UNIVERSITY OF CALGARY

ENEL 674 Industrial and Commercial Power Systems

Group 7

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Project Milestone 4

1 Contents

1. Executive Summary

This report is a comprehensive document that provides an analysis of the behavior and performance of an electrical power system. The report includes an overview of the power system, including its configuration, components, and operating conditions, as well as an analysis of the system's performance under various scenarios, such as normal operating conditions, emergency conditions, and fault conditions.

We are doing below analyses for the given network:

- Load flow studies: An analysis of the power flow through the system under normal operating conditions, including voltage levels and power losses.
- Short circuit studies: An analysis of the potential short circuit currents and the ability of the system's protective devices to interrupt these currents.
- Protective device coordination studies: An analysis of the coordination of protective devices, such as fuses, circuit breakers, and relays, to ensure that faults are cleared quickly and efficiently.
- Arc flash hazard analysis: An analysis of the potential for arc flash hazards and recommendations for mitigating these hazards.

2. Foreword

1.1 Purpose of the study

The purpose of power system studies is to analyze and evaluate the behavior and performance of electrical power systems under various operating conditions, identify potential problems or hazards, and provide recommendations for improving the system's reliability, safety, and efficiency.

1.2 Scope of the studies

The main scope of this project is to conduct various power system analyses like Load flow, short circuit, protection coordination and arc flash analyses. The scope of the study will depend on the specific needs and requirements of the power system, as well as the objectives of the study. Ultimately, the goal of a power system study is to evaluate the performance and behavior of the power system and provide recommendations for improving its reliability, safety, and efficiency.

1.3 Methodology

Study will be based on current codes, industry standards, practices, and client's expectations.

1.4 System Description

The whole system network is consisting of back up generator/UPS, utility transformer and solar farm. The network also includes the different panels for distributions. The single line diagram is mentioned in the Appendix A.

1.5 Basis and assumptions

The Electrical Transient Analyzer Program (ETAP, version 20.6) is used for performing the studies. And following assumptions are made.

1. Some of the technical data are assumed as typical value. i.e., Generator impedance, Transformer Impedance, transformer inrush current.
2. Motor starting curves were unavailable for the motors. So, motor acceleration is not considered at this stage.
3. The choice is given to client to go with UPS or Back-up generator; however, power system study is carried out for both conditions.
4. Power system studies carried out considering constant load demand.
5. For the lighting and receptacles, total load is considered as a static load.
6. Balanced three-phase system: ETAP assumes that the three phases of the power system are balanced, meaning that they have equal magnitudes and are separated by a 120-degree phase angle.
7. Ideal power sources: ETAP assumes that power sources such as generators, transformers, and batteries are ideal and provide a constant voltage and frequency.
8. Linear components: ETAP assumes that all components in the power system, such as cables, transformers, and loads, are linear and do not exhibit nonlinear behavior.
9. Accurate system parameters: ETAP assumes that the user has input accurate and up-to-date system parameters, such as component ratings, impedance values, and protection settings.

1.6 Input data

Utility impedance: For our analysis, we took the SC rating and SC impedance data as mentioned by the professor. The utility impedance and short circuit levels are as follow:

SC Rating

	MVAsc	MVAsc	X/R	kAsc
3-Phase	175		7	4.058
1-Phase	175	58.333	7	4.058
	sqrt(3)Vll If	Vln If		

SC Impedance (100 MVAb)

	% R	% X
Pos.	8.08122	56.5685
Neg.	8.08122	56.5685
Zero	8.08122	56.5685

Figure 1

Backup Diesel Generator Impedance: The impedance detail of the back up diesel generator is taken as typical values and are as follow:

Impedance

	%				%		Ohm
Xd"	19	Xd"/Ra	19	Ra	1	Ra	0.014421
X2	18	X2/R2	9	R2	2	R2	0.028843
Xo	7	X0/R0	7	R0	1	R0	0.014421
				Rdc	0	Rdc	0

Figure 2

Utility Transformer Impedance: The impedance detail of the utility transformer is taken as typical values and are as follow:

Impedance

	%Z	X/R	R/X	%X	%R
Positive	7.25	2.47	0.405	6.72	2.721
Zero	7.25	2.47	0.405	6.72	2.721

Figure 3

Conductors/Cables

1. TR O/G Cable: $208V, 3\emptyset - 4W$ Cable from TR outgoing to Main BUS BAR CHAMBER

Type of cable: CU

Size of conductor: $750\ kcmil$

Frequency: $60Hz$

Maximum allowable voltage limit: $5000V$

$T_a = 30\ ℃$

$T_c = 60\ ℃$

Cable length $= 100\ ft$

Allowable ampacity $= 426.9\ A$

Voltage drops $= 0.61\%$

The impedance detail of the TR O/G cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.0203	0.0332	0.0000881	0.03891	1.635	0	0
Zero	0.03248	0.08466	0.0002246	0.09068	2.607	0	0

Figure 4

2. O/G to 1P Cable: $208V, 3\emptyset - 4W$ Cable from Main BUS BAR CHAMBER to Distribution board panel – 1P

Type of cable: CU

Size of conductor: $350\ kcmil$

Frequency: $60Hz$

Maximum allowable voltage limit: $5000V$

$T_a = 30\ ℃$

$T_c = 60\ ℃$

Cable length $= 20\ ft$

Allowable ampacity $= 284\ A$

Voltage drops $= 0.07\%$

The impedance detail of the O/G to 1P cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.1365	0.096	0.0002546	0.16688	0.703	0	0
Zero	0.217	0.2438	0.0006467	0.32639	1.124	0	0

Figure 5

3. O/G to 2P Cable: $208V, 3\emptyset - 4W$ Cable from Main BUS BAR CHAMBER to Distribution board panel – 2P

   Type of cable: CU

   Size of conductor: 6 AWG

   Frequency: $60Hz$

   Maximum allowable voltage limit: $5000V$

   $T_a = 30$ °C

   $T_c = 60$ °C

   Cable length $=$ $20\ ft$

   Allowable ampacity $=$ $56.1\ A$

   Voltage drops $=$ 0.11%

   The impedance detail of the O/G to 2P cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.51	0.061	0.0001618	0.51364	0.12	0	0
Zero	1.6065	0.15006	0.000398	1.61349	0.093	0	0

Figure 6

4. O/G to 3P Cable: $208V, 3\emptyset - 4W$ Cable from Main BUS BAR CHAMBER to Distribution board panel – 3P

   Type of cable: CU

   Size of conductor: 500 $kcmil$

   Frequency: $60Hz$

   Maximum allowable voltage limit: $5000V$

   $T_a = 30$ °C

   $T_c = 60$ °C

   Cable length $=$ $20\ ft$

   Allowable ampacity $=$ $346\ A$

   Voltage drops $=$ 0.06%

The impedance detail of the O/G to 3P cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.0294	0.0299	0.0000793	0.04193	1.017	0	0
Zero	0.0926	0.0736	0.0001952	0.11829	0.795	0	0

Figure 7

5. O/G to U Cable: $208V, 3\emptyset - 4W$ Cable from Main BUS BAR CHAMBER to Distribution board panel – U

   Type of cable: CU

   Size of conductor: $3/0\ kcmil$

   Frequency: $60Hz$

   Maximum allowable voltage limit: $5000V$

   $T_a = 30\ ℃$

   $T_c = 60\ ℃$

   Cable length $= \ 20\ ft$

   Allowable ampacity $= \ 179\ A$

   Voltage drops $= \ 0.08\%$

   The impedance detail of the O/G to U cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.081	0.046	0.000122	0.09315	0.568	0	0
Zero	0.455	0.501	0.0013289	0.67678	1.101	0	0

Figure 8

6. Generator Cable: $208V, 3\emptyset - 4W$ Cable from Generator terminal to Distribution board panel – U

Type of cable: CU

Size of conductor: $3/0\ kcmil$

Frequency: $60Hz$

Maximum allowable voltage limit: $5000V$

$T_a = 30\ °\mathrm{C}$

$T_c = 60\ °\mathrm{C}$

Cable length $=\ 100\ ft$

Allowable ampacity $=\ 179\ A$

Voltage drops $=\ 0.06\%$

The impedance detail of the back up diesel generator cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.2744	0.11	0.0002918	0.29563	0.401	0	0
Zero	0.4363	0.2794	0.0007411	0.51809	0.64	0	0

Figure 9

7. Solar Panel Cable: $208V, 3\emptyset - 4W$ Cable from Solar Panel terminal to Main Bus bar chamber

Type of cable: CU

Size of conductor: $4/0\ kcmil$

Frequency: $60Hz$

Maximum allowable voltage limit: $5000V$

$T_a = 30\ °\mathrm{C}$

$T_c = 60\ °\mathrm{C}$

Cable length $=\ 150\ ft$

Allowable ampacity $=\ 208\ A$

Voltage drops $=\ 1.05\%$

The impedance detail of the Solar panel cable is as follow:

Impedance - Library

	R	X	L	Z	X/R	C	Y
Pos.	0.2198	0.1075	0.0002852	0.24468	0.489	0	0
Zero	0.3495	0.2731	0.0007244	0.44355	0.781	0	0

Figure 10

8. Voltage Regulation

   With pre defined Voltage Level and our load, we faced the reduced Voltage levels at down streams. To come over this issue we have added Tap Changer in the utility transformer.

   We have set the tap setting such that output voltage of transformer is 213V (2.5% increased tap) and eventually, at the bus of very down stream voltage is maintained 208V.

3. Short Circuit Study

The short circuit study was performed to ensure the short circuit rating of the equipment and the interrupting rating of protective devices exceed the maximum available short circuit current. Short circuit study is performed by ETAP for the following Busses and short circuit ratings for all equipment were found to be sufficient. Single line diagram with short circuit values for each bus can be found in Appendix A, and complete short circuit report can be found in Appendix B. Summary of short circuit levels at all busses is presented in Table 1 and Table 2.

Bus	Voltage Level (V)	RMS Symmetrical Short Circuit Current (kA)
Busbar Chamber	208	4.209
Distribution Board 1P	208	4.095
Distribution Board 2P	208	3.445
Distribution Board 3P	208	4.124
Distribution Board U	208	4.032

Table 1 Short circuit levels during utility in service

Bus	Voltage Level (V)	RMS Symmetrical Short Circuit Current (kA)
Distribution Board U	208	0.599

Table 2 Short circuit level during generator in service

Summary of Short Circuit Analysis:

The short circuit levels in a power system are decided to ensure the safety of the equipment and personnel, and to prevent damage to the power system during faults.

A short circuit occurs when a fault creates a low resistance path between two points in the power system, causing a large current to flow. This high current can damage equipment, cause voltage dips, and even result in the complete shutdown of the power system. Therefore, it is essential to design the power system with short circuit levels that can handle the expected fault currents without causing damage to equipment or affecting the safety of personnel.

By determining the short circuit levels, we can select and size protective devices such as fuses, circuit breakers, and relays that can interrupt the fault current within an acceptable time, thereby minimizing the potential for damage. Additionally, short circuit levels help us design and select the proper equipment, such as transformers and cables, that can handle the expected fault current.

Based on our calculation, we found that maximum short circuit current is 4.209kA. According to this, we need to select the breakers that has minimum short circuit current of 4.209kA. So, for our calculation, we chose the breakers that has minimum short circuit current of 10kA. We are attaching the breaker datasheets along with this report. Normal current rating of breakers are different but the short circuit current that they can withstand is minimum 10kA.

4. Protective Device Coordination

The main purpose of protective device coordination here is to ensure that the protective devices, such as circuit breakers and fuses, operate in a coordinated manner to isolate the faulty equipment or section of the power system while minimizing the impact on the rest of the system. The coordination study is performed to determine the appropriate protective device settings to achieve the following objectives:

a) Selectivity: The coordination study ensures that only the faulty equipment or section of the power system is isolated during a fault, while the rest of the system remains operational.
b) Reliability: Our study ensures that the protective devices operate as intended and can withstand the expected fault currents and other electrical stresses. This ensures that the power system remains reliable and can operate safely under normal and abnormal conditions.
c) Speed: The coordination study aims to achieve the fastest possible response time for the protective devices, to minimize the impact of a fault on the power system and to reduce downtime.
d) Ensure all electrical equipment are adequately protected without exceeding their thermal limits.

In summary, protective device coordination is essential for maintaining the safety, reliability, and efficiency of the power system. By ensuring that protective devices operate in a coordinated manner, the impact of faults can be minimized, reducing the risk of damage to equipment, personnel, and customers. Time current curves are shown below.

4.1 Transformer coordination and interlock with Solar Panel

Single line diagram of Utility to Transformer & Solar panel connection is shown in figure.

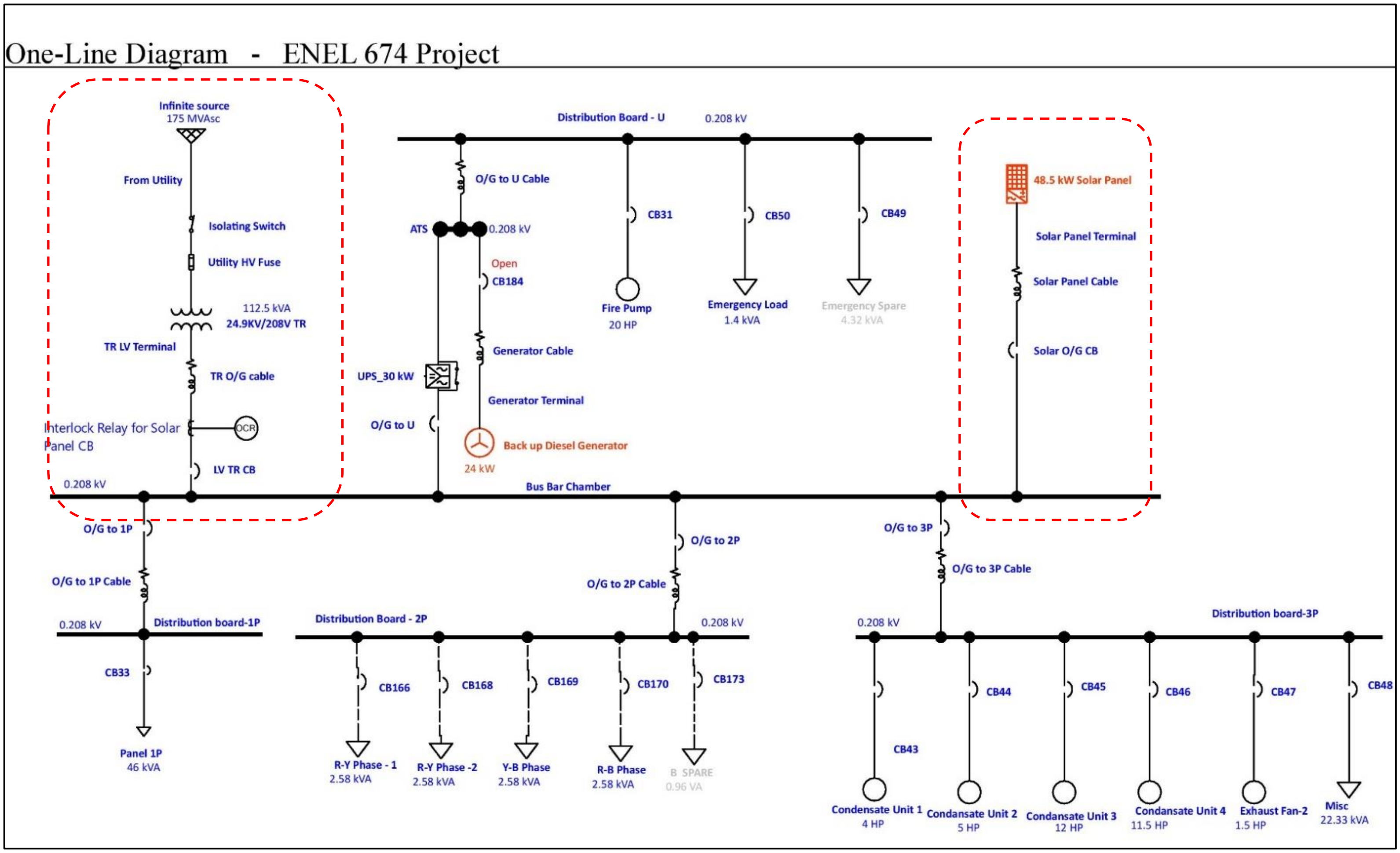
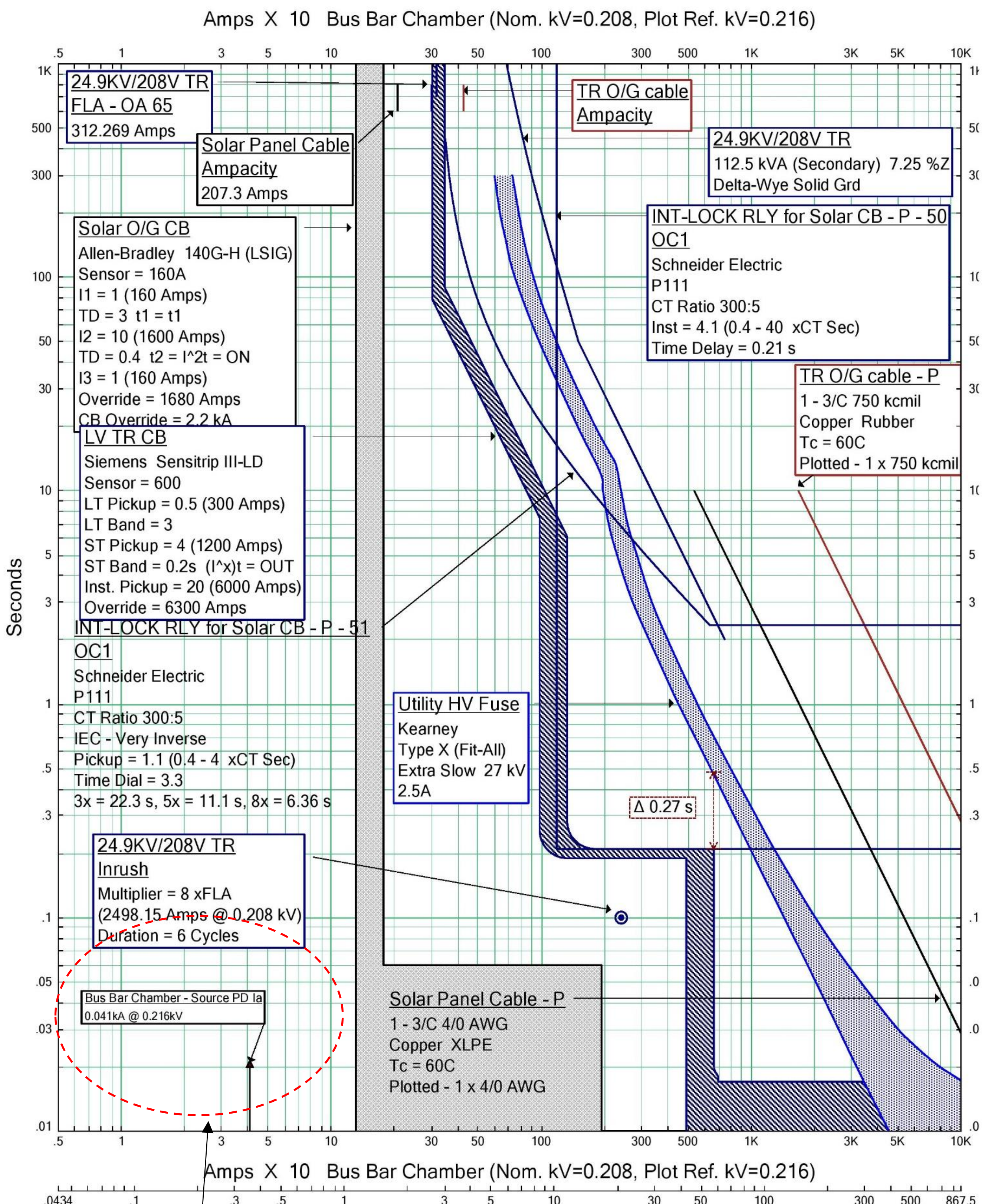


Figure 11

During 3 phase fault condition at Bus Bar Chamber, HV fuse will operate in $2629\ m\ sec$ while, LV TR CB and Solar O/G CB operate in $210\ m\ sec$.

