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[illegible]deland Solar LLC
Solar PV Project – 1.0 MW AC
Yellow Medicine County, Minnesota

POWER SYSTEM AND ARC FLASH HAZARD ANALYSIS REPORT

Rev.0

Certification

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly licensed professional ENGINEER under the laws of the state of Minnesota.

DURAK EVRIM ERCAN, P.E
Registration No. 57332 Date: 05/22/2021

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SECTION 1 - INTRODUCTION

1.1 SCOPE AND DESCRIPTION

1. The objective of this Power System Analysis was to perform a Short Circuit Study, Equipment and Device Evaluation Study, Protective Device Coordination Study and Arc Flash Hazard Analysis on the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility electrical power distribution system.

2. This report contains the results of the photo-voltaic Power System Analysis that consisted of a Short Circuit Study, Equipment and Device Evaluation Study, Protective Device Coordination Study and Arc Flash Hazard Analysis of the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility.

3. The analyses and report were conducted by Durak Evrim Ercan, P.E., Engineering, Estimating & Consulting in New Jersey. The analysis and report were performed under the direction of a professional engineer.

4. The Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility electrical distribution system consists of a simple radial distribution arrangement through a main switchgear. The main switchgear is fed from Xcel Energy utility connection through 1MVA 12.47/0.48kV transformer and twenty (20) 55 kVA solar inverters.

5. The analysis begins at the incoming 12.47 kV utility services through main distribution system, electrical equipment and loads downstream. Only 480V or more rated equipment were considered in this arc flash analysis. Single phase equipments are excluded in this report.

6. The Power System Analysis and related engineering calculations were performed using a computer software program specifically designed for complex power system analysis. EASY POWER was the computer software program used for the analysis, which is distributed nationally and in wide use. The Study One-Line Diagram was created and modeled within the software program. The Short Circuit Study calculations, Protective Device Coordination Study, Equipment Evaluation and Arc Flash Hazard Analysis calculations are all performed within the EASY POWER integrated software package suite.

7. Following references were used to conduct the study:

    a. National Fire Protection Association, NFPA-70E and NFPA-70.

    b. Institute of Electrical and Electronics Engineers, IEEE-1584-2018, IEEE-141, IEEE-214, IEEE-242, IEEE-399 and IEEE-551.

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1.2 LIMITATION OF LIABILITY

1. The content of this report, studies, related engineering performance and engineering analysis is based on the data as noted within as provided to Durak Evrim Ercan, P.E. as the latest and correct version at the time of issuing the study.

2. Any changes to the power system or equipment invalidates the results of this report and arc flash warning labels. Arc Flash labels cannot be printed for equipment failing short circuit interruption and withstand evaluation.

3. Durak Evrim Ercan, P.E. makes no warranty, either expressed or implied, and specifically disclaims any warranty as a consequence of engineering services. Under no circumstances shall Durak Evrim Ercan, P.E. be responsible for damages which result as a consequence of services performed by Durak Evrim Ercan, P.E. Durak Evrim Ercan, P.E. shall not be liable for special, indirect, incidental, or consequential damages whatsoever. Durak Evrim Ercan, P.E. will not be responsible for the misuse or misapplication of the information contained in this analysis and report. Those providing service for electrical equipment should be properly trained and qualified personnel.

4. The information and values provided within this report will be considered invalid if the electrical equipment and devices within the equipment are not operating and installed in an ambient environment recommended by the manufacturer for the correct operation of the devices. The equipment is to operate in accordance with manufacturer's requirements and tolerances. Similarly, information and values will be considered invalid if the electrical equipment and devices are not tested in accordance with industry standards.

5. Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility is responsible for training and educating personnel, contractors and all workers working on or near energized electrical equipment, circuits, and systems. This report is not intended to be a training manual or training guideline.

6. No alteration to this report is permitted except as provided under state law and the direction of a licensed professional engineer. Durak Evrim Ercan, P.E. reserves the right to change the content and results of this report at any time and with the receipt of information not previously provided.

7. Durak Evrim Ercan, P.E. does not assume responsibility for the results of any conclusions or recommendations resulting from the services provided under this contract and report, nor for achieving the best possible compromise between competing objectives, nor for achieving a desired objective. Nor does it assume responsibility or liability for any damage to property, injury to or death of personnel, or any loss that may result directly or indirectly from failure of the equipment or system or any part or parts of it to operate in accordance with the conclusions or recommendations resulting from the study. In addition to other disclaimers expressed or implied, the Durak Evrim Ercan, P.E. shall not be liable for special or consequential damages.

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SECTION 2 - SYSTEM MODELING AND INPUT DATA

2.1 INPUT DATA COLLECTION

1. Information related to the Power System Study for Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility project was provided through a series of documents and responses to clarifications. All received information are compiled and used to build the power system model.

2. The Study One-Line Diagram included as part of this report represents the interconnection of the electrical power distribution system under study. Data for this study, including the basic system configuration, was obtained from the following documents:

Name of the Document or Description	Document and / or Drawing Number	Revision and / or Issue Date
Novel Handeland Solar, LLC Electrical Submittal – IFC	All Sheets	05/10/2021
Xcel Energy Utility Fault Level	Table II – Three-Phase Fault Current in RMS Amps Symmetrical Expected at the Secondary Terminals of the Transformer	03/01/2021
Xcel-Energy Standard for Electric Installation	N/A	N/A
ABB SACE Tmax Catalog	SACE Tmax XT UL/CSA Technical Catalog	04/2020
Canadian Solar Cut Sheets	N/A	May 2020

2.2 UTILITY COMPANY DATA

1. Utility Company available fault current contribution data and protective device data for the facility electrical utility service was obtained from and provided by the Serving Electric Utility Company Xcel Energy.

