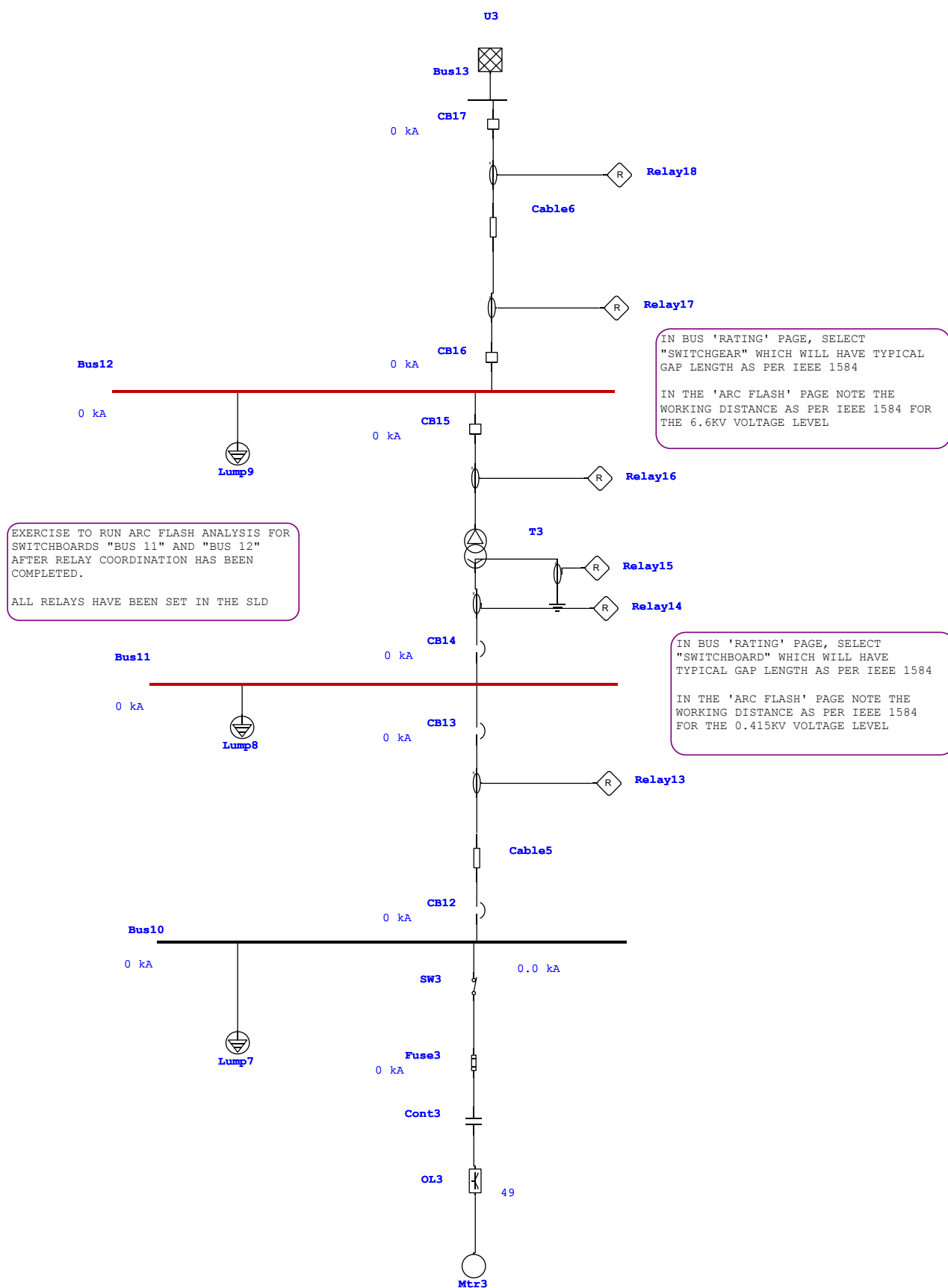
Form 4b:
Terminals not in same compartment
and associated functional unit



Form 4b:
Terminals not in same compartment
and associated functional unit



One-Line Diagram - OLV1 (Arc Flash)



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4. Create a new Arc Flash Study Case, in the Info page, fault buses Bus11 and Bus12.