We have considered the TR inrush current that is 8 times of the full load current and HV fuse is opted after considering the TR inrush current.

Interlock: Solar panel breaker should be tripped during fault condition. Thus, overcurrent relay is used to sense the overcurrent from the TR LV side and create an interlock/tripping command for Solar panel circuit breaker.



During three phase fault condition, solar panel only feed 0.041kA fault current which is less than its rated current. Thus, solar breaker could not trip during fault condition. To mitigate this problem, we have added separate interlock protection using OC relay to trip the solar panel O/G breaker during the fault condition.

Project:	Date: 04-06-2023
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Contract:	Rev: Base
Engineer:	Fault: Phase
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4.2 Transformer LV CB & Solar O/G CB coordination with Distribution board – 1P Incomer CB

Single line diagram of Transformer LV to Distribution board -1P.

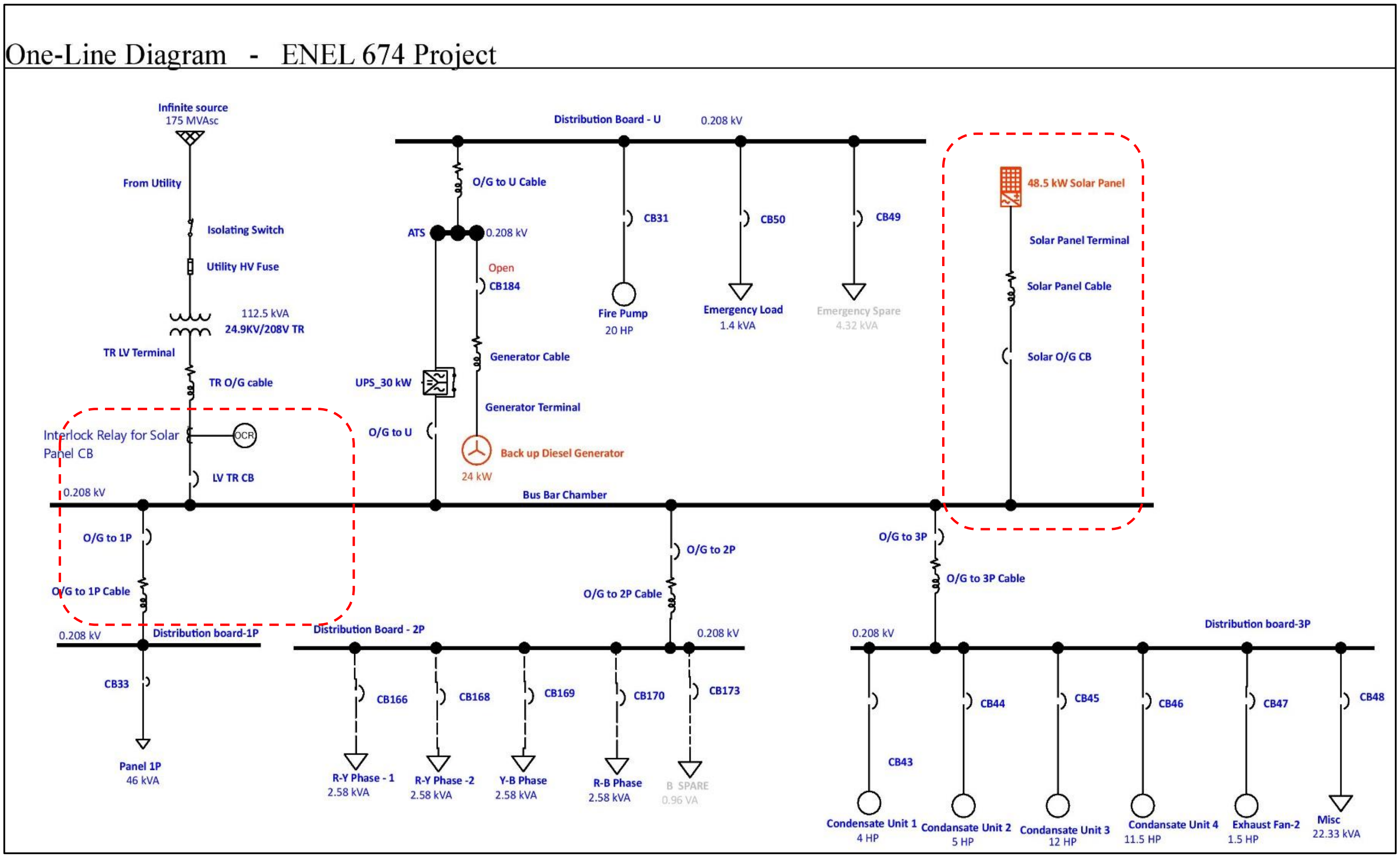
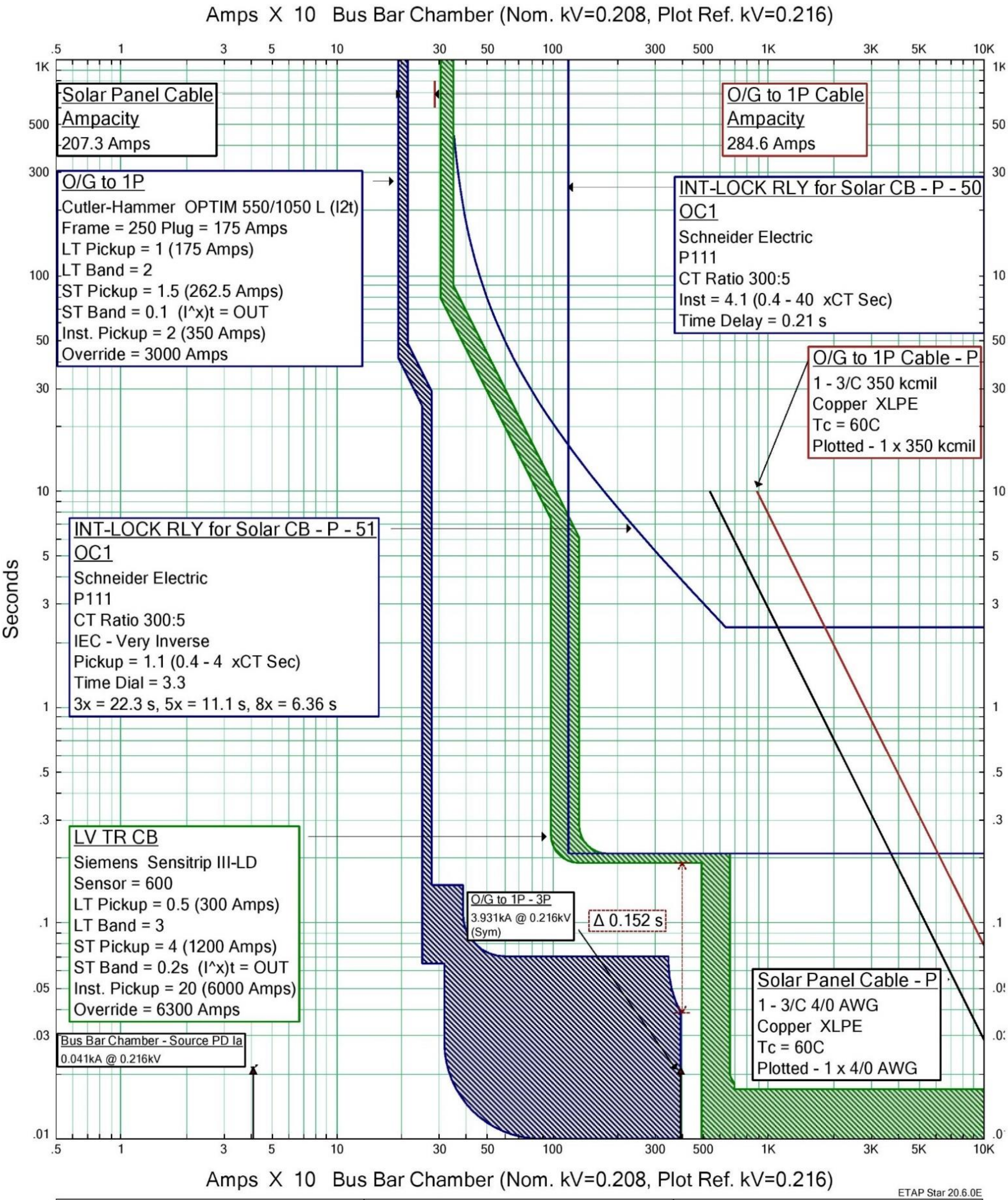


Figure 12

During 3 phase fault condition at Distribution board-1P, O/G to 1P circuit breaker operate in 35 $m\ sec$, while, LV TR CB and Solar O/G CB operate in 210 $m\ sec$.

TCC for Transformer LV CB & Solar O/G CB coordination with O/G to 1P CB is shown in figure.



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Project: Location: Contract: Engineer: Filename: C:\Users\manan.patel1\Downloads\Main (2)\Main\Main\Project.OTI		Date: 04-10-2023 SN: UOFCALGSSE Rev: Base Fault: Phase

4.3 Transformer LV CB & Solar O/G CB coordination with Distribution board – 2P Incomer CB

Single line diagram of Transformer LV to Distribution board -2P.

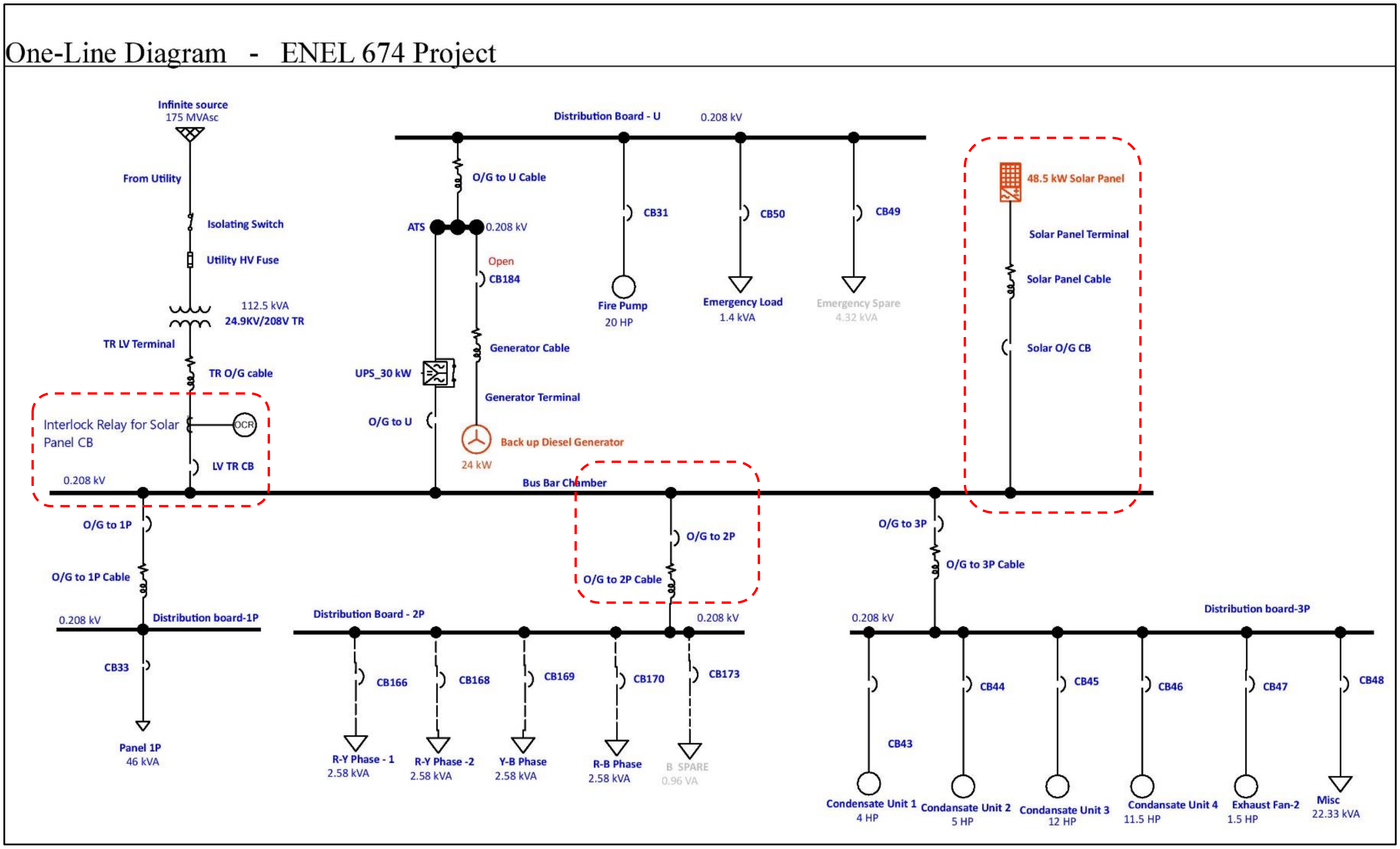
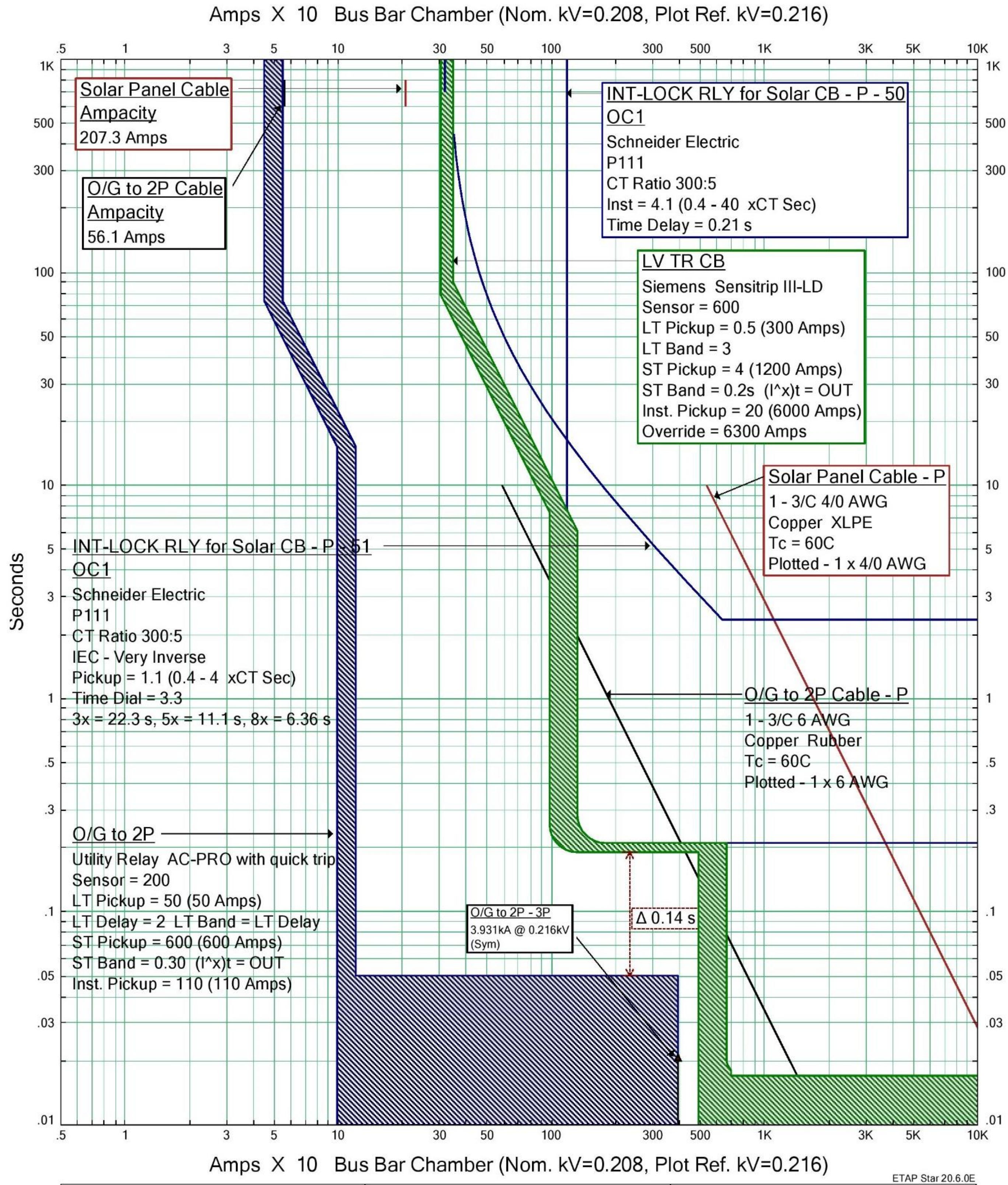


Figure 13

During 3 phase fault condition at Distribution board – 2P, O/G to 2P circuit breaker operate in $50\ m\ sec$, while LV CB and Solar O/G CB operate in $210\ m\ sec$.

TCC for Transformer LV CB & Solar O/G CB coordination with distribution board – 2P Incomer C/B is shown in figure.



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Date: 04-06-2023
SN: UOFCALGSSE
Rev: Base
Fault: Phase

4.4 Transformer LV CB & Solar O/G CB coordination with Distribution board – 3P Incomer CB

Single line diagram of Transformer LV to Distribution board -3P.