2. The following represents the utility fault contribution data:

   a. Maximum available three-phase RMS Symmetrical fault current contribution 22,600 Amps at 0.48 kV

   b. Maximum available one-line to ground RMS Symmetrical fault current contribution 22,600 Amps at 0.277 kV

3. Primary Protective Device is Cooper Bay-O-Net Dual Sensing, 15.5 kV, 65 A

4. Software model was created to 22,600A let thru current at the secondary of the utility owned transformer by injecting short circuit current at the primary side of the utility transformer by simulating EASY POWER software.

2.3 STUDY ONE-LINE DIAGRAM

1. This report includes a Study One-Line Diagram that represents the power system under study for the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility, and includes equipment data, CT ratios, relay types, circuit breaker types and sizes, fuse types and sizes, cable sizes and lengths.

2. An electrical power system one-line diagram is a simplified and graphical representation of a three-phase power system. The three-phases are represented by a single line and electrical equipment is denoted by symbols to present the arrangement and interconnection of electrical distribution equipment. The elements on the one-line diagram do not represent the physical location of the equipment.

3. The Study One-Line Diagram is a simplified version of the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility drawings and overall power system, showing only those parts of the electrical system under consideration and study. Various system components on the diagram have been labeled with equipment identification so input data could be supplied to the analysis program and the report output could be readily interpreted. The Study One-Line Diagram was created through the power analysis software program.

4. From the information provided to Durak Evrim Ercan, P.E., the Electrical Power System One-Line Diagram (Study One-Line Diagram) was developed through the power analysis computer software program EASY POWER. Then using the computer program, various power system scenarios were performed to calculate the maximum and minimum fault currents at each equipment bus and the maximum incident energy at each equipment. The Engineering Analysis and System Modeling included the Modes of Operation and Scenarios as noted in this report.

5. A copy of the Study One-Line Diagram has been included in this report. This drawing may not be legible at this size; however, is included to represent that the drawing was developed and included as part of the Power System Analysis.

6. Feeder Input Data table lists all feeders used in the One-Line Diagram and provide all necessary information on each feeder as obtained through the software library or referenced published data sheets. Feeder impedances are adjusted through the program according to the length of the cable included in the study. The Feeder Input Data Table includes the following:

    a. Column #1 - ID Name: Name of cable as on the study One-Line Diagram.

    b. Column #2 - No/Ph: Total number of cables per phase.

    c. Column #3 - Size: Conductor size in AWG or kcmil.

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d. Column #4 - Length: Length of cable in feet.

e. Column #5 - Rating: Conductor rating in amperes.

f. Column #6 - Material: The conductor material.

g. Column #7 - Raceway: Raceway material.

h. Column #8 - R1: Positive sequence resistance in Ohm / 1000 ft.

i. Column #9 - X1: Positive sequence reactance in Ohms / 1000 ft.

j. Column #10 - R0: Zero sequence resistance in Ohms 1000 ft.

k. Column #11 - X0: Zero sequence reactance in Ohms / 1000 ft.

7. Transformers are a significant impedance component and do not contribute any short circuit contribution. The analysis program provides a typical X/R ratio and uses this value and the specified impedance value to calculate per-unit reactance and resistance on the study base. The transformer impedance values were either obtained from the equipment nameplate, through the software library or typical standard industry values were used in the absence of any information. The transformer impedances, usually given on the nameplate in percent of the self-cooled kVA rating of the transformer, are converted to per unit impedances on the study bases. The transformer input data includes the following:

a. Column #1 - ID Name: Name of transformer on the study One-Line Diagram.

b. Column #2 – From Nom kV: Transformer nominal primary voltage

c. Column #3 – To Nom kV: Transformer nominal secondary voltage

d. Column #4 - MVA: Self cooled rating of the transformer.

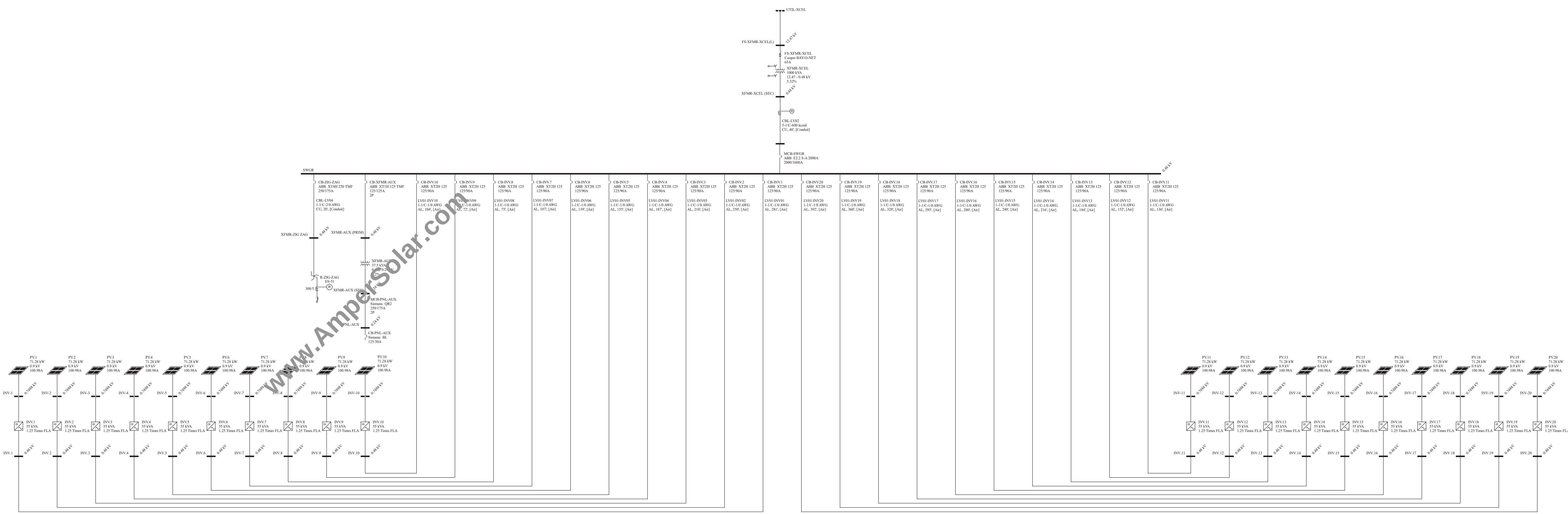
e. Column #5 – From Conn: The primary of the transformer winding connection type.