Arc Flash Study Case

Info Method Clearing Time Parameters Adjustment SC Standard Alert

Study Case ID: A_SC

Load Terminal Fault
☐ Calc. Load Term. SC

Equip. Cable & OL Heater
Include Impedance for:
☐ MV Motors
☐ LV Motors

Transformer Tap
☒ Adjust Base kV
☐ Use Nominal Tap

Report Contribution
Level: 2

1-Ph/Panel/1-Ph UPS Subsystem
☒ 1-Phase
☒ Panel
☒ 1-Phase UPS

Motor Contribution Based on
☒ Motor Status
☐ Loading Category
☐ Both

Bus Selection

Fault		Don't Fault
Bus11 Bus12	<input type="checkbox"/> All Buses <input type="checkbox"/> MV Buses <input type="checkbox"/> LV Buses -<< Fault ~Fault >>	Bus1 Bus2 Bus3 Bus5 Bus10 Bus13

Study Remarks

≤ A_SC ≥ Help OK Cancel

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Arc Flash Analysis

5. Select the method of calculation as IEEE 1584 in the Method page. Retain “15%” default for Arc Current Variation for LV in line with IEEE1584 so that ETAP can calculate incident energy for actual fault and 85% fault to arrive at max incident energy. ETAP will display 85% if the lower 85% fault current energy is more than 100% fault current energy. Retain default Check-ON settings for bus fault current as ‘Calculate’ and check ‘Update Fault current to Bus AF Page’.

The screenshot shows the 'Arc Flash Study Case' dialog box with the following settings:

- Method Tab:**
 - Arc Flash Method:** ☐ NFPA 70E Annex D.2, D.3; ☒ IEEE 1584. Arc Current Variation for LV (<1kV): 15 %.
 - Bus Fault Current:** ☐ User-Defined (Bus Editor); ☒ Calculate.
 - ☒ Update Fault Current to Bus AF Page.
 - Motor Contributions:** (Empty field)
 - ☐ Incident Energy for LV Equipment.
- Bottom Bar:** Includes navigation buttons (≤, ≥), a dropdown menu set to 'A_SC', and 'Help', 'OK', and 'Cancel' buttons.

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Arc Flash Analysis

6. In the Clearing Time page, select Auto Select Source Protective Device (PD). ETAP will select the fault clearing time based on the relay settings & TCC curves determined earlier. If 'Except if PD is Selected in Bus' is checked ON then ETAP can derive incident energy in the User-defined cells of Bus "Arc Flash" page once PD ID is selected.

'Limit Max FCT' to 2 seconds if found appropriate as per IEEE 1584 where there is adequate space for escape. Refer IEEE1584 for details.

The screenshot shows the 'Arc Flash Study Case' dialog box with the 'Clearing Time' tab selected. The dialog has several tabs: Info, Method, Clearing Time, Parameters, Adjustment, SC Standard, and Alert. The 'Clearing Time' tab contains three main sections:

- Fault Clearing Time (FCT):**
 - ☒ Auto Select Source Protective Device (PD)
 - ☐ Except if PD is Selected in Bus Editor
 - ☐ Limit Maximum FCT
 - ☐ User-Defined from Bus Editor
 - ☒ Update FCT to Bus AF Page
- Main Protective Device Isolation:**
 - ☒ Consider Main Protective Device Isolation
 - ☐ Individual (Bus Editor)
 - ☒ Typical IEEE 1584
 - ☒ Global
 - ☐ User-Defined
- Current Limiting Devices:**
 - ☒ Determine CLF operation based on Peak Let-Through Curves
 - ☒ For Class L & RK1, use IEEE 1584 Equations (if applicable)
 - ☒ Use bottom of CLF TCC (if peak let-through not available)

At the bottom of the dialog, there is a dropdown menu set to 'A_SC', and buttons for 'Help', 'OK', and 'Cancel'.

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Arc Flash Analysis

7. In the parameters page, Incident Energy levels shall be determined as per latest NFPA guidelines NFPA70E 2012 to 2015 and 'Edit/Approve PPE' for the Arc Flash run so that ETAP recognizes the standard for PPE.

Check ON the 'One Line Diagram Connection' for System grounding so that ETAP will automatically identify and enter the grounding type in the Bus 'Arc Flash' page. Retain the Shock Risk Assessment as per default.