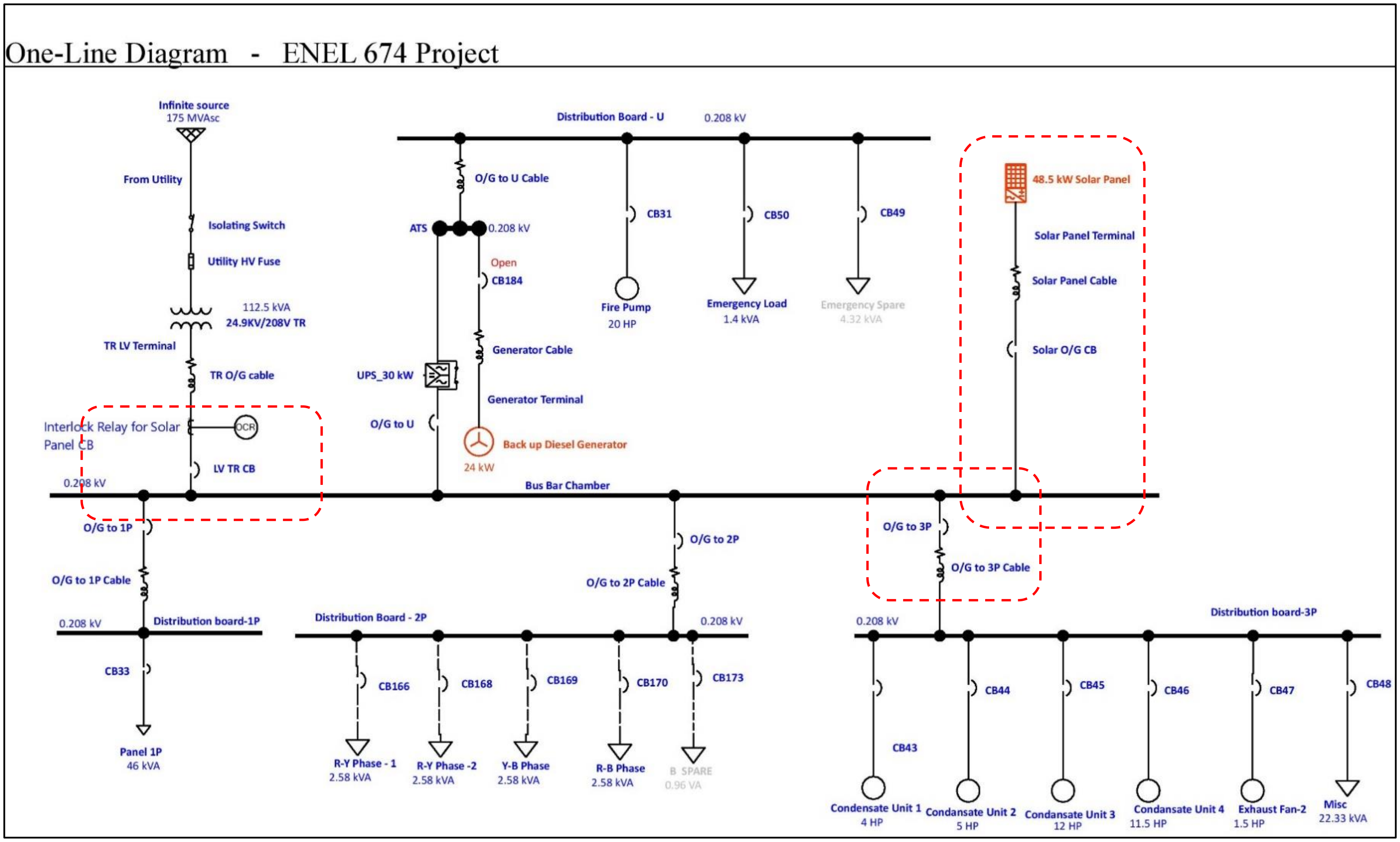
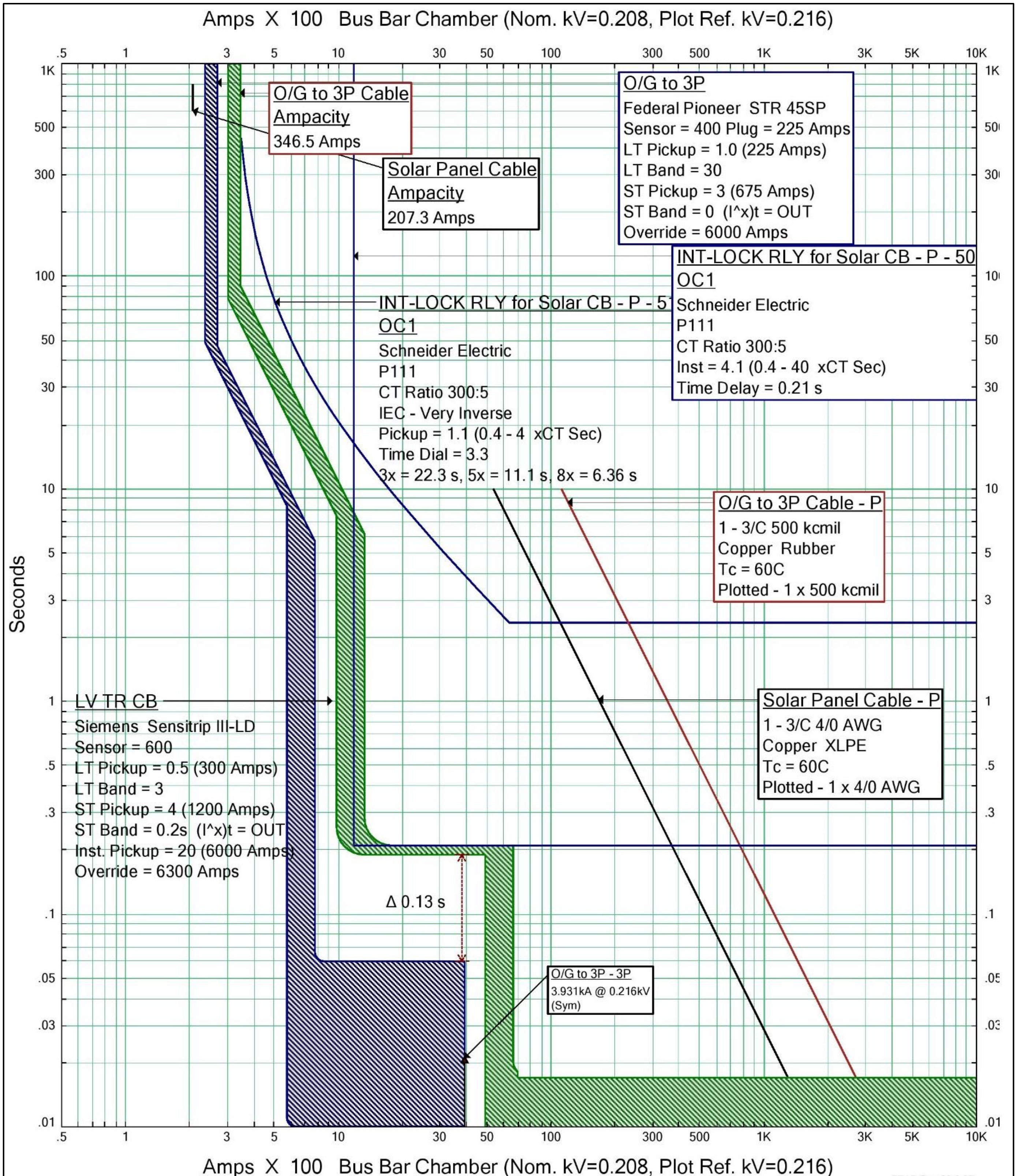


Figure 14

During 3 phase fault condition at Distribution board – 3P, O/G to 3P circuit breaker operate in 60 $m\ sec$. While, LV TR CB and Solar O/G CB operates in 210 $m\ sec$.

TCC for Transformer LV CB & Solar O/G CB coordination with distribution board – 3P is shown in figure.



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Fault: Phase

4.5 Transformer LV CB & Solar O/G CB coordination with Distribution board – U Incomer via UPS system

Single line diagram of Transformer LV to Distribution board -3P.

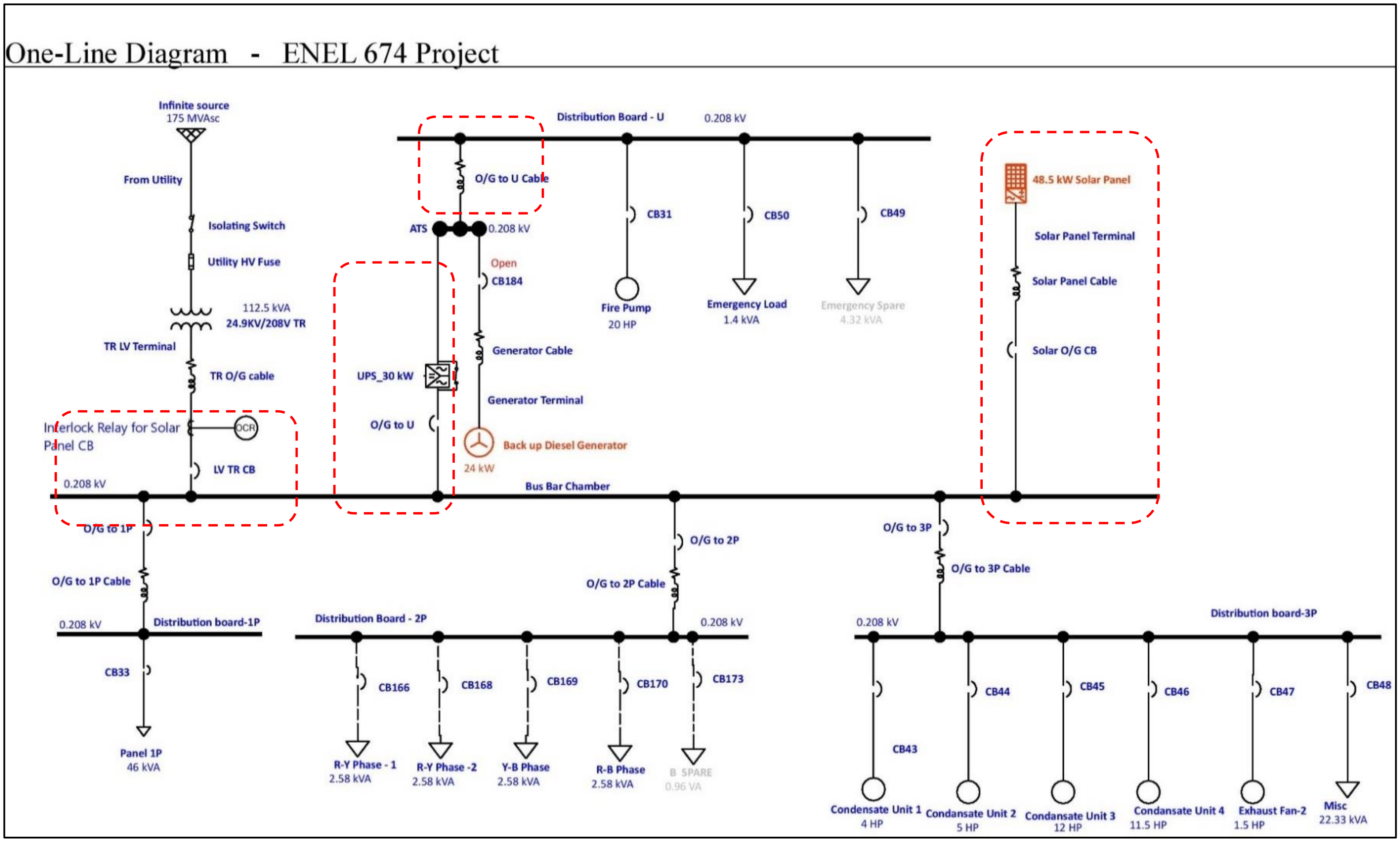
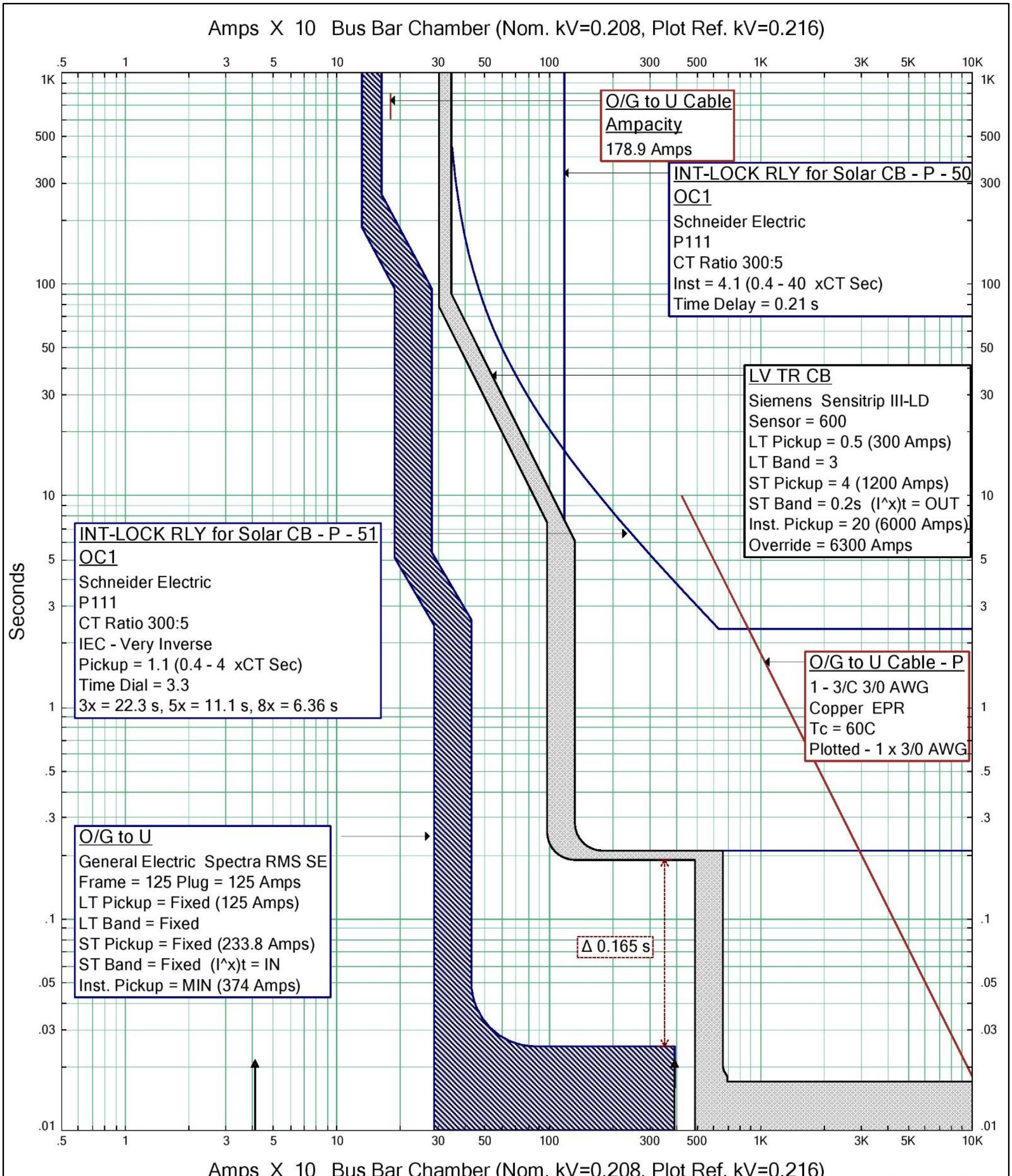


Figure 15

During 3 phase fault condition at Distributing board U, O/G to U circuit breaker operate in 25 $m\ sec$. While, TR LV CB and Solar O/G CB operate in 210 $m\ sec$.

TCC for Transformer LV CB & Solar Panel coordination with distribution board – U is shown in figure.



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4.6 Generator overcurrent protection coordination with Distribution board – U in the absence of utility

Solid state type low voltage breaker is used to protect our diesel back up generator. We are using Auto transfer switch to feed our Distribution panel board – U (Emergency bus) during the utility supply outage. Single line diagram of diesel generator and distribution circuit is shown in figure below.

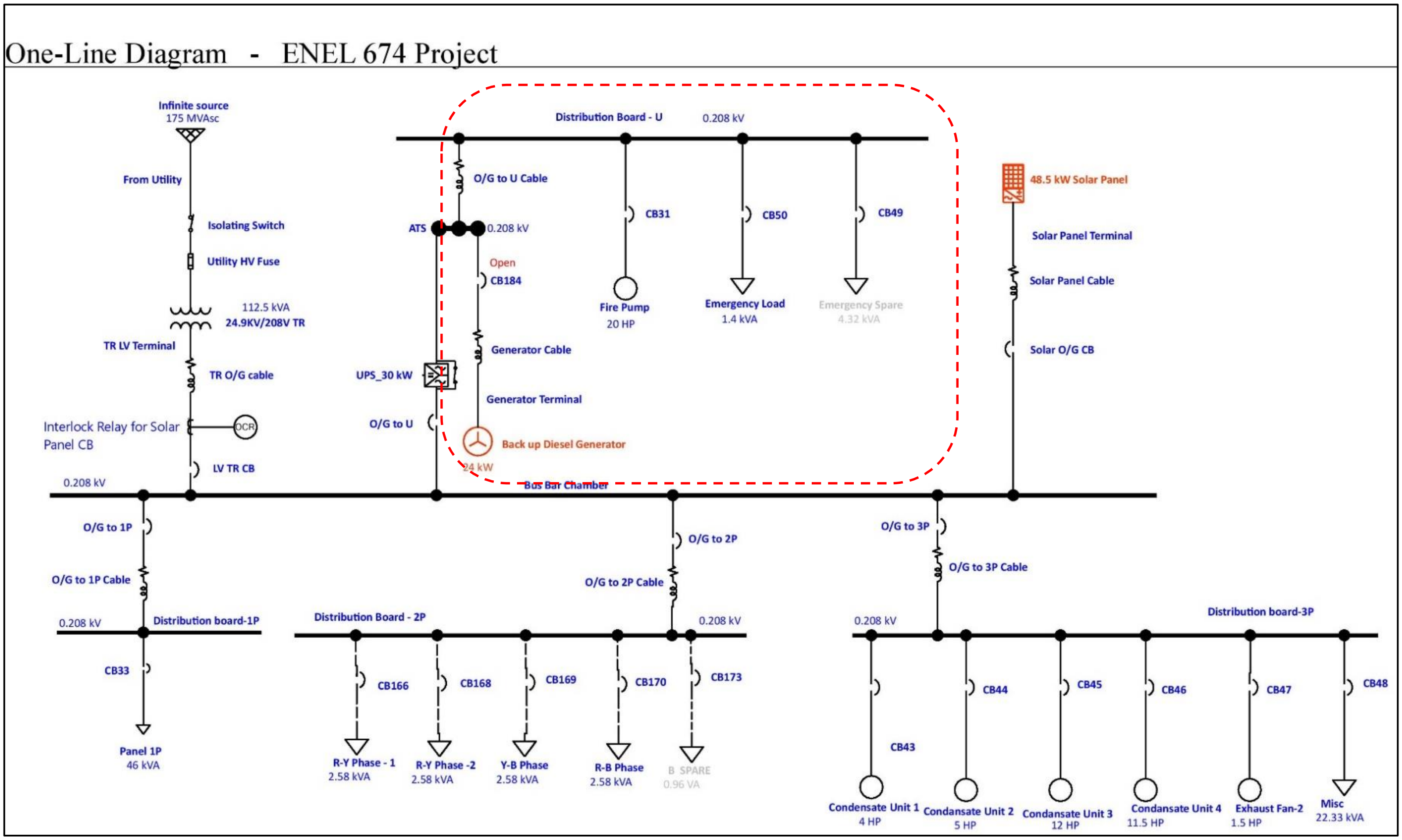
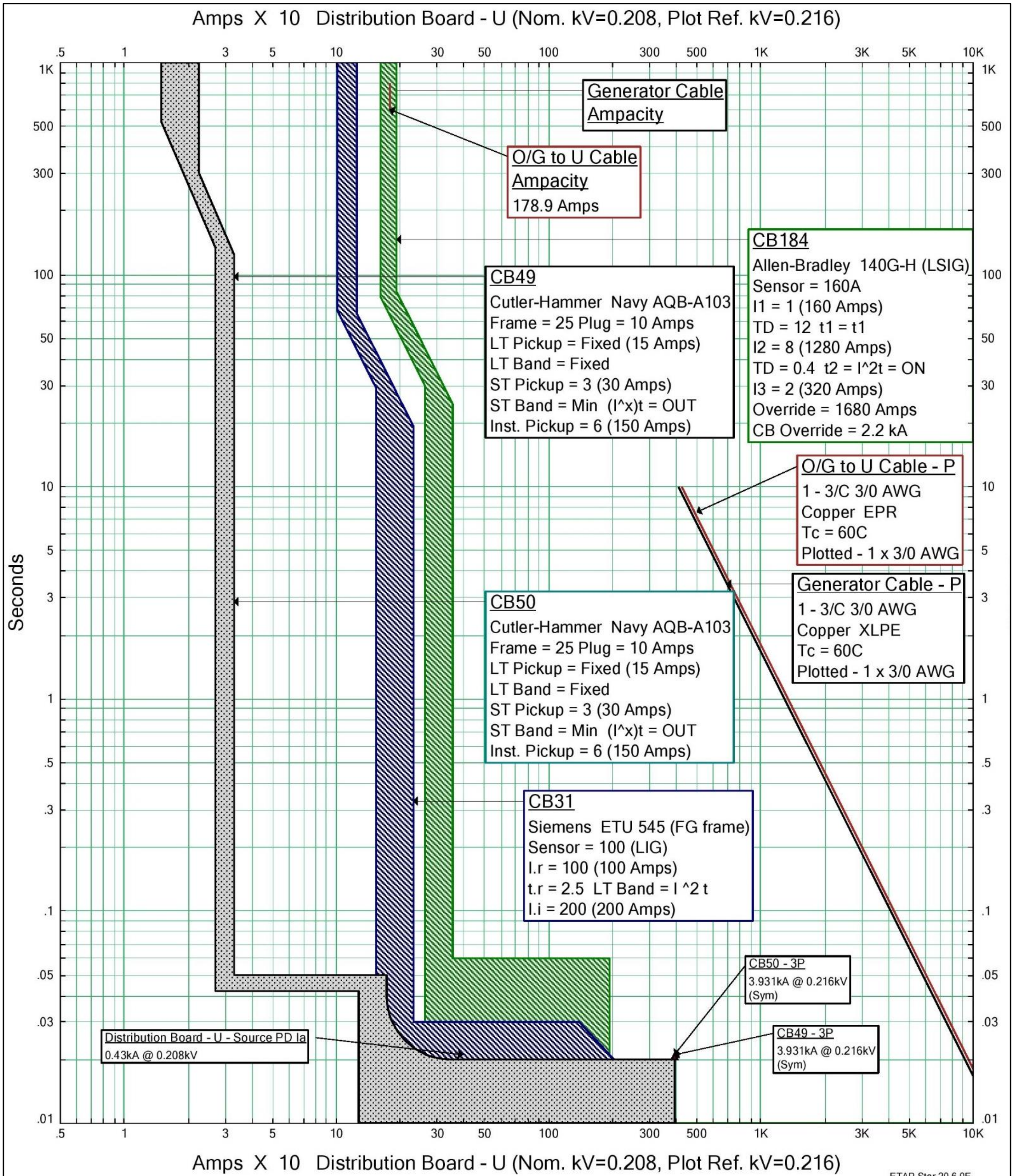


Figure 16

When generator is feeding power supply to Distribution Board U and 3 Phase fault occurs, CB 184 circuit breaker operate in 60 $m\ sec$.