f. Column #6 – To Conn: The secondary of the transformer winding connection type.

g. Column #7 – Z (pu): Transformer per-unit positive-sequence impedance.

h. Column #8 – Z0 (pu): Transformer per-unit zero-sequence impedance.

i. Column #9 – X/R: Transformer X/R ratio.



2.4 FEEDER INPUT DATA

Feeder Input Data										
ID Name	No/Ph	Size	Length (ft)	Rating (A)	Material	Raceway Mtl	R1 (Ω/1000′)	X1 (Ω/1000′)	R0 (Ω/1000′)	X0 (Ω/1000′)
LV01-INV01	1	1/0	281	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV02	1	1/0	250	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV03	1	1/0	218	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV04	1	1/0	187	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV05	1	1/0	155	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV06	1	1/0	139	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV07	1	1/0	107	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV08	1	1/0	75	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV09	1	1/0	72	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV10	1	1/0	104	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV11	1	1/0	136	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV12	1	1/0	152	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV13	1	1/0	184	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV14	1	1/0	216	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV15	1	1/0	248	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV16	1	1/0	280	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV17	1	1/0	295	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV18	1	1/0	328	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV19	1	1/0	360	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
LV01-INV20	1	1/0	392	205	Aluminum	Air	0.184192	0.0276044	0.368385	0.0552087
CBL-LV02	5	600	40	1000	Copper	Conduit	0.0705	0.0397	0.2818	0.159
CBL-LV04	1	2/0	20	175	Copper	Conduit	0.0888	0.0405	0.3553	0.1621

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2.5 TRANSFORMER INPUT DATA

Input Data – Two-Winding Transformers								
ID Name	From Nom kV	To Nom kV	MVA	From Conn	To Conn	Z (pu)	Z0 (pu)	X/R
XFMR-XCEL	12.47	0.48	1	D	YG	5.32	5.32	6.11

Input Data – Zig-Zag Transformers									
ID Name	Base kV	Rating (kVA)	Imped (Ohm)	RG Ohm	XG Ohm	3RG Ohm	3XG Ohm + X0	R0 pu	X0 pu
XFMR-ZIG ZAG	0.48	110	6.7	0.257	0.1257	0.771	7.077	334.635	3071.7

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SECTION 3 - ENGINEERING ANALYSIS

3.1 MODES OF OPERATION AND SCENARIOS

The Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility power system under study includes one (1) basic Modes of Operation.

1. Mode 1: Solar PV operating under normal conditions.

3.2 ASSUMPTIONS AND CLARIFICATIONS

1. The short circuit contributions of photo-voltaic modules with inverters for any type of fault exist but are typically very low and can be negligible.

2. Unless otherwise provided, transformer X/R ratios are obtained from ANSI C37.010.

3. System voltage is modeled at 100% nominal.

4. Maximum clearing time (arc duration) is 2 seconds. This is based on IEEE Standard 1584-2018, Annex B, Instructions and Examples. Even though a protective device may have a longer trip time for the calculated arc current, the time is limited for analysis purposes because it is reasonable to assume that a worker will either move away from the arc or be knocked away by the blast in 2 seconds.

5. Arc Flash Hazard Analysis and results are determined for the entire equipment and include a single incident energy value that is determined for the entire equipment enclosure based on worst case scenario. This is typical for all equipment including equipment that may have compartmentalized construction.

6. Chint inverter model number CPS SCA50KTL-DO/US-480 maximum AC fault current contribution is set to 5 milliseconds as per manufacturer recommendations.

7. The main electrical switchgear (SWGR) incident energy is calculated at the line side of the SWGR main load interrupter switch. The incident energy value is applied to all three (3) vertical sections of the SWGR. One (1) arc flash label will be provided for each vertical sections.

SECTION 4 - SHORT CIRCUIT STUDY

1. The purpose of a Short Circuit Study is to determine the calculated value of fault currents at electrical equipment. The study models the current that flows in the power system under abnormal conditions and determines the prospective fault currents and compares those calculated values with the actual equipment ratings to determine if the equipment is properly rated.

2. Short-circuit currents were calculated for a three-phase bolted fault and single-line-to-ground fault at each equipment bus shown on the Study One-Line Diagram. The system was modeled for worst-case fault currents that included the assumption that all motors (known and assumed) were connected to the system and running at their full load.

3. The Short Circuit Study was performed using EASY POWER computer program based on the ANSI short circuit calculation method and ANSI Standards C37.010, C37.5 and C37.13. The systematic Short Circuit Study begins by creating a system one-line diagram within the program and defining all electrical characteristics of the power system.

4. The computer program simulates a fault on each equipment bus and models the current that flows in the power system under abnormal conditions and calculates the maximum short-circuit fault current at each equipment bus included in the analysis model. The results include the short-circuit contribution from all buses connected to the faulted bus. This calculation verifies if circuit components are capable of withstanding the mechanical and thermal stresses experienced under fault conditions and interrupt the short-circuit currents available.