Arc Flash Study Case

Info Method Clearing Time Parameters Adjustment SC Standard Alert

Bus Gap, X-factor & Working Distance

☒ Individual (Bus Editor)

Edit

Incident Energy Levels

☐ NFPA 70E 2000

☐ NFPA 70E 2004

☐ NFPA 70E 2009

☒ NFPA 70E 2012 to 2015 / User-Defined

Edit/Approve PPE

System Grounding

☒ One-Line Diagram Connection

☐ User-Defined (Bus Editor)

☒ Update Grounding to Bus AF Page

Arc Flash Boundary

Shock Risk Assessment

Shock Protection Boundaries

☒ Individual (Bus Editor)

Global Voltage-Rated Glove Class

☒ ASTM D 120-14

Edit

≤ A_SC ≥

Help OK Cancel

8. Select IEC in the Short circuit page in the Arc Flash study editor.

Arc Flash Study Case

Info Method Clearing Time Parameters Adjustment SC Standard Alert

Standard

☒ IEC

☐ ANSI

Short-Circuit Current

☐ Max.

☒ User-Defined c Factor

☐ Min. (Exclude Duty Calc)

c Factor

< 1001 V 1.05

1001 to 35000 V 1.1

> 35000 V 1.1

Zero Sequence Mdl

☒ Include Branch Y & Static Load

Protective Device Duty

☒ Based on Total Bus Fault Current

☐ Based on Max I through Fault Current

☒ Report Breaking Duty vs. CB Time Delay

☒ Based on Total Bus If

☐ Based on Max Through If

LV CB Breaking

☒ Use Ics

☐ Use Icu

Thermal Withstand

☒ Use Tkr

☐ Use Tk

Calculation Method X/R for Peak kA

☐ Method A

☐ Method B

☒ Method C

Cmax for Z Adjustment (< 1001 V)

☒ 1.05 (+6% V Tol)

☐ 1.10 (+10% V Tol)

≤ A_SC ≥

Help OK Cancel

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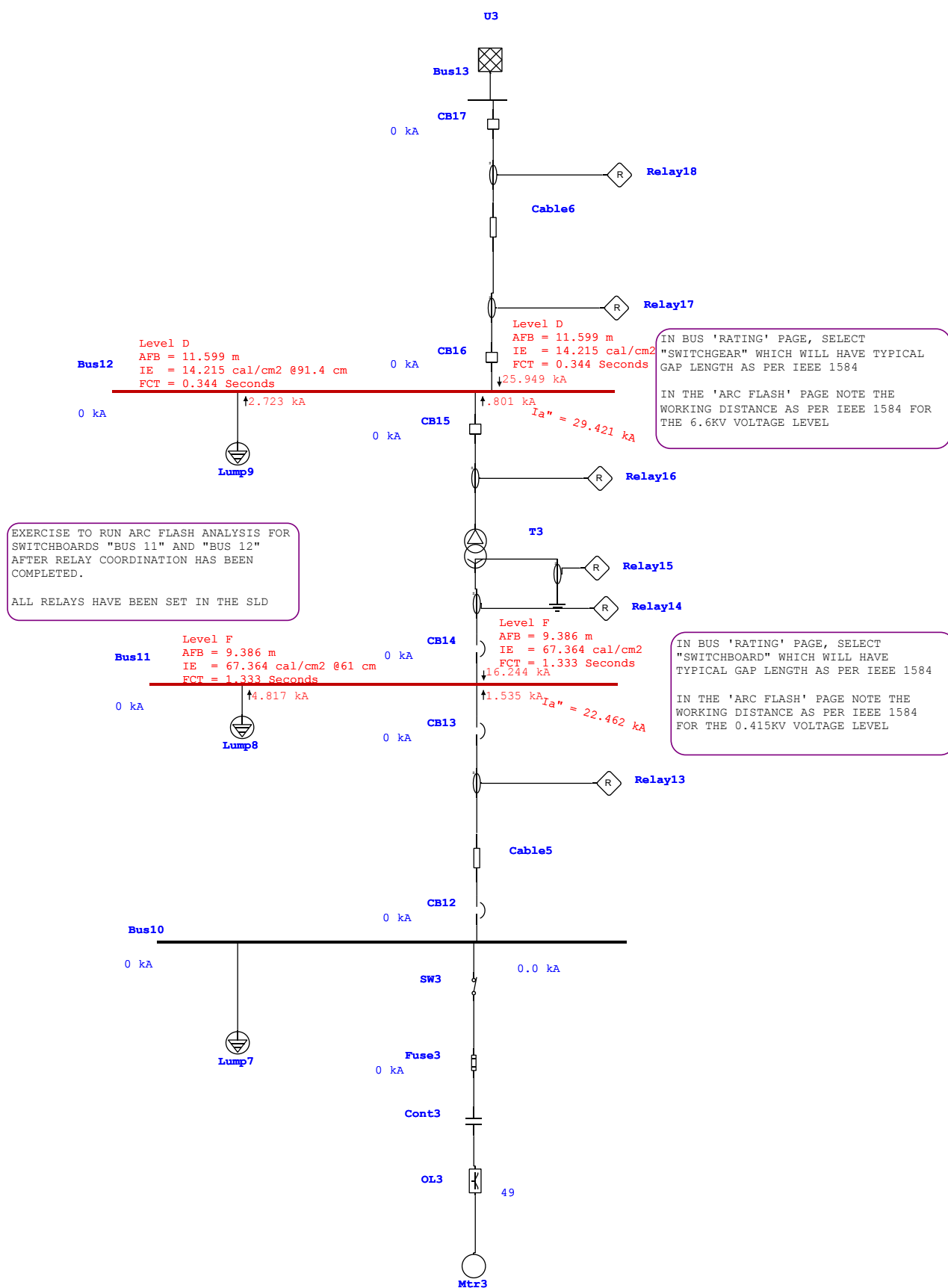
9. Run the Arc Flash Analysis, which will display the Arc flash category level, flash protection boundary, and incident energy as seen in the OLV below. Bus/load PD and source side PD arc flash results will be displayed after checking ON the units along with Arc Flash and Arc Flash Location check boxes.