TCC for Generator overcurrent protection coordination with Distribution board – U in the absence of utility is shown in figure.



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Project:	Date: 04-06-2023
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Contract:	Rev: Base
Engineer:	Fault: Phase
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5. Arc Flash Study

We calculate arc flash levels in power systems to evaluate the potential hazards associated with electrical arcs that may occur during maintenance or repair work on live electrical equipment. An arc flash is an explosion-like phenomenon that can occur when an electrical fault creates a high-energy discharge that can rapidly ionize the air around the fault. This discharge can cause an explosion-like blast wave, extreme temperatures, and intense light that can lead to serious injury, burns, or even death to personnel nearby.

Calculating arc flash levels involves analyzing the power system to determine the magnitude of the fault current and the duration of the fault. Using this information, we can calculate the energy that would be released during an arc flash event and determine the safe working distance for personnel.

Case 1: Network is running through utility supply and solar panel.

The short circuit calculations and the Fault Clearing Time (FCT) required by the protective devices are calculated by ETAP. The results are summarized in Table 2.

Bus	Voltage Level (V)	Arcing Current (kA)	Fault Clearing Time (cycles)	Arc Flash Boundary (Feet)	Incident Energy (Cal/cm2)
Busbar Chamber	208	2.461	12.6	1.76	1.6
Distribution Board 1P	208	2.411	4.2	1.0	0.5
Distribution Board 2P	208	2.122	3	0.79	0.3
Distribution Board 3P	208	2.423	3.6	0.93	0.5
Distribution Board U	208	2.384	1.5	0.6	0.2

Table 3

PPE requirements upon the incident energy is mentioned in the table below:

Bus	Incident Energy (Cal/cm2)	PPE Category	Hazard/Risk Category	Required PPE
Busbar Chamber	1.6	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses
Distribution Board 1P	0.5	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses
Distribution Board 2P	0.3	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses
Distribution Board 3P	0.5	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses
Distribution Board U	0.2	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses

Table 4

Hazard/Risk Category for table 4 and table 6 has been identified based on below table

Table 130.7(C) (10) Protective Clothing and Personal Protective Equipment (PPE) Matrix

Protective Clothing and Equipment	Protective Systems for Hazard/Risk Category					
Hazard/Risk Category Number	**-1** (Note 3)	**0**	**1**	**2**	**3**	**4**
Non-melting (according to ASTM F 1506-00) or Untreated Natural Fiber						
a. T-shirt (short-sleeve)	X			X	X	X
b. Shirt (long-sleeve)		X				
c. Pants (long)	X	X	X (Note 4)	X (Note 6)	X	X
FR Clothing (Note 1)						
a. Long-sleeve shirt			X	X	X (Note 9)	X
b. Pants			X (Note 4)	X (Note 6)	X (Note 9)	X
c. Coverall			(Note 5)	(Note 7)	X (Note 9)	(Note 5)
d. Jacket, parka, or rainwear			AN	AN	AN	AN
FR Protective Equipment						
a. Flash suit jacket (multilayer)						X
b. Flash suit pants (multilayer)						X
c. Head protection						
1. Hard hat			X	X	X	X
2. FR hard hat liner					AR	AR
d. Eye protection		—	—	—	—	—
1. Safety glasses	X	X	X	AL	AL	AL
2. Safety goggles				AL	AL	AL
e. Face and head area protection		—	—	—	—	—
1. Arc-rated face shield, or flash suit hood				X (Note 8)		
2. Flash suit hood					X	X
3. Hearing protection (ear canal inserts)				X (Note 8)	X	X
f. Hand protection			—	—	—	—
Leather gloves (Note 2)			AN	X	X	X
g. Foot protection						
Leather work shoes			AN	X	X	X

AN = As needed

AL = Select one in group

AR = As required

X = Minimum required

Case 2: Emergency load at distribution panel – U is running through generator only.

The short circuit calculations and the Fault Clearing Time (FCT) required by the protective devices are calculated by ETAP. The results are summarized in below mentioned table.

Bus	Voltage Level (V)	Arcing Current (kA)	Fault Clearing Time (cycles)	Arc Flash Boundary (Feet)	Incident Energy (Cal/cm2)
Distribution Board U	208	0.43	269.21	0.6	1.37

Table 5

PPE requirements upon the incident energy is mentioned in the table below:

Bus	Incident Energy (Cal/cm2)	PPE Category	Hazard/Risk Category	Required PPE
Distribution Board U	1.37	Category 1	Category 0	Non-melting or untreated natural fiber long-sleeve shirt, long pants, and safety glasses

Table 6

Complete arc flash results are available in Appendix E.