5. The results of the Short Circuit Study and related analysis are summarized in Short Circuit Tables and represent the maximum short circuit values. The tables and results include Momentary Fault Values and Interrupting Fault Values for three-phase bolted and single-line-to-ground short circuit values.

6. Momentary Fault Current: The momentary fault current is defined as the short circuit peak current that flows at the first one-half cycle after the onset of the fault. Electrical apparatus must withstand the mechanical and thermal effects of this momentary current. Protective devices and switches must be capable of closing and latching into this momentary current. Momentary current can be highly asymmetrical (with the time axis). The calculated first-cycle short circuit current is used to evaluate equipment mechanical strength requirements and to determine interrupting duty for fuses and circuit breakers. This sub-transient period is the initial stage of the short circuit current and lasts approximately for the first five cycles after the fault. During this period, the fault current is at its highest value. This is the current that circuit breakers and fuses will have to interrupt, and therefore, it is this value that determines the interrupting capacity of the devices and equipment. This calculation verifies if circuit components are capable of withstanding the mechanical and thermal stresses experienced under fault conditions and interrupt the short-circuit currents available. These calculations also determine the time current coordination of protective devices.

7. Interrupting Fault Current: The interrupting fault current is defined as the short circuit current that flows through a protective device at the time of its contact separation. The interrupting duty of a circuit breaker may be lower than its associated closing and latching (momentary) rating. The interrupting current tends to be more symmetrical with the time axis than the momentary fault current. Medium and high voltage circuit breakers in particular may have interrupting ratings based on contact parting times of 3 or 5 cycles after the onset of the fault.

8. The short circuit calculations and results include short circuit currents for a three-phase bolted fault and single-line-to-ground fault at each electrical equipment bus shown on the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota Facility Study One-Line Diagram drawing. A three-phase bolted fault is one in which the three phases are simultaneously short-circuited ("bolted") at a given point in the system, with no current limiting impedance present between phases. This type of fault is considered to produce the highest magnitude of current at any given location. In a solidly grounded system, such as that of the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility, there are certain conditions under which a single-line-to-ground fault could produce short-circuit current in excess of that produced by a three-phase bolted fault. However, such an occurrence would be unusual due to the magnitude of zero-sequence impedances present in ground faults, which are not present in three phase faults. Therefore, to verify the equipment ratings for both conditions, calculations were performed, and result presented for three phase faults and single-line-to-ground faults with power system worst-case short circuit current configuration.

9. The calculated Momentary first-cycle short circuit currents are used to evaluate electrical equipment and protective devices ratings in the Equipment and Device Evaluation Study.

10. Where a device may respond to asymmetrical current, the maximum value of such current is determined by applying a multiplying factor to the calculated first-cycle symmetrical current. The calculated X/R ratio is used to predict the rate of decay of any DC component, which determines the amount of asymmetry at any time after the occurrence of a fault. This is particularly important when applied to fast-acting protective devices (i.e., fuses or instantaneous trip features in circuit breakers).

11. The short circuit calculations were performed using actual utility contributions, and PV solar modules. The calculations were performed to determine symmetrical fault currents at the first half-cycle (momentary duty) and 3-8 cycles (interrupting duty) after the occurrence of a three-phase bolted fault or a ground fault for all equipment within the system.

12. The calculated three-phase bolted, and single-line-to-ground short circuit values are based upon the results of the short circuit report generated by the analysis program.

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13. Three-Phase and Single-Line-to-Ground (SLG) Momentary and Interrupting fault current tables provide a summary of the Short Circuit Study results. The following table column headings describe the results:

    a. Column #1 – Bus Name: The names in this column correlate to the names implemented in the software system model (reference the Study One Line within this report) These locations correspond to equipment.

    b. Column #2 – Bus kV: The values in this column show the nominal voltage of the equipment bus name noted in Column #1.

    c. Column #3 – Sym Amps: This column displays the three-phase or SLG RMS value of the AC component available for the equipment bus name referenced in Column #1. This current value corresponds to the system operating conditions that will result in the worst- case calculated value.

    d. Column #4 –X/R Ratio: Three phase or SLG X/R ratio.

    e. Column #5 – Mult Factor: Multiplication factor applied to the symmetrical fault current to calculate the asymmetrical fault current.

    f. Column #6 – 3 Phase Asym (kA): This column displays the RMS value of the AC and DC components (total) combined available for the bus location referenced in Column #1. This current value corresponds to the system operating conditions that will result in the worst-case calculated value.

4.1 LINE TO LINE DC MOMENTARY FAULT CURRENT RESULTS

Line to Line Low Voltage DC Momentary Fault Current Results							
Line to Line Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV-1	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-2	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-3	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-4	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-5	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-6	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-7	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-8	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-9	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-10	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-11	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101

Line to Line Low Voltage DC Momentary Fault Current Results							
Line to Line Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV-12	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-13	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-14	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-15	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-16	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-17	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-18	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-19	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-20	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101