The 'Display Options - Arc Flash' dialog box is shown. It has tabs for 'Results', 'AC', 'AC-DC', and 'Colors'. The 'Results' tab is active. Under 'Voltage Unit', 'kV' is selected and 'Show Units' is checked. Under 'Fault Current', '3-Phase' is selected. Below that, 'Ia - Arcing Current' is selected. Under 'Display Load Contributions', 'Medium Voltage Motors', 'Large Low Voltage Motors', and 'Small Low Voltage Motors' are all checked. Under 'Arc-Flash', 'Energy Level', 'Arc Flash Boundary', 'Incident Energy', and 'FCT' (set to 'sec') are checked. Under 'Arc Fault Location', 'Bus & Load PD' and 'Source PDs' are checked. At the bottom, 'Arc-Flash Sequence of Op.' is set to 'Flash 3 Times'. Buttons for 'Help', 'OK', and 'Cancel' are at the bottom.

10. As part of arc flash exercise, warning labels have to be created which should be affixed to the panel door. An example label has been created for Bus 12 and Bus 12 PD.

The 'IEC Arc Flash Report Manager' dialog box is shown. It has tabs for 'Complete', 'Input', 'Label-English', 'Result', and 'Summary'. The 'Label-English' tab is active. A list of labels is shown, with '3X6 Danger 1-Bus' selected. On the right, 'Viewer' is selected. Below the list, 'Output Report Name' is 'Untitled' and 'Path' is 'C:\Anirudh\ETAP Training\VEC\Relay Co-ordination OTI File\Relay Coordination'. Buttons for 'Help', 'OK', and 'Cancel' are at the bottom.




One-Line Diagram - OLV1 (Arc Flash)






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Arc Flash Analysis

 DANGER		
	Arc Flash and Shock Hazard	
	Arc Flash Boundary	11.60 m
	Incident Energy (cal/cm ²)	14.2
	Working Distance	91.4 cm
	Level D	
	Shock Hazard Voltage	6600 V
	Limited Approach	1.52 m
	Restricted Approach	0.66 m
CB16		
		08-01-2018

 DANGER		
	Arc Flash and Shock Hazard	
	Arc Flash Boundary	11.60 m
	Incident Energy(cal/cm ²)	14.2
	Working Distance	91 cm
	Level D	
	Shock Hazard Voltage	6600 VAC
	Limited Approach	1.52 m
	Restricted Approach	0.66 m
Bus12		
		08-01-2018

11. Conclusions – typical industry practice is to reduce arc flash to Category C. to achieve this differential protection needs to be added at the bus bar and transformer/ cable feeders. An example of the procedure to add differential is discussed in AF_Differential.