Appendix A: Single Line Diagrams with Short Circuit and Arc Flash Energy Levels

Normal SLD

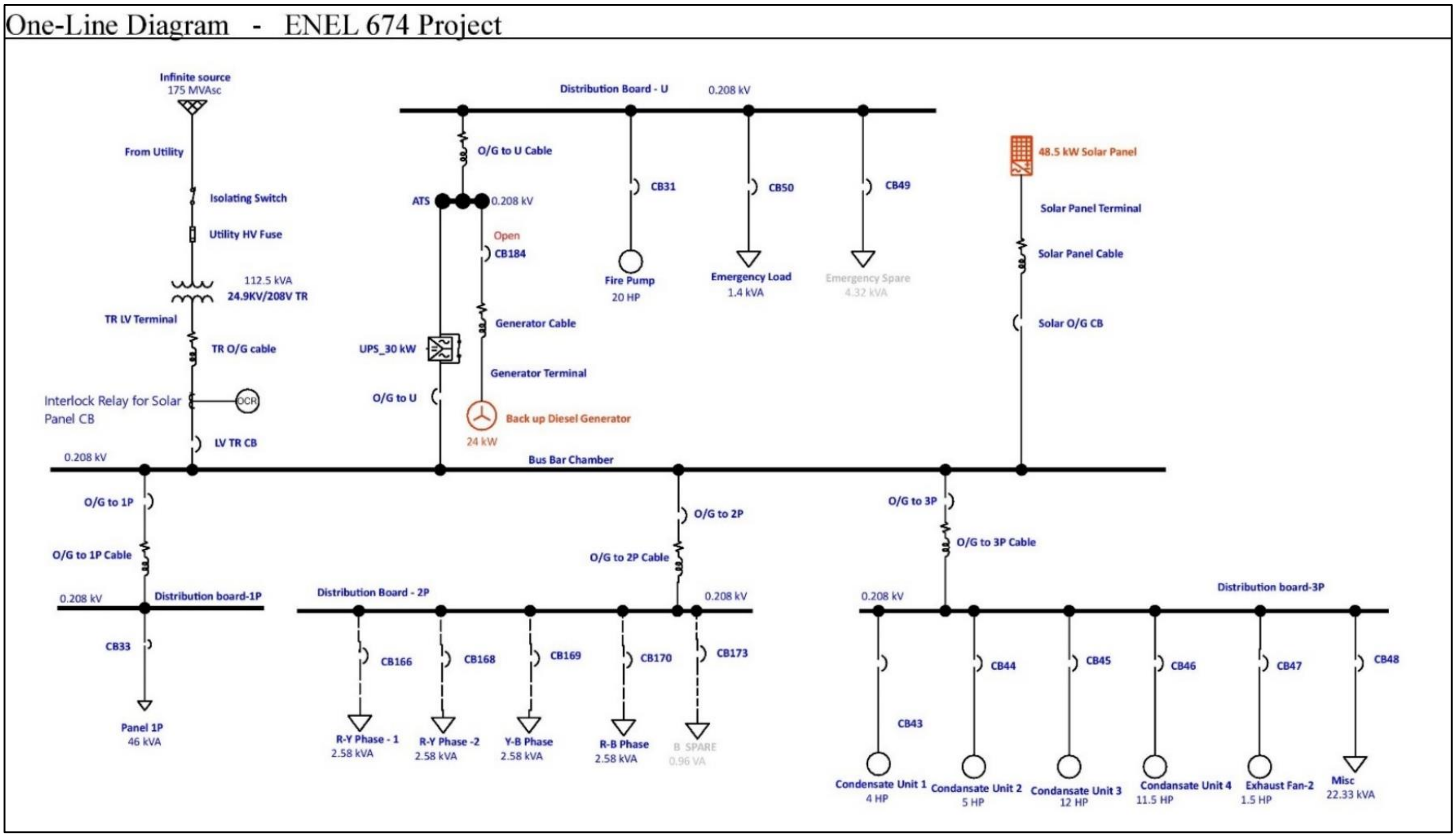

Figure 17

Short Circuit Analysis - Utility integration with Solar Power

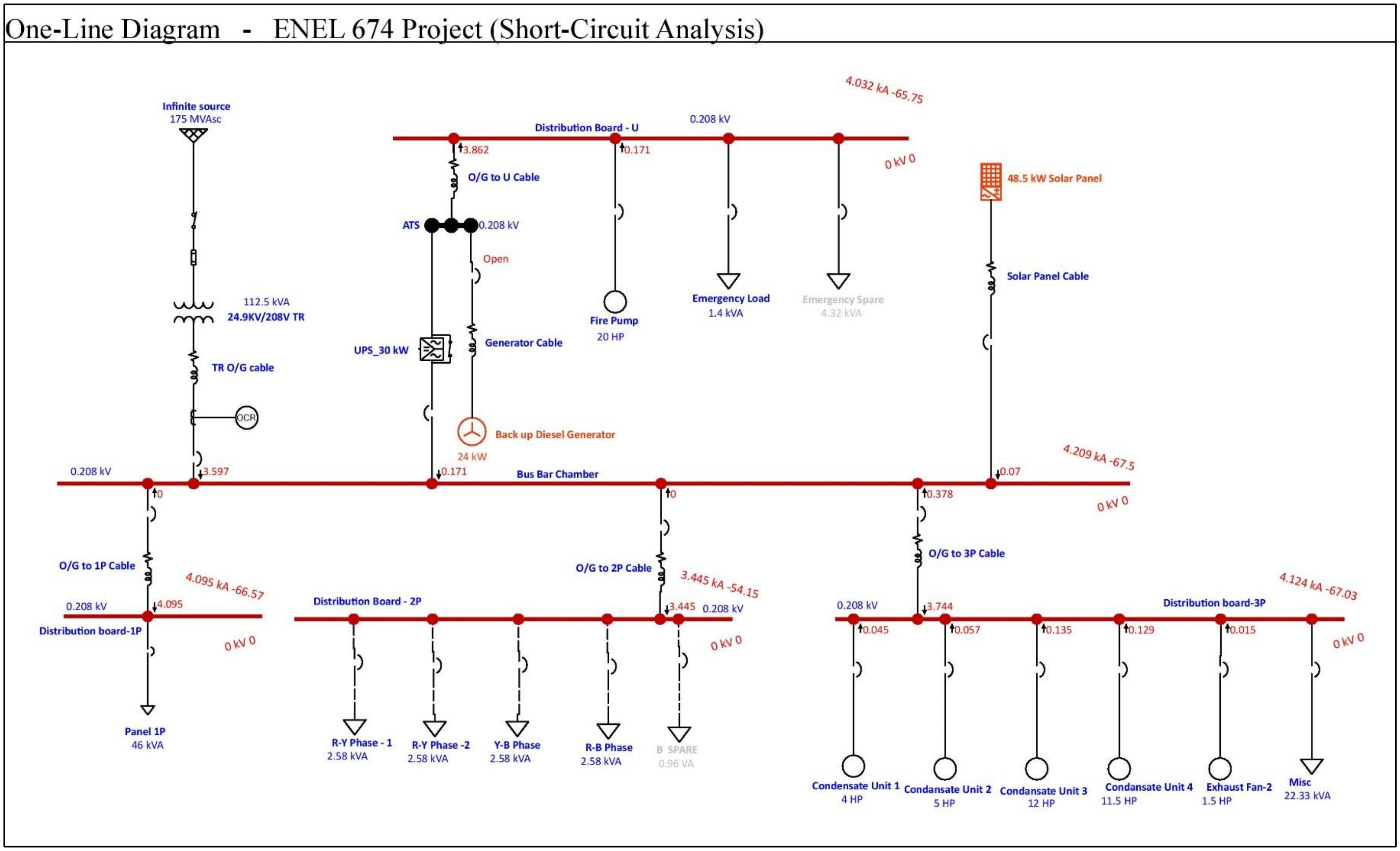

Figure 18

Short Circuit Analysis – Back up Generator integration with Emergency Load

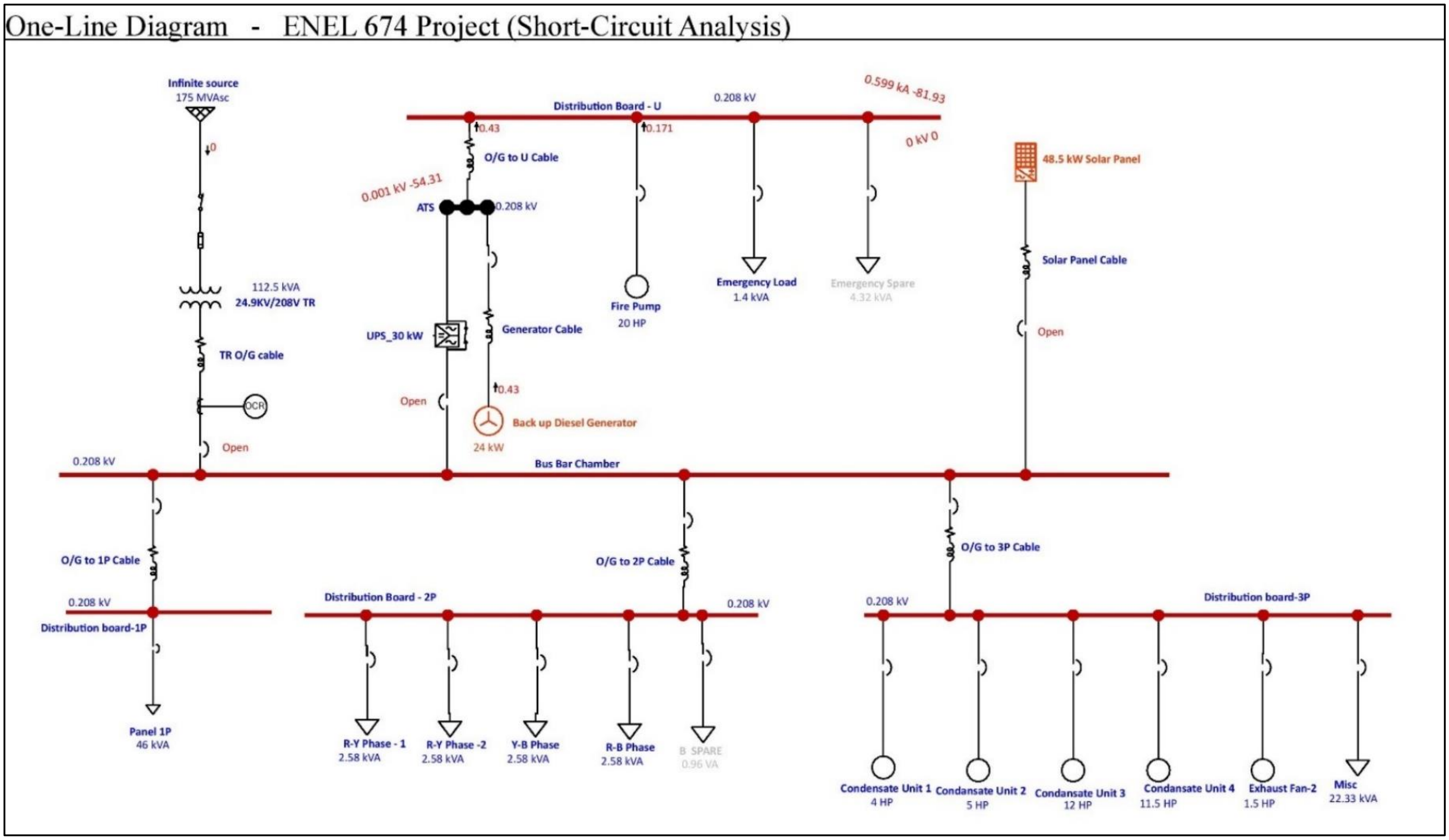

Figure 19

Arc Flash Analysis – Utility integration with Solar Power

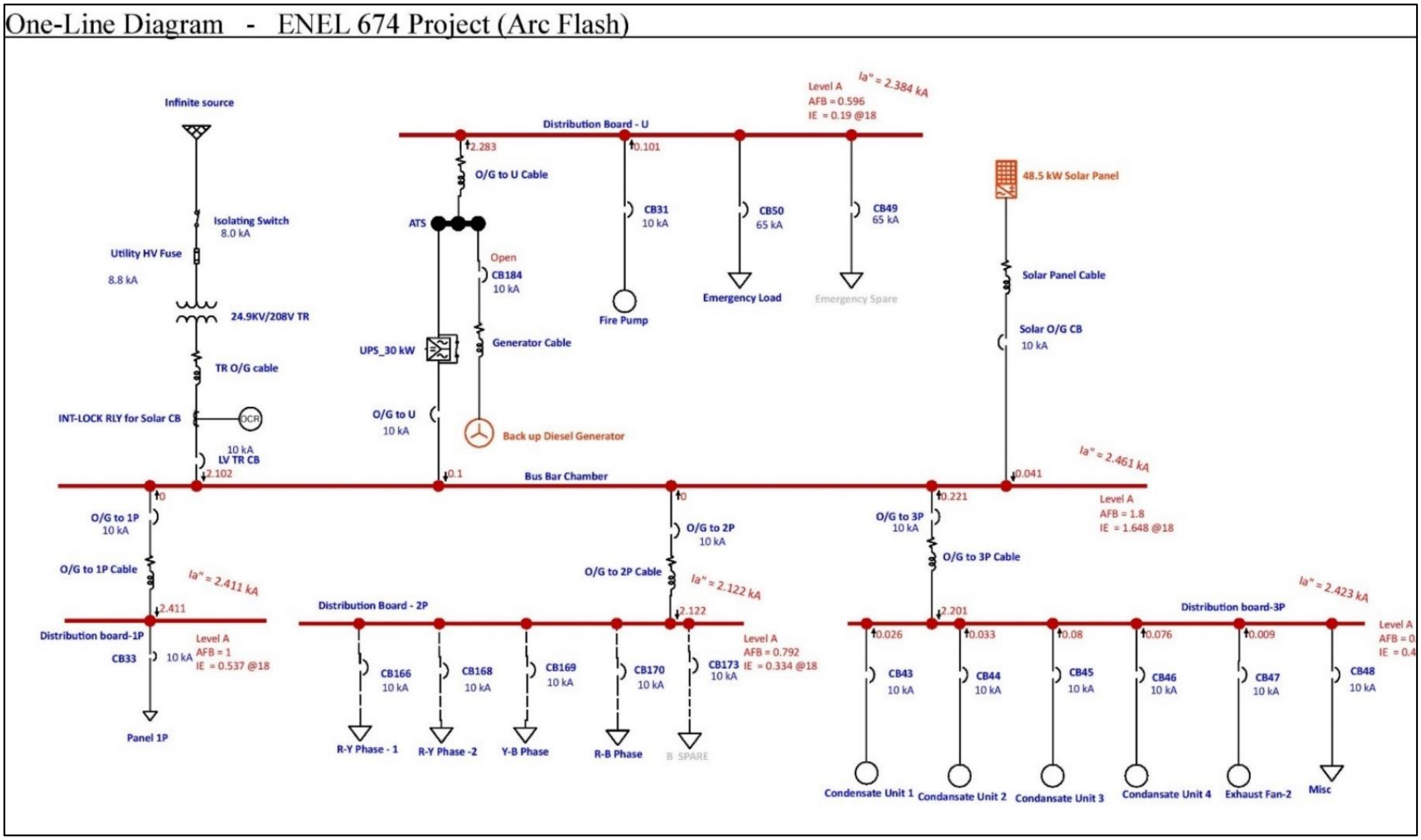

Figure 20

Arc Flash Analysis – Back up Generator integration with Emergency Load

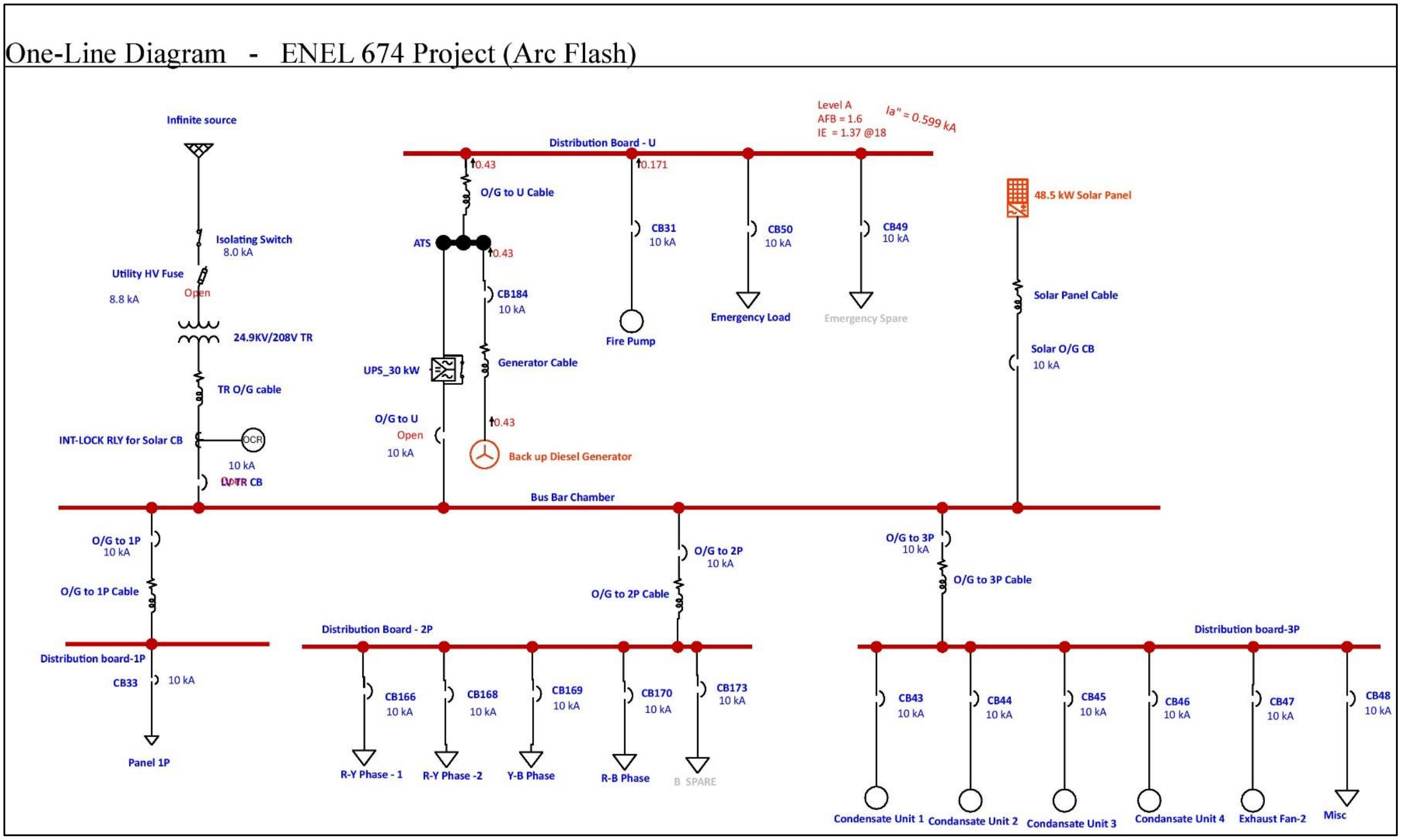

Figure 21

Appendix B: Data from the Short Circuit Study

We have studied the short circuit analyses for two cases.

1. Short circuit analyses for utility and Solar Power integration.
2. Short circuit analyses for back-up generator to feed emergency load.

<u>Short circuit analyses for utility and Solar Power integration</u>

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<u>Short-Circuit Summary Report</u>

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus Bar Chamber	0.208	1.611	-3.889	4.209	1.538	-3.523	3.844	-3.420	-1.455	3.717	2.765	3.077	4.137
Distribution board-1P	0.208	1.628	-3.758	4.095	1.539	-3.371	3.706	-3.295	-1.473	3.610	2.646	3.018	4.014
Distribution Board - 2P	0.208	2.017	-2.792	3.445	1.997	-2.020	2.841	-2.404	-1.882	3.053	-3.310	-1.043	3.471
Distribution Board - U	0.208	1.656	-3.676	4.032	1.494	-2.952	3.308	-3.217	-1.498	3.549	-3.851	-0.211	3.857
Distribution board-3P	0.208	1.609	-3.797	4.124	1.544	-3.377	3.713	-3.332	-1.456	3.636	-4.014	0.108	4.015

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

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Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus Bar Chamber	0.208	0.01126	0.02670	0.02897	0.01126	0.02670	0.02897	0.01424	0.03562	0.03836	0.00000	0.00000	0.00000
Distribution board-1P	0.208	0.01205	0.02728	0.02983	0.01205	0.02728	0.02983	0.01550	0.03710	0.04021	0.00000	0.00000	0.00000
Distribution Board - 2P	0.208	0.02146	0.02792	0.03521	0.02146	0.02792	0.03521	0.04637	0.03862	0.06035	0.00000	0.00000	0.00000
Distribution Board - U	0.208	0.01266	0.02756	0.03033	0.01266	0.02756	0.03033	0.02292	0.04564	0.05107	0.00000	0.00000	0.00000
Distribution board-3P	0.208	0.01174	0.02718	0.02961	0.01174	0.02718	0.02961	0.01609	0.03709	0.04043	0.00000	0.00000	0.00000

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SHORT- CIRCUIT REPORT

Fault at bus: **Bus Bar Chamber**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
				% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus Bar Chamber	Total	0.00	4.209	0.00	108.68	107.54	3.844	3.844	2.48E+003	5.87E+003	3.13E+003	7.84E+003
Distribution board-1P	Bus Bar Chamber	0.00	0.000	0.00	108.68	107.54	0.000	0.000				
Distribution Board - 2P	Bus Bar Chamber	0.00	0.000	0.00	108.68	107.54	0.000	0.000				
Distribution board-3P	Bus Bar Chamber	0.26	0.378	0.16	108.69	107.60	0.224	0.000	2.89E+004	6.36E+004		
Solar Panel Terminal	Bus Bar Chamber	0.63	0.070	1.27	109.96	108.80	0.142	0.000	3.71E-002	3.77E+005		
TR LV Terminal	Bus Bar Chamber	11.65	3.597	16.47	104.32	104.49	3.407	3.844	2.87E+003	6.76E+003	3.13E+003	7.84E+003
Distribution Board - U	ATS	0.26	0.171	0.15	108.66	107.61	0.101	0.000	4.29E+004	1.48E+005		

\# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Distribution board-1P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		**3-Phase Fault**		**Line-To-Ground Fault**					**Positive & Zero Sequence Impedances Looking into "From Bus"**			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution board-1P	Total	0.00	4.095	0.00	109.07	107.84	3.706	3.706	2.65E+003	6.00E+003	3.41E+003	8.16E+003
Bus Bar Chamber	Distribution board-1P	3.36	4.095	4.01	108.54	107.18	3.706	3.706	2.57E+003	5.92E+003	3.41E+003	8.16E+003

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Distribution Board - 2P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		**3-Phase Fault**		**Line-To-Ground Fault**					**Positive & Zero Sequence Impedances Looking into "From Bus"**			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution Board - 2P	Total	0.00	3.445	0.00	107.09	120.32	2.841	2.841	4.72E+003	6.14E+003	1.02E+004	8.50E+003
Bus Bar Chamber	Distribution Board - 2P	29.47	3.445	41.64	108.64	103.41	2.841	2.841	4.49E+003	6.22E+003	1.02E+004	8.50E+003

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Distribution Board - U**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		**3-Phase Fault**		**Line-To-Ground Fault**					**Positive & Zero Sequence Impedances Looking into "From Bus"**			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution Board - U	Total	0.00	4.032	0.00	112.27	114.34	3.308	3.308	2.79E+003	6.06E+003	5.04E+003	1.00E+004
ATS	Distribution Board - U	5.78	3.862	15.22	108.01	106.31	3.219	3.308	2.85E+003	6.22E+003	5.04E+003	1.00E+004
Fire Pump	Distribution Board - U	104.00	0.171	104.00	104.00	104.00	0.091	0.000	4.26E+004	1.48E+005		

\# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Fault at bus: **Distribution board-3P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution board-3P	Total	0.00	4.124	0.00	108.67	108.76	3.713	3.713	2.58E+003	5.98E+003	3.54E+003	8.16E+003
Bus Bar Chamber	Distribution board-3P	2.61	3.744	4.01	108.58	107.25	3.492	3.713	2.74E+003	6.50E+003	3.54E+003	8.16E+003
Condensate Unit 1	Distribution board-3P	104.00	0.045	104.00	104.00	104.00	0.026	0.000	3.19E+005	4.96E+005		
Condansate Unit 2	Distribution board-3P	104.00	0.057	104.00	104.00	104.00	0.033	0.000	2.32E+005	4.04E+005		
Condansate Unit 3	Distribution board-3P	104.00	0.135	104.00	104.00	104.00	0.079	0.000	6.78E+004	1.83E+005		
Condansate Unit 4	Distribution board-3P	104.00	0.129	104.00	104.00	104.00	0.075	0.000	7.23E+004	1.91E+005		
Exhaust Fan-2	Distribution board-3P	104.00	0.015	104.00	104.00	104.00	0.009	0.000	1.24E+006	1.18E+006		

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Electrical Transient Analyzer Program

Short-Circuit Analysis

ANSI Standard

3-Phase, LG, LL, & LLG Fault Currents

1/2 Cycle Network

	Swing	V-Control	Load	Total
Number of Buses:	2	0	8	10

	XFMR2	XFMR3	Reactor	Line/Cable/ Busway	Impedance	Tie PD	Total
Number of Branches:	1	0	0	6	0	1	8

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	1	1	0	6	0	8

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable / Busway Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable / Busway Resistance:	Yes	Individual	

Bus Input Data

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
ATS	Load	0.208	0.213	1	100.00	-30.00
Bus Bar Chamber	Load	0.208	0.213	1	100.00	-30.00
Distribution board-1P	Load	0.208	0.213	1	100.00	-30.00
Distribution Board - 2P	Load	0.208	0.213	1	100.00	-30.00
Distribution Board - U	Load	0.208	0.213	1	100.00	-30.00
Distribution board-3P	Load	0.208	0.213	1	100.00	-30.00
From Utility	SWNG	24.900	24.900	1	100.00	0.00
Generator Terminal	SWNG	0.208	0.208	2	100.00	0.00
Solar Panel Terminal	Load	0.208	0.213	1	100.00	-30.00
TR LV Terminal	Load	0.208	0.213	1	100.00	-30.00

10 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

Line/Cable/Busway Input Data

ohms or siemens per 1000 ft per Conductor (Cable) or per Phase (Line/Busway)

Line/Cable/Busway			Length									
ID	Library	Size	Adj. (ft)	% Tol.	#/Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
O/G to 1P Cable	5.0NCUN3	350	20.0	0.0	1	75	0.039682	0.0292608		0.0630842	0.0743102	
O/G to 2P Cable	5.0MCUS3	6	20.0	0.0	1	75	0.51	0.061		1.6065	0.15006	
O/G to 3P Cable	5.0MCUN3	500	20.0	0.0	1	75	0.0294	0.0299		0.0926	0.0736	
O/G to U Cable	5.0MCUS3	3/0	20.0	0.0	1	75	0.0772558	0.046		0.4339677	0.501	
Solar Panel Cable	5.0NCUS3	4/0	150.0	0.0	1	75	0.0638982	0.032766		0.1016034	0.0832409	
TR O/G cable	5.0NCUS3	750	100.0	0.0	1	75	0.0203	0.0332		0.03248	0.08466	

Line / Cable / Busway resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
24.9KV/208V TR	0.113	24.900	0.208	7.25	2.47	0	0	0	0	2.500	7.25	Dyn	30.00

2-Winding Transformer Grounding Input Data

				Grounding							
Transformer	Rating			Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	ohm	Type	kV	Amp	ohm
24.9KV/208V TR	0.113	24.900	0.208	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
24.9KV/208V TR	2W XFMR	From Utility	TR LV Terminal	2418.40	5973.46	6444.45	
O/G to 1P Cable	Cable	Bus Bar Chamber	Distribution board-1P	174.60	128.75	216.94	
O/G to 2P Cable	Cable	Bus Bar Chamber	Distribution Board - 2P	2244.02	268.40	2260.01	
O/G to 3P Cable	Cable	Bus Bar Chamber	Distribution board-3P	129.36	131.56	184.51	
O/G to U Cable	Cable	Distribution Board - U	ATS	339.93	202.40	395.62	
Solar Panel Cable	Cable	Solar Panel Terminal	Bus Bar Chamber	2108.65	1081.29	2369.73	
TR O/G cable	Cable	TR LV Terminal	Bus Bar Chamber	446.60	730.40	856.12	
UPS_30 kW	Tie Switch	Bus Bar Chamber	ATS				

Power Grid Input Data

Power Grid	Connected Bus	Rating		% Positive Seq. Impedance 100 MVA Base			Grounding	% Zero Seq. Impedance 100 MVA Base		
ID	ID	MVASC	kV	X/R	R	X	Type	X/R	R0	X0
Infinite source	From Utility	175.000	24.900	7.00	8.08122	56.56854	Wye - Solid	7.00	0.345426	2.41798

Total Power Grids (= 1) 175.000 MVA

Synchronous Generator Input Data

Synchronous Generator		Rating			Positive Seq. Impedance					Grounding			Zero Seq. Impedance		
							% Xd"								
ID	Type	MVA	kV	RPM	X"/R	% R	Adj.	Tol.	% Xd'	Conn.	Type	Amp	X/R	% R0	% X0
Back up Diesel Generator	Diesel	0.030	0.208	1800	19.00	1.000	19.00	0.0	28.00	Wye	Solid		7.00	1.000	7.00

Total Connected Synchronous Generators (= 1): 0.030 MVA

Induction Machine Input Data

Induction Machine			Rating (Base)			Positive Seq. Imp.				Grounding			Zero Seq. Imp.		
ID	Type	Qty	kVA	kV	RPM	X"/R	% R	% X"	% X'	Conn.	Type	Amp	X/R	% R0	% X0
Fire Pump	Motor	1	16.53	0.200	1800	3.48	7.991	27.83	9999.00	Wye	Open		3.48	7.99	27.83
Condensate Unit 1	Motor	1	4.94	0.200	1800	1.56	17.869	27.83	9999.00	Wye	Open		1.56	17.87	27.83
Condansate Unit 2	Motor	1	6.06	0.200	1800	1.74	15.983	27.83	9999.00	Wye	Open		1.74	15.98	27.83
Condansate Unit 3	Motor	1	13.39	0.200	1800	2.70	10.317	27.83	9999.00	Wye	Open		2.70	10.32	27.83
Condansate Unit 4	Motor	1	12.83	0.200	1800	2.64	10.539	27.83	9999.00	Wye	Open		2.64	10.54	27.83
Exhaust Fan-2	Motor	1	2.08	0.200	1800	0.95	29.181	27.83	9999.00	Wye	Open		0.95	29.18	27.83

Total Connected Induction Machines (= 6): 55.8 kVA

SHORT- CIRCUIT REPORT

Fault at bus: **Bus Bar Chamber**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Bus Bar Chamber	Total	0.00	4.209	0.00	108.68	107.54	3.844	3.844	2.48E+003	5.87E+003	3.13E+003	7.84E+003
Distribution board-1P	Bus Bar Chamber	0.00	0.000	0.00	108.68	107.54	0.000	0.000				
Distribution Board - 2P	Bus Bar Chamber	0.00	0.000	0.00	108.68	107.54	0.000	0.000				
Distribution board-3P	Bus Bar Chamber	0.26	0.378	0.16	108.69	107.60	0.224	0.000	2.89E+004	6.36E+004		
Solar Panel Terminal	Bus Bar Chamber	0.63	0.070	1.27	109.96	108.80	0.142	0.000	3.71E-002	3.77E+005		
TR LV Terminal	Bus Bar Chamber	11.65	3.597	16.47	104.32	104.49	3.407	3.844	2.87E+003	6.76E+003	3.13E+003	7.84E+003
Distribution Board - U	ATS	0.26	0.171	0.15	108.66	107.61	0.101	0.000	4.29E+004	1.48E+005		

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Distribution board-1P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution board-1P	Total	0.00	4.095	0.00	109.07	107.84	3.706	3.706	2.65E+003	6.00E+003	3.41E+003	8.16E+003
Bus Bar Chamber	Distribution board-1P	3.36	4.095	4.01	108.54	107.18	3.706	3.706	2.57E+003	5.92E+003	3.41E+003	8.16E+003

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

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Fault at bus: **Distribution Board - 2P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution Board - 2P	Total	0.00	3.445	0.00	107.09	120.32	2.841	2.841	4.72E+003	6.14E+003	1.02E+004	8.50E+003
Bus Bar Chamber	Distribution Board - 2P	29.47	3.445	41.64	108.64	103.41	2.841	2.841	4.49E+003	6.22E+003	1.02E+004	8.50E+003

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

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Filename: Project		Config.:	Normal

Fault at bus: **Distribution Board - U**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution Board - U	Total	0.00	4.032	0.00	112.27	114.34	3.308	3.308	2.79E+003	6.06E+003	5.04E+003	1.00E+004
ATS	Distribution Board - U	5.78	3.862	15.22	108.01	106.31	3.219	3.308	2.85E+003	6.22E+003	5.04E+003	1.00E+004
Fire Pump	Distribution Board - U	104.00	0.171	104.00	104.00	104.00	0.091	0.000	4.26E+004	1.48E+005		

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Fault at bus: **Distribution board-3P**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 97.56 % of base kV (0.213 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
				% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Distribution board-3P	Total	0.00	4.124	0.00	108.67	108.76	3.713	3.713	2.58E+003	5.98E+003	3.54E+003	8.16E+003
Bus Bar Chamber	Distribution board-3P	2.61	3.744	4.01	108.58	107.25	3.492	3.713	2.74E+003	6.50E+003	3.54E+003	8.16E+003
Condensate Unit 1	Distribution board-3P	104.00	0.045	104.00	104.00	104.00	0.026	0.000	3.19E+005	4.96E+005		
Condansate Unit 2	Distribution board-3P	104.00	0.057	104.00	104.00	104.00	0.033	0.000	2.32E+005	4.04E+005		
Condansate Unit 3	Distribution board-3P	104.00	0.135	104.00	104.00	104.00	0.079	0.000	6.78E+004	1.83E+005		
Condansate Unit 4	Distribution board-3P	104.00	0.129	104.00	104.00	104.00	0.075	0.000	7.23E+004	1.91E+005		
Exhaust Fan-2	Distribution board-3P	104.00	0.015	104.00	104.00	104.00	0.009	0.000	1.24E+006	1.18E+006		