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4.2 THREE-PHASE AC MOMENTARY FAULT CURRENT RESULTS

3 Phase Low Voltage AC Momentary Fault Current Results							
3 PHASE Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV.1	0.48	4846.4	0.39	1	4846.4	LVPCB	4846.4
						Fuse X/R = 1.73	4846.4
						Fuse X/R = 4.9	4846.4
						MCCB 10-20 kA	4846.4
						MCCB >20 kA	4846.4
INV.2	0.48	5367.7	0.42	1	5367.8	LVPCB	5367.7
						Fuse X/R = 1.73	5367.7
						Fuse X/R = 4.9	5367.7
						MCCB 10-20 kA	5367.7
						MCCB >20 kA	5367.7
INV.3	0.48	6034.3	0.45	1	6034.3	LVPCB	6034.3
						Fuse X/R = 1.73	6034.3
						Fuse X/R = 4.9	6034.3
						MCCB 10-20 kA	6034.3
						MCCB >20 kA	6034.3
INV.4	0.48	6852	0.49	1	6852.2	LVPCB	6852
						Fuse X/R = 1.73	6852
						Fuse X/R = 4.9	6852
						MCCB 10-20 kA	6852
						MCCB >20 kA	6852
INV.5	0.48	7950.4	0.56	1	7951.[illegible]	LVPCB	7950.4
						Fuse X/R = 1.73	7950.4
						Fuse X/R = 4.9	7950.4
						MCCB 10-20 kA	7950.4
						MCCB >20 kA	7950.4
INV.6	0.48	8632.5	0.6	1	8634.1	LVPCB	8632.5
						Fuse X/R = 1.73	8632.5
						Fuse X/R = 4.9	8632.5
						MCCB 10-20 kA	8632.5
						MCCB >20 kA	8632.5
INV.7	0.48	10373	0.71	1	10380.5	LVPCB	10373
						Fuse X/R = 1.73	10373
						Fuse X/R = 4.9	10373
						MCCB 10-20 kA	10373
						MCCB >20 kA	10373
INV.8	0.48	12830.4	0.92	1	12873.1	LVPCB	12830.4
						Fuse X/R = 1.73	12830.4
						Fuse X/R = 4.9	12830.4
						MCCB 10-20 kA	12830.4
						MCCB >20 kA	12830.4
INV.9	0.48	13108.7	0.94	1	13159.7	LVPCB	13108.7
						Fuse X/R = 1.73	13108.7
						Fuse X/R = 4.9	13108.7
						MCCB 10-20 kA	13108.7
						MCCB >20 kA	13108.7
INV.10	0.48	10568.3	0.73	1	10577	LVPCB	10568.3
						Fuse X/R = 1.73	10568.3
						Fuse X/R = 4.9	10568.3
						MCCB 10-20 kA	10568.3
						MCCB >20 kA	10568.3
INV.11	0.48	8772.6	0.61	1	8774.5	LVPCB	8772.6
						Fuse X/R = 1.73	8772.6
						Fuse X/R = 4.9	8772.6
						MCCB 10-20 kA	8772.6
						MCCB >20 kA	8772.6

3 Phase Low Voltage AC Momentary Fault Current Results							
3 PHASE Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV.12	0.48	8070.5	0.56	1	8071.4	LVPCB	8070.5
						Fuse X/R = 1.73	8070.5
						Fuse X/R = 4.9	8070.5
						MCCB 10-20 kA	8070.5
						MCCB >20 kA	8070.5
INV.13	0.48	6942.5	0.5	1	6942.8	LVPCB	6942.5
						Fuse X/R = 1.73	6942.5
						Fuse X/R = 4.9	6942.5
						MCCB 10-20 kA	6942.5
						MCCB >20 kA	6942.5
INV.14	0.48	6081.3	0.45	1	6081.4	LVPCB	6081.3
						Fuse X/R = 1.73	6081.3
						Fuse X/R = 4.9	6081.3
						MCCB 10-20 kA	6081.3
						MCCB >20 kA	6081.3
INV.15	0.48	5405.2	0.42	1	5405.2	LVPCB	5405.2
						Fuse X/R = 1.73	5405.2
						Fuse X/R = 4.9	5405.2
						MCCB 10-20 kA	5405.2
						MCCB >20 kA	5405.2
INV.16	0.48	4861.7	0.39	1	4861.7	LVPCB	4861.7
						Fuse X/R = 1.73	4861.7
						Fuse X/R = 4.9	4861.7
						MCCB 10-20 kA	4861.7
						MCCB >20 kA	4861.7
INV.17	0.48	4642.3	0.38	1	4642.3	LVPCB	4642.3
						Fuse X/R = 1.73	4642.3
						Fuse X/R = 4.9	4642.3
						MCCB 10-20 kA	4642.3
						MCCB >20 kA	4642.3
INV.18	0.48	4222.2	0.36	1	4222.2	LVPCB	4222.2
						Fuse X/R = 1.73	4222.2
						Fuse X/R = 4.9	4222.2
						MCCB 10-20 kA	4222.2
						MCCB >20 kA	4222.2
INV.19	0.48	3881.1	0.35	1	3881.1	LVPCB	3881.1
						Fuse X/R = 1.73	3881.1
						Fuse X/R = 4.9	3881.1
						MCCB 10-20 kA	3881.1
						MCCB >20 kA	3881.1
INV.20	0.48	3590.6	0.34	1	3590.6	LVPCB	3590.6
						Fuse X/R = 1.73	3590.6
						Fuse X/R = 4.9	3590.6
						MCCB 10-20 kA	3590.6
						MCCB >20 kA	3590.6
SWGR	0.48	21830.9	5.6	1.3	28376	LVPCB	21830.9
						Fuse X/R = 1.73	28709.5
						Fuse X/R = 4.9	22397.3
						MCCB 10-20 kA	24631.6
						MCCB >20 kA	22397.3
XFMR-XCEL (SEC)	0.48	22305.5	6.05	1.32	29446	LVPCB	22305.5
						Fuse X/R = 1.73	29744.7
						Fuse X/R = 4.9	23204.9
						MCCB 10-20 kA	25519.8
						MCCB >20 kA	23204.9
XFMR-ZIG ZAG	0.48	19940.4	3.32	1.16	23209.1	LVPCB	19940.4
						Fuse X/R = 1.73	23480.4
						Fuse X/R = 4.9	19940.4

3 Phase Low Voltage AC Momentary Fault Current Results							
3 PHASE Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
						MCCB 10-20 kA	20145.3
						MCCB >20 kA	19940.4

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4.3 LINE TO LINE DC INTERRUPTING FAULT CURRENT RESULTS

Line to Line Low Voltage DC Interrupting Fault Current Results					
Line to Line Fault		Total Fault Currents			
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps
INV-1	0.749	101	0	1	101
INV-2	0.749	101	0	1	101
INV-3	0.749	101	0	1	101
INV-4	0.749	101	0	1	101
INV-5	0.749	101	0	1	101
INV-6	0.749	101	0	1	101
INV-7	0.749	101	0	1	101
INV-8	0.749	101	0	1	101
INV-9	0.749	101	0	1	101
INV-10	0.749	101	0	1	101
INV-11	0.749	101	0	1	101
INV-12	0.749	101	0	1	101
INV-13	0.749	101	0	1	101
INV-14	0.749	101	0	1	101
INV-15	0.749	101	0	1	101
INV-16	0.749	101	0	1	101
INV-17	0.749	101	0	1	101
INV-18	0.749	101	0	1	101
INV-19	0.749	101	0	1	101
INV-20	0.749	101	0	1	101

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4.4 THREE-PHASE AC INTERRUPTING FAULT CURRENT RESULTS

3 Phase Low Voltage AC Interrupting Fault Current Results					
3 PHASE Fault		Total Fault Currents			
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps
INV.1	0.48	4846.4	1.16	1	4846.4
INV.2	0.48	5367.7	1.16	1	5367.7
INV.3	0.48	6034.3	1.16	1	6034.3
INV.4	0.48	6852	1.17	1	6852
INV.5	0.48	7950.4	1.19	1	7950.4
INV.6	0.48	8632.5	1.21	1	8632.5
INV.7	0.48	10373	1.26	1	10373
INV.8	0.48	12830.4	1.38	1	12830.4
INV.9	0.48	13108.7	1.4	1	13108.7
INV.10	0.48	10568.3	1.27	1	10568.3
INV.11	0.48	8772.6	1.21	1	8772.6
INV.12	0.48	8070.5	1.2	1	8070.5
INV.13	0.48	6942.5	1.17	1	6942.5
INV.14	0.48	6081.3	1.16	1	6081.3
INV.15	0.48	5405.2	1.16	1	5405.2
INV.16	0.48	4861.7	1.16	1	4861.7
INV.17	0.48	4642.3	1.16	1	4642.3
INV.18	0.48	4222.2	1.16	1	4222.2
INV.19	0.48	3881.1	1.17	1	3881.1
INV.20	0.48	3590.6	1.17	1	3590.6
SWGR	0.48	21830.9	5.69	1	21831.2
XFMR-XCEL (SEC)	0.48	22305.5	6.14	1	22306.3
XFMR-ZIG ZAG	0.48	19940.4	3.47	1	19940.4

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4.5 LINE TO GROUND DC MOMENTARY FAULT CURRENT RESULT

Line to Ground Low Voltage DC Momentary Fault Current Results							
Line to Ground Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV-1	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-2	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-3	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-4	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-5	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-6	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-7	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-8	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-9	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-10	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-11	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101

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Line to Ground Low Voltage DC Momentary Fault Current Results							
Line to Ground Fault		**Total Fault Currents**				**Equipment Duties**	
Bus Name	**Bus kV**	**Sym Amps**	**X/R Ratio**	**Mult Factor**	**Asym Amps**	**Equip Type**	**Duty Amps**
INV-12	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-13	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-14	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-15	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-16	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-17	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-18	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-19	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101
INV-20	0.749	101	0	1	101	LVPCB	101
						Fuse X/R = 1.73	101
						Fuse X/R = 4.9	101
						MCCB 10-20 kA	101
						MCCB >20 kA	101

4.6 SINGLE-LINE TO GROUND AC MOMENTARY FAULT CURRENT RESULT

Single Line to Ground Low Voltage AC Momentary Fault Current Results							
S L-GND Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV.1	0.48	3689.7	0.35	1	3689.7	LVPCB	3689.7
						Fuse X/R = 1.73	3689.7
						Fuse X/R = 4.9	3689.7
						MCCB 10-20 kA	3689.7
						MCCB >20 kA	3689.7
INV.2	0.48	4095.2	0.37	1	4095.2	LVPCB	4095.2
						Fuse X/R = 1.73	4095.2
						Fuse X/R = 4.9	4095.2
						MCCB 10-20 kA	4095.2
						MCCB >20 kA	4095.2
INV.3	0.48	4618	0.39	1	4618	LVPCB	4618
						Fuse X/R = 1.73	4618
						Fuse X/R = 4.9	4618
						MCCB 10-20 kA	4618
						MCCB >20 kA	4618
INV.4	0.48	5266.7	0.42	1	5266.7	LVPCB	5266.7
						Fuse X/R = 1.73	5266.7
						Fuse X/R = 4.9	5266.7
						MCCB 10-20 kA	5266.7
						MCCB >20 kA	5266.7
INV.5	0.48	6152.8	0.47	1	6152.9	LVPCB	6152.8
						Fuse X/R = 1.73	6152.8
						Fuse X/R = 4.9	6152.8
						MCCB 10-20 kA	6152.8
						MCCB >20 kA	6152.8
INV.6	0.48	6712.7	0.5	1	6713	LVPCB	6712.7
						Fuse X/R = 1.73	6712.7
						Fuse X/R = 4.9	6712.7
						MCCB 10-20 kA	6712.7
						MCCB >20 kA	6712.7
INV.7	0.48	8181.2	0.59	1	8182.6	LVPCB	8181.2
						Fuse X/R = 1.73	8181.2
						Fuse X/R = 4.9	8181.2
						MCCB 10-20 kA	8181.2
						MCCB >20 kA	8181.2
INV.8	0.48	10375.6	0.74	1	10385.4	LVPCB	10375.6
						Fuse X/R = 1.73	10375.6
						Fuse X/R = 4.9	10375.6
						MCCB 10-20 kA	10375.6
						MCCB >20 kA	10375.6
INV.9	0.48	10634.9	0.76	1	10646.9	LVPCB	10634.9
						Fuse X/R = 1.73	10634.9
						Fuse X/R = 4.9	10634.9
						MCCB 10-20 kA	10634.9
						MCCB >20 kA	10634.9
INV.10	0.48	8350	0.6	1	8351.7	LVPCB	8350
						Fuse X/R = 1.73	8350
						Fuse X/R = 4.9	8350
						MCCB 10-20 kA	8350
						MCCB >20 kA	8350
INV.11	0.48	6828.8	0.51	1	6829.1	LVPCB	6828.8
						Fuse X/R = 1.73	6828.8
						Fuse X/R = 4.9	6828.8
						MCCB 10-20 kA	6828.8
						MCCB >20 kA	6828.8