\# Indicates fault current contribution is from three-winding transformers
* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus Bar Chamber	0.208	1.611	-3.889	4.209	1.538	-3.523	3.844	-3.420	-1.455	3.717	2.765	3.077	4.137
Distribution board-1P	0.208	1.628	-3.758	4.095	1.539	-3.371	3.706	-3.295	-1.473	3.610	2.646	3.018	4.014
Distribution Board - 2P	0.208	2.017	-2.792	3.445	1.997	-2.020	2.841	-2.404	-1.882	3.053	-3.310	-1.043	3.471
Distribution Board - U	0.208	1.656	-3.676	4.032	1.494	-2.952	3.308	-3.217	-1.498	3.549	-3.851	-0.211	3.857
Distribution board-3P	0.208	1.609	-3.797	4.124	1.544	-3.377	3.713	-3.332	-1.456	3.636	-4.014	0.108	4.015

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Bus Bar Chamber	0.208	0.01126	0.02670	0.02897	0.01126	0.02670	0.02897	0.01424	0.03562	0.03836	0.00000	0.00000	0.00000
Distribution board-1P	0.208	0.01205	0.02728	0.02983	0.01205	0.02728	0.02983	0.01550	0.03710	0.04021	0.00000	0.00000	0.00000
Distribution Board - 2P	0.208	0.02146	0.02792	0.03521	0.02146	0.02792	0.03521	0.04637	0.03862	0.06035	0.00000	0.00000	0.00000
Distribution Board - U	0.208	0.01266	0.02756	0.03033	0.01266	0.02756	0.03033	0.02292	0.04564	0.05107	0.00000	0.00000	0.00000
Distribution board-3P	0.208	0.01174	0.02718	0.02961	0.01174	0.02718	0.02961	0.01609	0.03709	0.04043	0.00000	0.00000	0.00000

Short circuit analyses for back-up generator and emergency load

Project:		ETAP	Page:	1
Location:		20.6.0E	Date:	04-06-2023
Contract:			SN:	UOFCALGSSE
Engineer:		Study Case: SC	Revision:	Base
Filename:	Project		Config.:	Normal

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Distribution Board - U	0.208	0.084	-0.593	0.599	0.133	-0.683	0.696	0.521	0.085	0.528	-0.602	0.309	0.677

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

Project:		ETAP	Page:	2
Location:		20.6.0E	Date:	04-06-2023
Contract:			SN:	UOFCALGSSE
Engineer:		Study Case: SC	Revision:	Base
Filename:	Project		Config.:	Normal

Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Distribution Board - U	0.208	0.02816	0.19850	0.20049	0.03495	0.19033	0.19351	0.03578	0.11949	0.12473	0.00000	0.00000	0.00000

SHORT- CIRCUIT REPORT

Fault at bus: **Distribution Board - U**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 100.00 % of base kV (0.208 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0	% Impedance on 100 MVA base R1	X1	R0	X0
Distribution Board - U	Total	0.00	0.599	0.00	90.02	95.52	0.696	0.696	6.51E+003	4.59E+004	8.27E+003	2.76E+004
ATS	Distribution Board - U	0.64	0.430	3.03	90.17	93.77	0.567	0.696	5.53E+003	6.43E+004	8.27E+003	2.76E+004
Fire Pump	Distribution Board - U	104.00	0.171	104.00	104.00	104.00	0.130	0.000	4.47E+004	1.56E+005		

\# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Electrical Transient Analyzer Program

Short-Circuit Analysis

ANSI Standard

3-Phase, LG, LL, & LLG Fault Currents

1/2 Cycle Network

	Swing	V-Control	Load	Total
Number of Buses:	2	0	3	5

	XFMR2	XFMR3	Reactor	Line/Cable/ Busway	Impedance	Tie PD	Total
Number of Branches:	1	0	0	2	0	0	3

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	1	1	0	1	0	3

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable / Busway Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable / Busway Resistance:	Yes	Individual	

Bus Input Data

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
ATS	Load	0.208	0.208	2	100.00	0.00
Distribution Board - U	Load	0.208	0.208	2	100.00	0.00
From Utility	SWNG	24.900	24.900	1	100.00	0.00
Generator Terminal	SWNG	0.208	0.208	2	100.00	0.00
TR LV Terminal	Load	0.208	0.213	1	100.00	-30.00

5 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

Line/Cable/Busway Input Data

ohms or siemens per 1000 ft per Conductor (Cable) or per Phase (Line/Busway)

Line/Cable/Busway			Length									
ID	Library	Size	Adj. (ft)	% Tol.	#/Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Generator Cable	5.0NCUS3	3/0	100.0	0.0	1	75	0.079771	0.033528		0.126837	0.0851611	
O/G to U Cable	5.0MCUS3	3/0	20.0	0.0	1	75	0.0772558	0.046		0.4339677	0.501	

Line / Cable / Busway resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
24.9KV/208V TR	0.113	24.900	0.208	7.25	2.47	0	0	0	0	2.500	7.25	Dyn	30.00

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	ohm	Type	kV	Amp	ohm
24.9KV/208V TR	0.113	24.900	0.208	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
24.9KV/208V TR	2W XFMR	From Utility	TR LV Terminal	2418.40	5973.46	6444.45	
Generator Cable	Cable	ATS	Generator Terminal	1843.82	774.96	2000.06	
O/G to U Cable	Cable	Distribution Board - U	ATS	357.14	212.65	415.65	

Power Grid Input Data

Power Grid	Connected Bus	Rating		% Positive Seq. Impedance 100 MVA Base			Grounding	% Zero Seq. Impedance 100 MVA Base		
ID	ID	MVASC	kV	X/R	R	X	Type	X/R	R0	X0
Infinite source	From Utility	175.000	24.900	7.00	8.08122	56.56854	Wye - Solid	7.00	0.345426	2.41798

Total Power Grids (= 1) 175.000 MVA

Synchronous Generator Input Data

Synchronous Generator		Rating			Positive Seq. Impedance					Grounding			Zero Seq. Impedance		
							% Xd"								
ID	Type	MVA	kV	RPM	X"/R	% R	Adj.	Tol.	% Xd'	Conn.	Type	Amp	X/R	% R0	% X0
Back up Diesel Generator	Diesel	0.030	0.208	1800	19.00	1.000	19.00	0.0	28.00	Wye	Solid		7.00	1.000	7.00

Total Connected Synchronous Generators (= 1): 0.030 MVA

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Filename: Project		Config.:	Normal

Induction Machine Input Data

Induction Machine			Rating (Base)			Positive Seq. Imp.				Grounding			Zero Seq. Imp.		
ID	Type	Qty	kVA	kV	RPM	X"/R	% R	% X"	% X'	Conn.	Type	Amp	X/R	% R0	% X0
Fire Pump	Motor	1	16.53	0.200	1800	3.48	7.991	27.83	9999.00	Wye	Open		3.48	7.99	27.83

Total Connected Induction Machines (= 1): 16.5 kVA

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Contract:		SN:	UOFCALGSSE
Engineer:	Study Case: SC	Revision:	Base
Filename: Project		Config.:	Normal

SHORT- CIRCUIT REPORT

Fault at bus: **Distribution Board - U**

Prefault voltage = 0.208 kV = 100.00 % of nominal bus kV (0.208 kV)
= 100.00 % of base kV (0.208 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
				% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Distribution Board - U	Total	0.00	0.599	0.00	90.02	95.52	0.696	0.696	6.51E+003	4.59E+004	8.27E+003	2.76E+004
ATS	Distribution Board - U	0.64	0.430	3.03	90.17	93.77	0.567	0.696	5.53E+003	6.43E+004	8.27E+003	2.76E+004
Fire Pump	Distribution Board - U	104.00	0.171	104.00	104.00	104.00	0.130	0.000	4.47E+004	1.56E+005		

# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta-Y transformer

Short-Circuit Summary Report

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus		3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
ID	kV	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Distribution Board - U	0.208	0.084	-0.593	0.599	0.133	-0.683	0.696	0.521	0.085	0.528	-0.602	0.309	0.677

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.
* LLG fault current is the larger of the two faulted line currents.

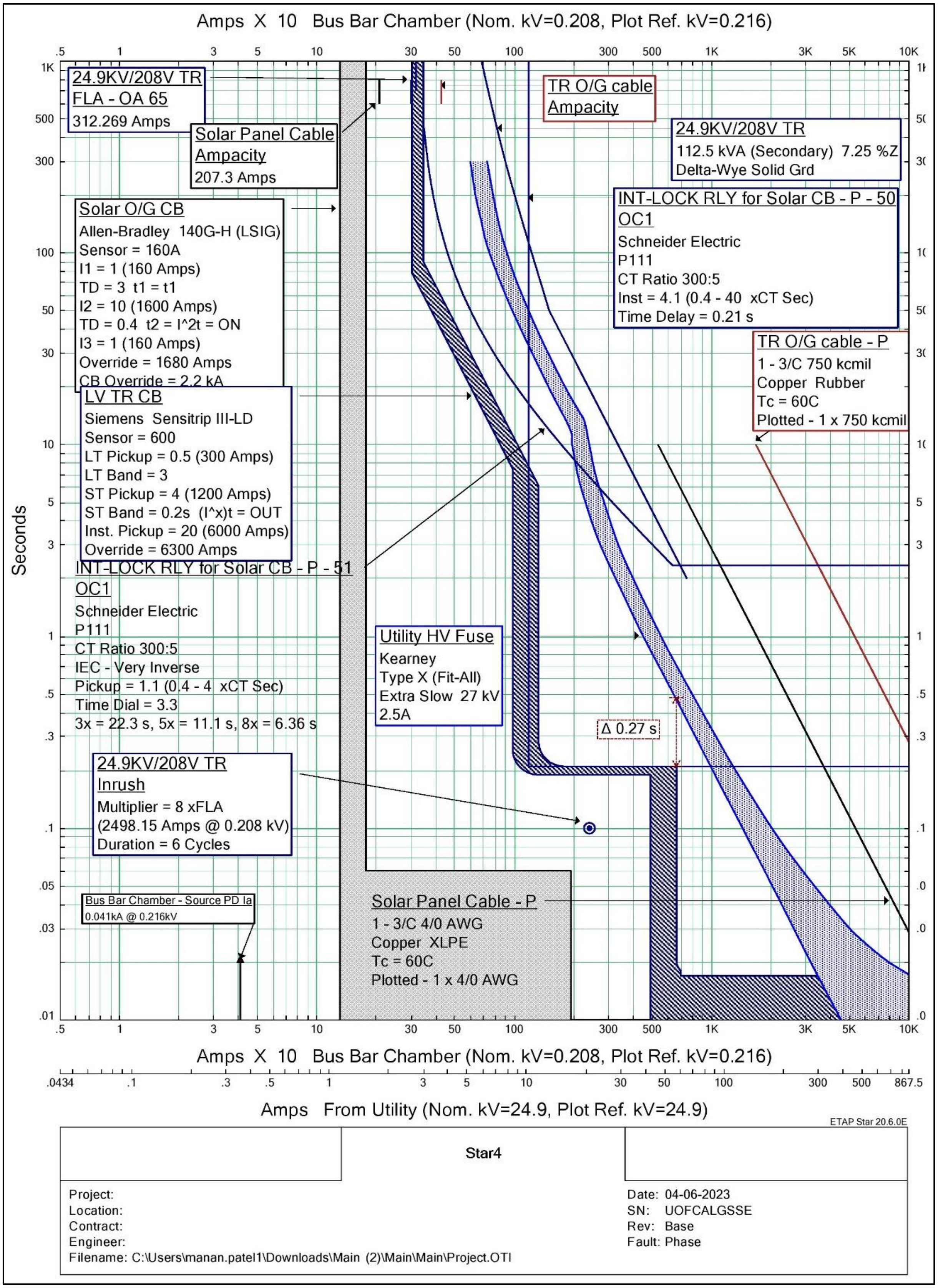
Sequence Impedance Summary Report

Bus		Positive Seq. Imp. (ohm)			Negative Seq. Imp. (ohm)			Zero Seq. Imp. (ohm)			Fault Zf (ohm)		
ID	kV	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance	Resistance	Reactance	Impedance
Distribution Board - U	0.208	0.02816	0.19850	0.20049	0.03495	0.19033	0.19351	0.03578	0.11949	0.12473	0.00000	0.00000	0.00000

Appendix C: Time Current Characteristics (TCC) Curves:

Time Current Curves are mentioned below. There are total 6 time current curves.

1) Transformer Coordination and interlock with solar panel.
2) Transformer LV CB & Solar O/G CB coordination with Distribution board – 1P incomer CB.
3) Transformer LV CB & Solar O/G CB coordination with Distribution board – 2P incomer CB.
4) Transformer LV CB & Solar O/G CB coordination with Distribution board – 3P incomer CB.
5) Transformer LV CB & Solar O/G CB coordination with Distribution board – U via UPS incomer CB.
6) Generator overcurrent protection coordination with Distribution board – U in the absent of Utility power supply.



1

Figure 22 Transformer Coordination and interlock with solar panel

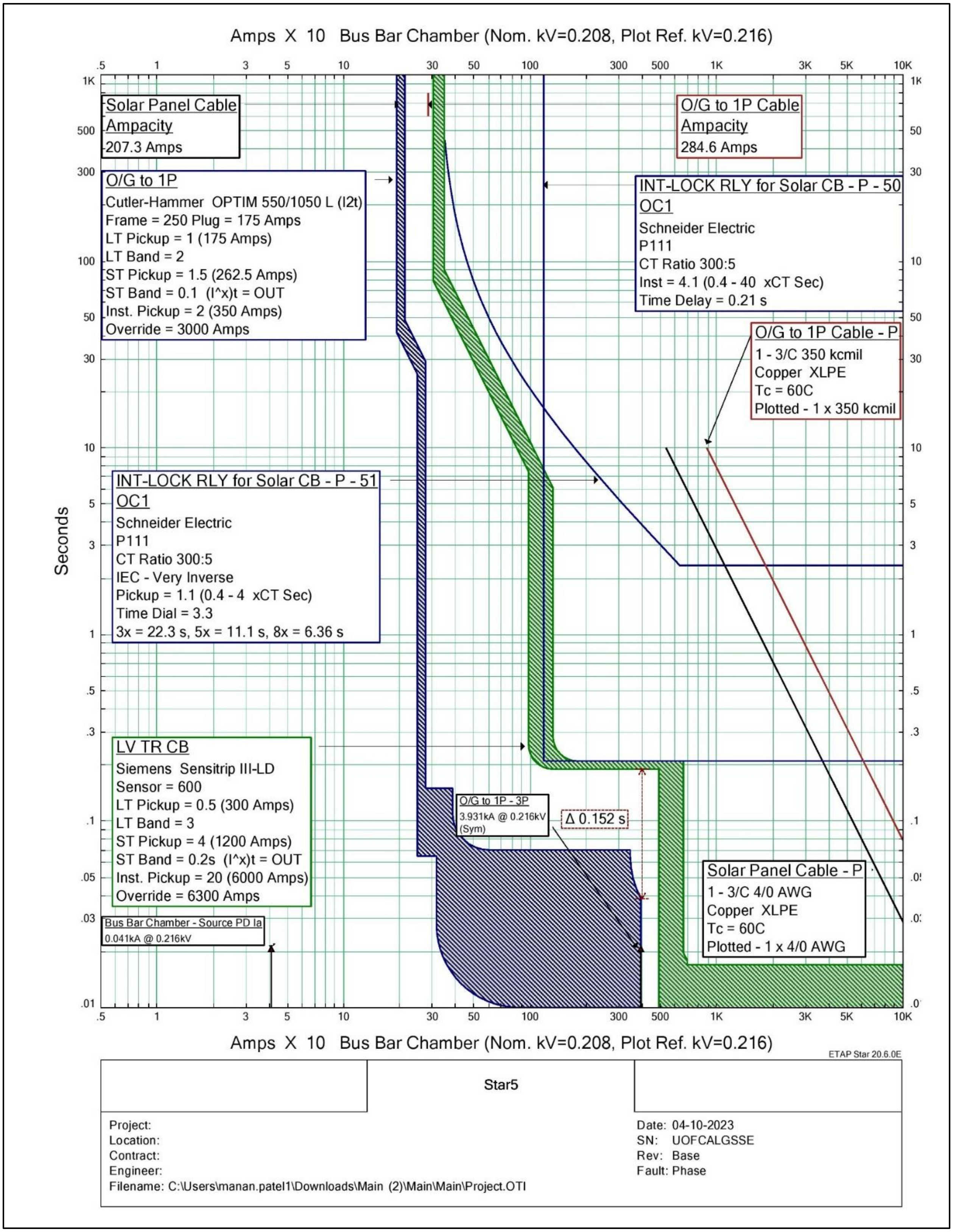


Figure 23 Transformer LV CB & Solar O/G CB coordination with Distribution board – 1P incomer CB

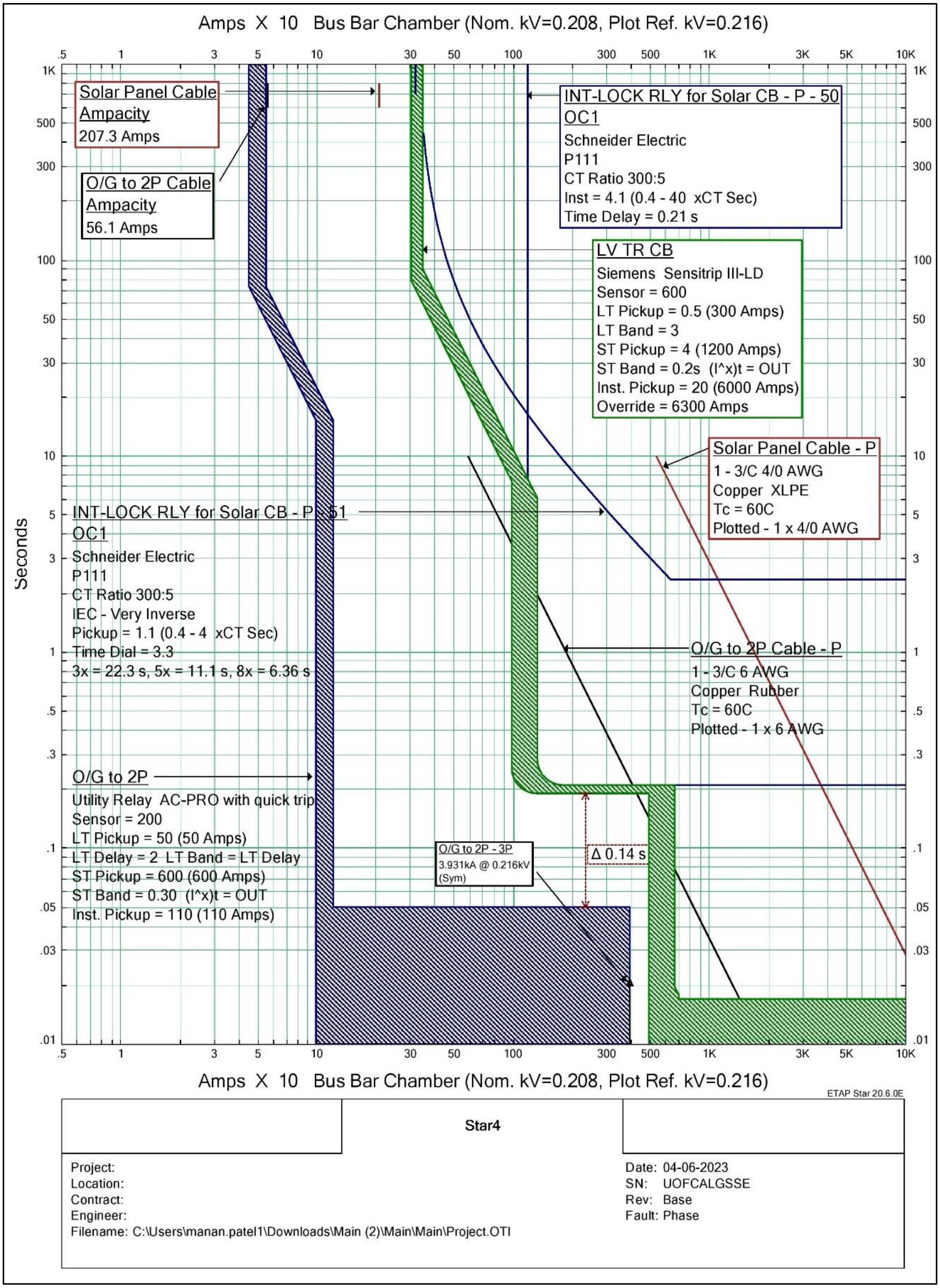


Figure 24 Transformer LV CB & Solar O/G CB coordination with Distribution board – 2P incomer CB