Single Line to Ground Low Voltage AC Momentary Fault Current Results							
S L-GND Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
INV.12	0.48	6250.8	0.48	1	6251	LVPCB	6250.8
						Fuse X/R = 1.73	6250.8
						Fuse X/R = 4.9	6250.8
						MCCB 10-20 kA	6250.8
						MCCB >20 kA	6250.8
INV.13	0.48	5339.1	0.43	1	5339.1	LVPCB	5339.1
						Fuse X/R = 1.73	5339.1
						Fuse X/R = 4.9	5339.1
						MCCB 10-20 kA	5339.1
						MCCB >20 kA	5339.1
INV.14	0.48	4655.1	0.39	1	4655.1	LVPCB	4655.1
						Fuse X/R = 1.73	4655.1
						Fuse X/R = 4.9	4655.1
						MCCB 10-20 kA	4655.1
						MCCB >20 kA	4655.1
INV.15	0.48	4124.5	0.37	1	4124.5	LVPCB	4124.5
						Fuse X/R = 1.73	4124.5
						Fuse X/R = 4.9	4124.5
						MCCB 10-20 kA	4124.5
						MCCB >20 kA	4124.5
INV.16	0.48	3701.6	0.35	1	3701.6	LVPCB	3701.6
						Fuse X/R = 1.73	3701.6
						Fuse X/R = 4.9	3701.6
						MCCB 10-20 kA	3701.6
						MCCB >20 kA	3701.6
INV.17	0.48	3531.7	0.34	1	3531.7	LVPCB	3531.7
						Fuse X/R = 1.73	3531.7
						Fuse X/R = 4.9	3531.7
						MCCB 10-20 kA	3531.7
						MCCB >20 kA	3531.7
INV.18	0.48	3207.7	0.33	1	3207.7	LVPCB	3207.7
						Fuse X/R = 1.73	3207.7
						Fuse X/R = 4.9	3207.7
						MCCB 10-20 kA	3207.7
						MCCB >20 kA	3207.7
INV.19	0.48	2945.6	0.32	1	2945.6	LVPCB	2945.6
						Fuse X/R = 1.73	2945.6
						Fuse X/R = 4.9	2945.6
						MCCB 10-20 kA	2945.6
						MCCB >20 kA	2945.6
INV.20	0.48	2723.2	0.31	1	2723.2	LVPCB	2723.2
						Fuse X/R = 1.73	2723.2
						Fuse X/R = 4.9	2723.2
						MCCB 10-20 kA	2723.2
						MCCB >20 kA	2723.2
SWGR	0.48	20571.5	4.06	1.21	24985.1	LVPCB	20571.5
						Fuse X/R = 1.73	25353.1
						Fuse X/R = 4.9	20571.5
						MCCB 10-20 kA	21752
						MCCB >20 kA	20571.5
XFMR-XCEL (SEC)	0.48	22306.7	6.02	1.32	29423	LVPCB	22306.7
						Fuse X/R = 1.73	29724.2
						Fuse X/R = 4.9	23188.9
						MCCB 10-20 kA	25502.2
						MCCB >20 kA	23188.9
XFMR-ZIG ZAG	0.48	17125.5	2.17	1.08	18410.9	LVPCB	17125.5
						Fuse X/R = 1.73	18149.7

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Single Line to Ground Low Voltage AC Momentary Fault Current Results							
S L-GND Fault		Total Fault Currents				Equipment Duties	
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps	Equip Type	Duty Amps
						Fuse X/R = 4.9	17125.5
						MCCB 10-20 kA	17125.5
						MCCB >20 kA	17125.5

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4.7 LINE TO GROUND DC INTERRUPTING FAULT CURRENT RESULTS

Line to Ground Low Voltage DC Interrupting Fault Current Results					
L-GND Fault		**Total Fault Currents**			
Bus Name	**Bus kV**	**Sym Amps**	**X/R Ratio**	**Mult Factor**	**Asym Amps**
INV-1	0.749	101	0	1	101
INV-2	0.749	101	0	1	101
INV-3	0.749	101	0	1	101
INV-4	0.749	101	0	1	101
INV-5	0.749	101	0	1	101
INV-6	0.749	101	0	1	101
INV-7	0.749	101	0	1	101
INV-8	0.749	101	0	1	101
INV-9	0.749	101	0	1	101
INV-10	0.749	101	0	1	101
INV-11	0.749	101	0	1	101
INV-12	0.749	101	0	1	101
INV-13	0.749	101	0	1	101
INV-14	0.749	101	0	1	101
INV-15	0.749	101	0	1	101
INV-16	0.749	101	0	1	101
INV-17	0.749	101	0	1	101
INV-18	0.749	101	0	1	101
INV-19	0.749	101	0	1	101
INV-20	0.749	101	0	1	101