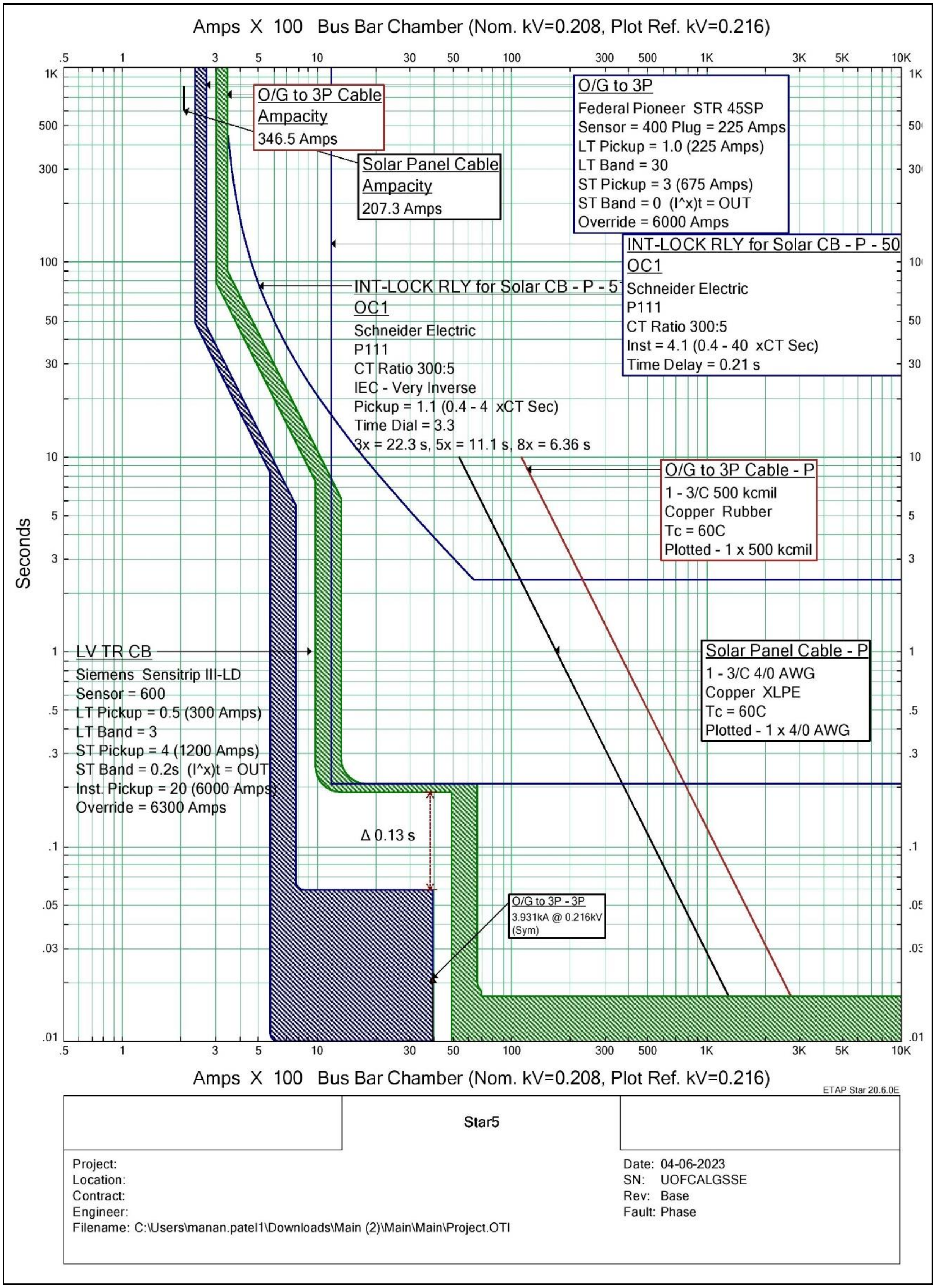


Figure 25 Transformer LV CB & Solar O/G CB coordination with Distribution board – 3P incomer CB

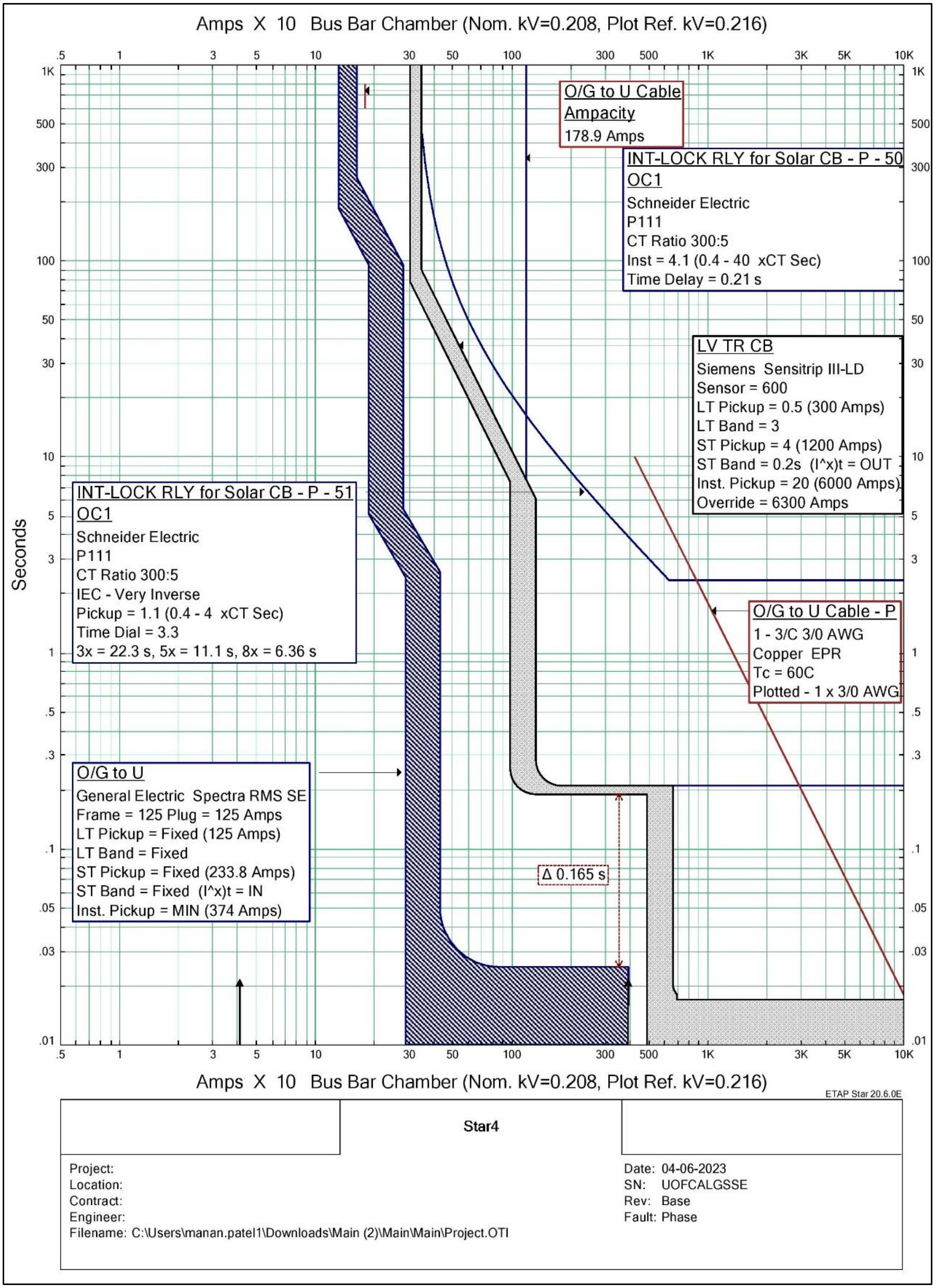


Figure 26 Transformer LV CB & Solar O/G CB coordination with Distribution board – U via UPS incomer CB.

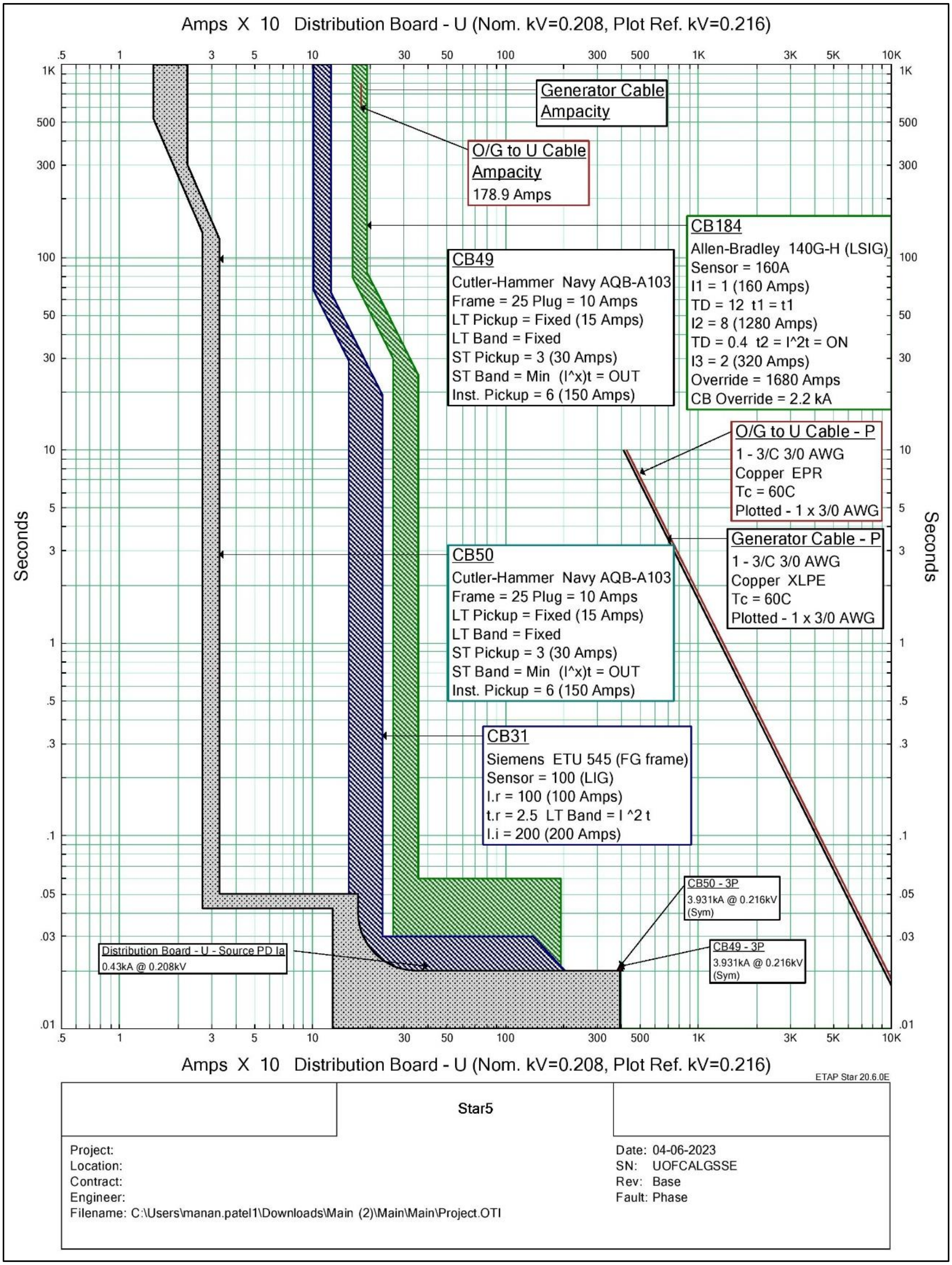


Figure 27 Generator overcurrent protection coordination with Distribution board – U in the absent of Utility power supply

Appendix D: Recommended Protection settings

Here, we are mentioning the suggested settings for the different protective devices. We plot the graph for the same. We found the best coordination with the below mentioned settings. For more details, we are attaching the datasheets for our selected breakers. Pick up value for short term and long term are mentioned in the TCCs.

CB: O/G to U

MFR:	General Electric*	Tag #:		3-Phase kA:	3.93	Sym. (Calc.)
Model:	SEDA (40-160A)	Rating:	36 kA, 0.24 kV	LG kA:	3.45	Sym. (Calc.)
Size:	150	Rated Amp:	130.000	Base kV:	0.216	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device

MFR: General Electric
Model: Spectra RMS SE
Sensor: 125
Rating Plug: 125.00

		Phase Setting	
Long-Time	LT Pickup	Fixed	
	LT Band	Fixed	
Short-Time	ST Pickup	Fixed	
	ST Band	Fixed	I^xt=IN
INST	Inst. Pickup	MIN	

CB: Solar O/G CB

MFR:	Allen-Bradley*	Tag #:		3-Phase kA:	0.00	Sym. (Calc.)
Model:	140G-H6	Rating:	17 kA, 0.22 kV	LG kA:	0.00	Sym. (Calc.)
Size:	160	Rated Amp:	150.000	Base kV:	0.000	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device

MFR: Allen-Bradley
Model: 140G-H (LSIG)
Sensor: 160A

		Phase Setting					Ground Setting	
Long-Time	I1	1.00	Multiples	t1	t1	I4	0.2	t4 I4 = OUT
	TD	3				TD	0.1	
Short-Time	I2	10		t2	I^2t = ON			
	TD	0.4						
INST	I3	1						

CB:	O/G to 2P					
MFR:	Allen-Bradley*	Tag #:		3-Phase kA:	3.93	Sym. (Calc.)
Model:	140G-J0	Rating:	10 kA, 0.24 kV	LG kA:	3.45	Sym. (Calc.)
Size:	50	Cont. Amp:	40.000	Base kV:	0.216	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device#

MFR: Utility Relay

Model: AC-PRO with quick trip

Sensor: 200

		Phase Setting			
Long-Time	LT Pickup	50.00	Amp	LT Band	LT Delay
	LT Delay	2.0000			
Short-Time	ST Pickup	600.00	Amp		
	ST Band	0.30	I^xt=OUT		
INST	Inst. Pickup	110.00	Amp		

The selected trip device does not match the circuit breaker.

CB:	O/G to 3P					
MFR:	Federal Pioneer*	Tag #:		3-Phase kA:	3.93	Sym. (Calc.)
Model:	CK-N	Rating:	10 kA, 0.24 kV	LG kA:	3.45	Sym. (Calc.)
Size:	225	Cont. Amp:	225.000	Base kV:	0.216	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device

MFR: Federal Pioneer

Model: STR 45SP

Sensor: 400

Rating Plug: 225.00

		Phase Setting	
Long-Time	LT Pickup	1.0	
	LT Band	30	
Short-Time	ST Pickup	3	
	ST Band	0	I^xt=OUT

Fuse:	Utility HV Fuse					
MFR:	Kearney*	Tag #:		3-Phase kA:	4.06	Sym. (Calc.)
Model:	Type X (Fit-All)	kV:	27.000	LG kA:	5.97	Sym. (Calc.)
Speed:	Extra Slow	Int. kA:	8.800	Base kV:	24.900	(Calc.)
Size:	2.5A	Cont. Amp:	2.500			

* Retrieved library data is modified by user.

CB: LV TR CB

MFR:	Siemens*	Tag #:		3-Phase kA:	0.00	Sym. (Calc.)
Model:	SCLD6	Rating:	10 kA, 0.24 kV	LG kA:	0.00	Sym. (Calc.)
Size:	600	Cont. Amp:	600.000	Base kV:	0.000	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device

MFR: Siemens

Model: Sensitrip III-LD

Sensor: 600

		Phase Setting		Ground Setting		
Long-Time	LT Pickup	0.5		Ground Pickup	0.2	
	LT Band	3		Ground Band	0.1	I^xt=IN
Short-Time	ST Pickup	4				
	ST Band	0.2s	I^xt=OUT			
INST	Inst. Pickup	20				

CB: O/G to 1P

MFR:	Cutler-Hammer*	Tag #:		3-Phase kA:	3.93	Sym. (Calc.)
Model:	CHLD	Rating:	10 kA, 0.24 kV	LG kA:	3.45	Sym. (Calc.)
Size:	250	Cont. Amp:	250.000	Base kV:	0.216	(Calc.)

* The retrieved library data is modified by user.

LV Solid State Trip Device

MFR: Cutler-Hammer

Model: OPTIM 550/1050 L (I2t)

Sensor: 250

Rating Plug: 175.00

		Phase Setting		Ground Setting		
Long-Time	LT Pickup	1.00	Multiples	Ground Pickup	0.20	Multiples
	LT Band	2.0000	Range=(2 - 24)	Ground Band	0.1	I^xt=OUT
Short-Time	ST Pickup	1.50	Multiples			
	ST Band	0.1	I^xt=OUT			
INST	Inst. Pickup	2.00	Multiples			

Appendix E: Incident arc flash energy

We have studied the arc flash analyses for two cases.

1. Arc flash analyses for utility and Solar Power integration.
2. Arc flash analyses for back-up generator feeding emergency load.

Arc flash analyses for utility and Solar Power integration

Project:	ETAP	Page:	1
Location:	20.6.0E	Date:	04-06-2023
Contract:		SN:	UOFCALGSSE
Engineer:	Study Case: A_SC	Revision:	Base
Filename: Project		Config.:	Normal

Bus Incident Energy Summary

Bus			Total Fault Current (kA)		Arc-Flash Analysis Results			
ID	Nom. kV	Type	Bolted	Arcing	FCT (cycles)	Incident E (cal/cm²)	AFB (ft)	Energy Level
Bus Bar Chamber	0.208	Other	4.209	2.461	12.600	1.648	1.76	Level A
Distribution board-1P	0.208	Other	4.095	2.411	4.200	0.537	1.00	Level A
Distribution Board - 2P	0.208	Other	3.445	2.122	3.000	0.334	0.79	Level A
Distribution Board - U	0.208	Other	4.032	2.384	1.500	0.190	0.60	Level A
Distribution board-3P	0.208	Other	4.124	2.423	3.600	0.463	0.93	Level A

Bus Incident Energy Summary

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Bus Arc Flash Hazard Analysis Summary

Faulted Bus				Fault Current			Trip Device							
ID	Nom. kV	Equipment Type	Gap (mm)	Bolted Fault (kA) Bus	Bolted Fault (kA) PD	PD Arc Fault (kA)	Source Trip Device ID	Trip (cycle)	Open (cycle)	FCT (cycle)	Arc Flash Boundary (ft)	Incident Energy (cal/cm²)	Working Distance (in)	Energy Level
Bus Bar Chamber	0.208	Other	13	4.209	0.070	0.041	Solar O/G CB	12.60	0.00	12.60	1.8	1.6	18	Level A
Distribution board-1P	0.208	Other	13	4.095	4.095	2.411	O/G to 1P	4.20	0.00	4.20	1.0	0.5	18	Level A
Distribution Board - 2P	0.208	Other	13	3.445	3.445	2.122	O/G to 2P	3.00	0.00	3.00	0.8	0.3	18	Level A
Distribution Board - U	0.208	Other	13	4.032	3.862	2.283	O/G to U	1.50	0.00	1.50	0.6	0.2	18	Level A
Distribution board-3P	0.208	Other	13	4.124	3.744	2.201	O/G to 3P	3.60	0.00	3.60	0.9	0.5	18	Level A

Arc Flash Hazard Analysis Summary

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Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Bus Bar Chamber**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208   Prefault Voltage = 100% of nominal bus kV   System Grounding = Grounded

Base kV = 0.213   = 98% of base kV   Working Distance = 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	Fault Clearing Time (Seconds)		(cal/cm²)
Ibf" = 4.209	Ia" = 2.461	FCT =	12.6	0.210	Incident Energy =	1.648
		Fault Clearing Time =	12.6	0.210	**Total Incident Energy =**	1.648

For Protective Device: Solar O/G CB@ Ia" =0.041 kA   Energy Level*   **Level A**

Relay: INT-LOCK RLY for Solar CB - Phase - OC1 - 50   Arc Flash Boundary = 1.76 ft

Type: Overcurrent

Arc Fault at Device			Individual Contribution to Bus Arc Fault			Incident Energy					
ID	Phase Type	Type	Bolted (kA)	Arcing (kA)	FCT (cycles)	Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm²)	AFB (ft)	Energy Level*
♦ LV TR CB	3Ph	LV CB	3.597	2.102		2.092	1264.7	Utility HV Fuse	138.757		
						FCT =	1264.7	**Total =**	138.757	16.13	**>Max.**
O/G to 1P	3Ph	LV CB	0.000	0.000		2.461	12.6	Solar O/G CB	1.648		
						FCT =	12.6	**Total =**	1.648	1.76	**Level A**
O/G to 2P	3Ph	LV CB	0.000	0.000		2.461	12.6	Solar O/G CB	1.648		
						FCT =	12.6	**Total =**	1.648	1.76	**Level A**
O/G to 3P	3Ph	LV CB	0.378	0.221		2.461	12.6	Solar O/G CB	1.648		
						FCT =	12.6	**Total =**	1.648	1.76	**Level A**
O/G to U	3Ph	LV CB	0.171	0.100		2.461	12.6	Solar O/G CB	1.648		
						FCT =	12.6	**Total =**	1.648	1.76	**Level A**
Solar O/G CB	3Ph	LV CB	0.070	0.041				Cannot be Determined			

Arc Flash analysis for Bus Bar Chamber

Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Distribution board-1P**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208	Prefault Voltage = 100% of nominal bus kV	System Grounding	= Grounded
Base kV = 0.213	= 98% of base kV	Working Distance	= 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	(Seconds)		(cal/cm²)
Ibf" = 4.095	Ia" = 2.411	FCT =	4.2	0.070	Incident Energy =	0.537
		Fault Clearing Time =	4.2	0.070	**Total Incident Energy =**	0.537

For Protective Device: O/G to 1P@ Ia" =2.411 kA

Energy Level* **Level A**

Arc Flash Boundary = 1.00 ft

Arc Fault at Device			**Individual Contribution to Bus Arc Fault**			**Incident Energy**					
ID	Phase Type	Type	Bolted (kA)	Arcing (kA)	FCT (cycles)	Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm²)	AFB (ft)	Energy Level*
CB33	3Ph	LV CB	0.000	0.000		2.411	4.2	O/G to 1P	0.537		
						FCT =	4.2	**Total =**	0.537	1.00	**Level A**

Arc Flash analysis for Distribution board – 1P

Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Distribution Board - 2P**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208 Prefault Voltage = 100% of nominal bus kV System Grounding = Grounded

Base kV = 0.213 = 98% of base kV Working Distance = 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	Fault Clearing Time (Seconds)		(cal/cm²)
Ibf" = 3.445	Ia" = 2.122	FCT =	3.0	0.050	Incident Energy =	0.334
		Fault Clearing Time =	3.0	0.050	**Total Incident Energy =**	0.334

For Protective Device: O/G to 2P@ Ia" =2.122 kA

Energy Level* **Level A**

Arc Flash Boundary = 0.79 ft

Arc Fault at Device: ID	Phase Type	Type	Individual Contribution to Bus Arc Fault: Bolted (kA)	Arcing (kA)	FCT (cycles)	Incident Energy: Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm²)	AFB (ft)	Energy Level*
CB166	3Ph	LV CB	0.000	0.000		2.122	3.0	O/G to 2P	0.334		
						FCT =	3.0	**Total =**	0.334	0.79	**Level A**
CB168	3Ph	LV CB	0.000	0.000		2.122	3.0	O/G to 2P	0.334		
						FCT =	3.0	**Total =**	0.334	0.79	**Level A**
CB169	3Ph	LV CB	0.000	0.000		2.122	3.0	O/G to 2P	0.334		
						FCT =	3.0	**Total =**	0.334	0.79	**Level A**
CB170	3Ph	LV CB	0.000	0.000		2.122	3.0	O/G to 2P	0.334		
						FCT =	3.0	**Total =**	0.334	0.79	**Level A**
CB173	3Ph	LV CB	0.000	0.000		2.122	3.0	O/G to 2P	0.334		
						FCT =	3.0	**Total =**	0.334	0.79	**Level A**

Arc Flash analysis for Distribution board – 2P

Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Distribution Board - U**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208	Prefault Voltage = 100% of nominal bus kV	System Grounding = Grounded
Base kV = 0.213	= 98% of base kV	Working Distance = 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	Fault Clearing Time (Seconds)		(cal/cm²)
Ibf" = 4.032	Ia" = 2.384	FCT =	1.5	0.025	Incident Energy =	0.190
		Fault Clearing Time =	1.5	0.025	**Total Incident Energy =**	0.190

For Protective Device: O/G to U@ Ia" =2.283 kA

Energy Level*: **Level A**

Arc Flash Boundary = 0.60 ft

Arc Fault at Device			**Individual Contribution to Bus Arc Fault**			**Incident Energy**					
ID	Phase Type	Type	Bolted (kA)	Arcing (kA)	FCT (cycles)	Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm²)	AFB (ft)	Energy Level*
CB31	3Ph	LV CB	0.171	0.101		2.384	1.5	O/G to U	0.190		
						FCT =	1.5	**Total =**	0.190	0.60	**Level A**
CB49	3Ph	LV CB	0.000	0.000		2.384	1.5	O/G to U	0.190		
						FCT =	1.5	**Total =**	0.190	0.60	**Level A**
CB50	3Ph	LV CB	0.000	0.000		2.384	1.5	O/G to U	0.190		
						FCT =	1.5	**Total =**	0.190	0.60	**Level A**

Arc Flash analysis for Distribution board – U

Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Distribution board-3P**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208   Prefault Voltage = 100% of nominal bus kV   System Grounding = Grounded

Base kV = 0.213   = 98% of base kV   Working Distance = 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	Fault Clearing Time (Seconds)		(cal/cm^2)
Ibf" = 4.124	Ia" = 2.423	FCT =	3.6	0.060	Incident Energy =	0.463
		Fault Clearing Time =	3.6	0.060	**Total Incident Energy =**	0.463

For Protective Device: O/G to 3P@ Ia" =2.201 kA   Energy Level*   **Level A**

Arc Flash Boundary = 0.93 ft

Arc Fault at Device			Individual Contribution to Bus Arc Fault			Incident Energy					
ID	Phase Type	Type	Bolted (kA)	Arcing (kA)	FCT (cycles)	Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm^2)	AFB (ft)	Energy Level*
CB43	3Ph	LV CB	0.045	0.026		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**
CB44	3Ph	LV CB	0.057	0.033		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**
CB45	3Ph	LV CB	0.135	0.080		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**
CB46	3Ph	LV CB	0.129	0.076		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**
CB47	3Ph	LV CB	0.015	0.009		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**
CB48	3Ph	LV CB	0.000	0.000		2.423	3.6	O/G to 3P	0.463		
						FCT =	3.6	**Total =**	0.463	0.93	**Level A**

Arc Flash analysis for Distribution board – 3P

Arc flash analyses for back-up generator and emergency load

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Bus Incident Energy Summary

Bus			Total Fault Current (kA)		Arc-Flash Analysis Results			
ID	Nom. kV	Type	Bolted	Arcing	FCT (cycles)	Incident E (cal/cm²)	AFB (ft)	Energy Level
# Distribution Board - U	0.208	Other	0.599	0.599	269.211	1.370	1.61	Level A

Bus Incident Energy Summary

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Filename:	Project		Config.:	Normal

Bus Arc Flash Hazard Analysis Summary

Faulted Bus				Fault Current			Trip Device							
				Bolted Fault (kA)										
ID	Nom. kV	Equipment Type	Gap (mm)	Bus	PD	PD Arc Fault (kA)	Source Trip Device ID	Trip (cycle)	Open (cycle)	FCT (cycle)	Arc Flash Boundary (ft)	Incident Energy (cal/cm²)	Working Distance (in)	Energy Level
# Distribution Board - U	0.208	Other		0.599	0.430	0.430	CB184	269.21	0.00	269.21	1.6	1.4	18	Level A

Arc Flash Hazard Analysis Summary

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Filename: Project		Config.:	Normal

Arc Flash Analysis

1/2 Cycle Calculation Method

Arc Fault at Bus: **Distribution Board - U**

Solution Method: **1/2 Cycle**

Nominal kV = 0.208 Prefault Voltage = 100% of nominal bus kV System Grounding = Grounded

Base kV = 0.208 = 100% of base kV Working Distance = 18 inches

Bus Arc Flash Results

Total Bolted (kA)	Total Arcing (kA)		Fault Clearing Time (cycles)	Fault Clearing Time (Seconds)		(cal/cm²)	
Ibf" = 0.599	Ia" = 0.599	FCT =	269.2	4.487	Incident Energy =	1.370	
		Fault Clearing Time =	269.2	4.487	**Total Incident Energy =**	1.370	+

For Protective Device: CB184@ Ia" =0.430 kA

Energy Level* **Level A**

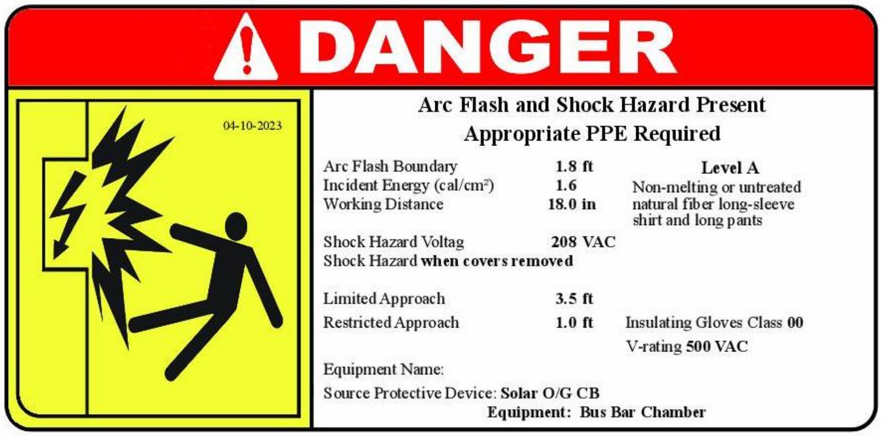
Arc Flash Boundary = 1.61 ft

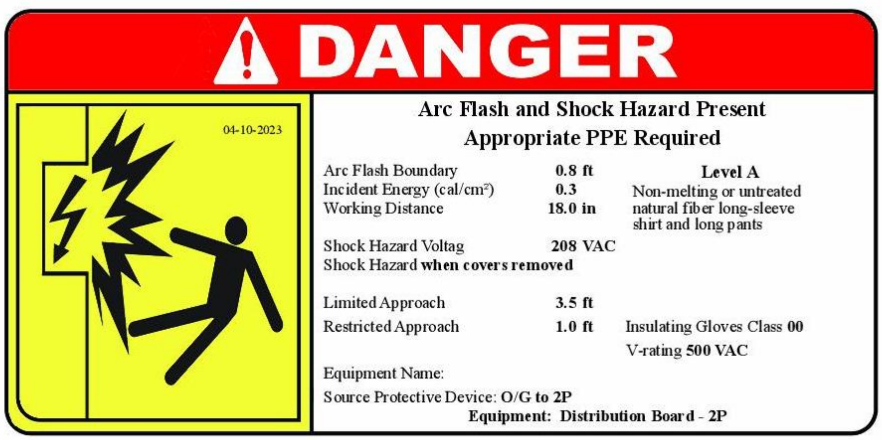
Arc Fault at Device			Individual Contribution to Bus Arc Fault			Incident Energy					
ID	Phase Type	Type	Bolted (kA)	Arcing (kA)	FCT (cycles)	Arcing (kA)	FCT (cycles)	Protective Device ID for FCT	Incident E (cal/cm²)	AFB (ft)	Energy Level*
CB31	3Ph	LV CB	0.171	0.171		0.599	269.2	CB184	1.370		
						FCT =	269.2	**Total =**	1.370	1.61	Level A
CB49	3Ph	LV CB	0.000	0.000		0.599	269.2	CB184	1.370		
						FCT =	269.2	**Total =**	1.370	1.61	Level A
CB50	3Ph	LV CB	0.000	0.000		0.599	269.2	CB184	1.370		
						FCT =	269.2	**Total =**	1.370	1.61	Level A

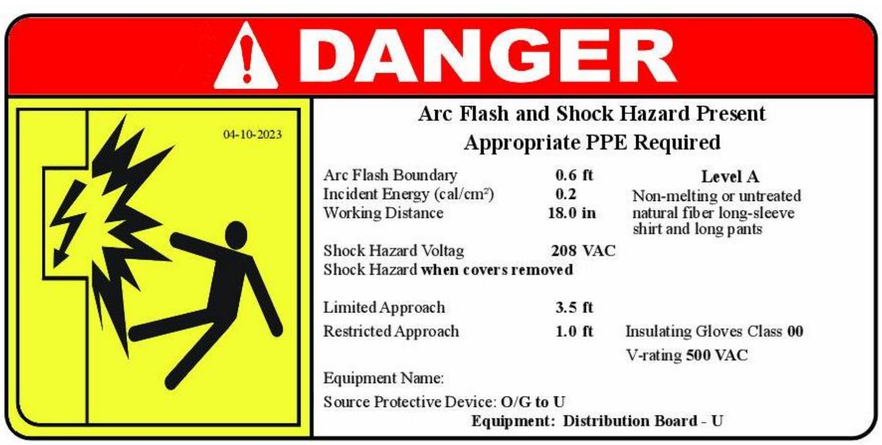
Arc Flash Analysis for Distribution board – U

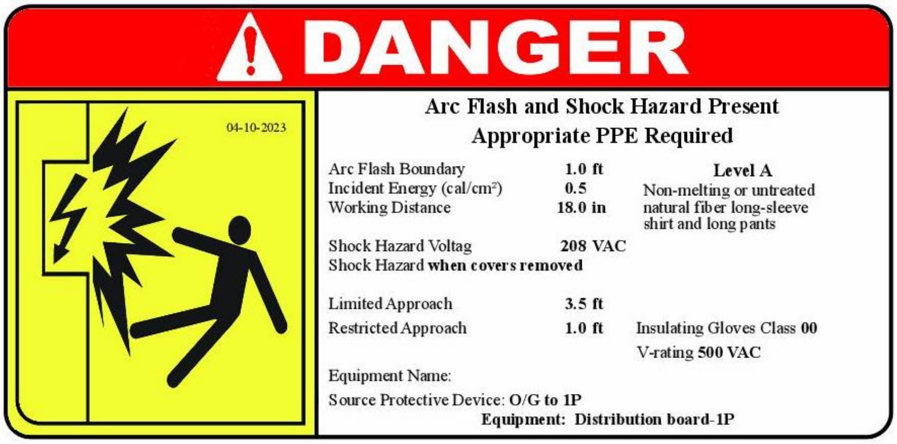
Arc flash Labels

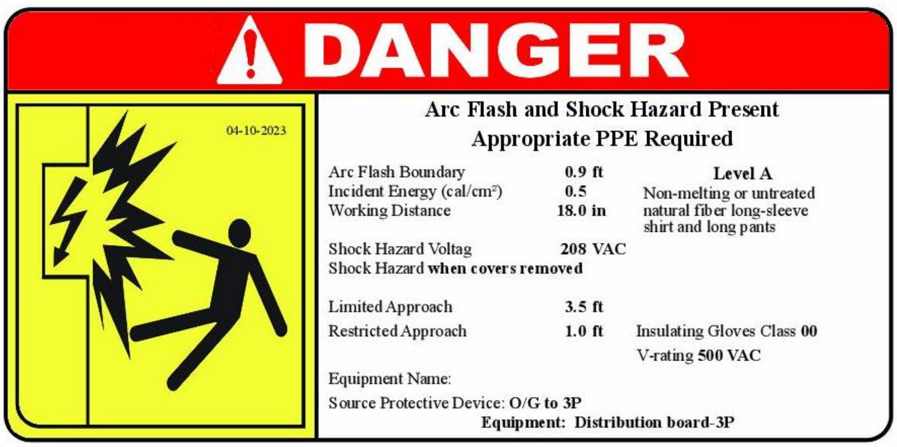
Case:1 Arc flash during utility feeding supply



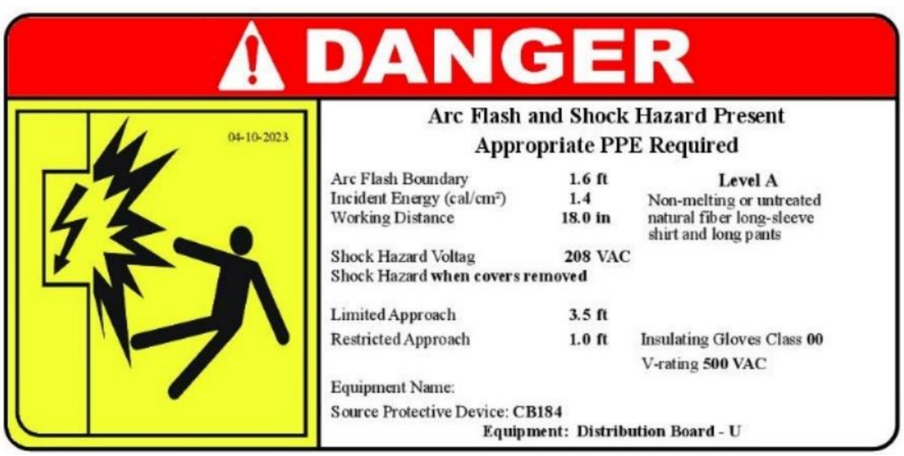








Case:2 Arc flash during generator feeding emergency supply



Appendix F: Definitions and concepts from NFPA 70E-2004

NFPA 70E-2004 is a standard established by the National Fire Protection Association (NFPA) that outlines requirements for electrical safety in the workplace. Here are key definitions and concepts from NFPA 70E-2004:

- Arc flash: An explosive release of energy caused by an electrical arc.
- Arc flash hazard: The danger associated with the release of energy caused by an electrical arc.
- Flash protection boundary: The distance from an energized part within which a worker could receive a second-degree burn if an arc flash occurred.
- Incident energy: The amount of thermal energy impressed on a surface at a specific distance from the source of an electrical arc, measured in calories per square centimeter (Cal/cm^2).
- Personal Protective Equipment (PPE): Clothing, helmets, goggles, or other equipment designed to protect workers from injury or harm.
- Hazard Risk Category (HRC): A rating system used to specify the minimum PPE required for a worker to be protected from the arc flash hazard. HRC is determined based on the incident energy exposure.
- Restricted approach boundary: The minimum distance from an exposed energized conductor or circuit part within which a shock hazard exists.
- Limited approach boundary: The minimum distance from an exposed energized conductor or circuit part that an unqualified person may approach.
- Prohibited approach boundary: The minimum distance from an exposed energized conductor or circuit part that an unqualified person may not cross.
- Qualified person: A person who has received training in and has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and the hazards involved.

Overall, NFPA 70E-2004 provides a framework for employers and employees to identify electrical hazards, assess risks, and implement effective controls to prevent electrical accidents and injuries in the workplace.