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4.8 SINGLE-LINE TO GROUND AC INTERRUPTING FAULT CURRENT RESULTS

Line to Ground Low Voltage AC Interrupting Fault Current Results					
S L-GND Fault		Total Fault Currents			
Bus Name	Bus kV	Sym Amps	X/R Ratio	Mult Factor	Asym Amps
INV.1	0.48	3689.7	1.19	1	3689.7
INV.2	0.48	4095.2	1.18	1	4095.2
INV.3	0.48	4618	1.18	1	4618
INV.4	0.48	5266.7	1.18	1	5266.7
INV.5	0.48	6152.8	1.18	1	6152.8
INV.6	0.48	6712.7	1.19	1	6712.7
INV.7	0.48	8181.2	1.22	1	8181.2
INV.8	0.48	10375.6	1.3	1	10375.6
INV.9	0.48	10634.9	1.31	1	10634.9
INV.10	0.48	8350	1.23	1	8350
INV.11	0.48	6828.8	1.19	1	6828.8
INV.12	0.48	6250.8	1.18	1	6250.8
INV.13	0.48	5339.1	1.18	1	5339.1
INV.14	0.48	4655.1	1.18	1	4655.1
INV.15	0.48	4124.5	1.18	1	4124.5
INV.16	0.48	3701.6	1.19	1	3701.6
INV.17	0.48	3531.7	1.19	1	3531.7
INV.18	0.48	3207.7	1.2	1	3207.7
INV.19	0.48	2945.6	1.21	1	2945.6
INV.20	0.48	2723.2	1.22	1	2723.2
SWGR	0.48	20571.5	4.27	1	20571.5
XFMR-XCEL (SEC)	0.48	22306.7	6.12	1	22307.4
XFMR-ZIG ZAG	0.48	17125.5	2.14	1	17125.5

SECTION 5 - EQUIPMENT AND DEVICE EVALUATION STUDY

1. The Equipment and Device Evaluation Study was also performed within the integrated computer program EASY POWER. Based on the results from the Short Circuit Study and calculated maximum short-circuit fault current at each equipment bus included in the analysis model, this maximum short-circuit fault current was compared to the device and equipment ratings to determine if the equipment can withstand the levels of short circuit current anticipated by the calculations.

2. Equipment and devices are tested and rated to withstand a level of fault current and should be applied to within its rating. If the equipment and device is under rated where the calculated short circuit current is higher than the rating, the equipment and devices are subject to failure and could lead to more serious hazards. The equipment ratings are required to conform to the requirements of the National Electric Code Article 110.9.

3. This Section includes Equipment Duty Results Tables that show the tabular results of the Equipment and Device Evaluation Study. The following table column headings describe the results.

   a. Column #1 – Bus Name: The names in this column correlate to the names implemented in the software system model (reference the Study One Line within this report) These locations correspond to equipment.

   b. Column #2 – Voltage (V) Bus/Device: The values in this column show the nominal voltage of the equipment.

   c. Column #3 – Equipment ID: Nomenclature of the bus or protective device as referenced within the analysis model an on the Study One Line Diagram.

   d. Column #4 – Equipment Manufacturer: Manufacturer name of the equipment identified in Column #3.

   e. Column #5 – Equipment Style: the brand name of the equipment identified in Column #3.

   f. Column #6 – Equipment Test Standard: The standard based on which the equipment is tested symmetrical fault withstand.

   g. Column #7 – Ratings 1/2 Cycle (kA): Equipment half-cycle fault withstand.

   h. Column #8 – Duties 1/2 Cycle (kA): The calculated half-cycle duty current at the equipment.

   i. Column #9 – Duties 1/2 Cycle Percent: The available percentage of the equipment interrupting rating.

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5.1 THREE-PHASE TO GROUND FAULT EQUIPMNET DUTY RESULTS

3-Phase to Ground Fault Equipment Results								
Bus		Equipment				Ratings	Duties	
Name	Base kV	ID	Manufacturer	Style	Test Standard	1/2 Cycle (kA)	1/2 Cycle (kA)	1/2 Cycle Percent
SWGR	0.48	CB-INV.1	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.2	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.3	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.4	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.5	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.6	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.7	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.8	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.9	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.10	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.11	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.12	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.13	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.14	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.15	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.16	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.17	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.18	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.19	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-INV.20	ABB	XT2H 125	ANSI-SYM	65	22.313	34.30%
		CB-XFMR-AUX	ABB	XT1H 125 TMF	ANSI-SYM	65	22.397	34.50%
		CB-ZIG-ZAG	ABB	XT4H 250 TMF	ANSI-SYM	65	22.397	34.50%
		MCB-SWGR	ABB	E2.2 S-A 2000A	ANSI-SYM	65	20.183	31.10%
		SWGR	EMI		ANSI-SYM	65	21.831	33.60%

5.2 SINGLE-LINE TO GROUND FAULT EQUIPMENT DUTY RESULTS

Single Line to Ground Fault Equipment Duty Results								
Bus		Equipment				Ratings	Duties	
Name	Base kV	ID	Manufacturer	Style	Test Standard	1/2 Cycle (kA)	1/2 Cycle (kA)	1/2 Cycle Percent
SWGR	0.48	CB-INV.1	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.2	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.3	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.4	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.5	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.6	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.7	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.8	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.9	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.10	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.11	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.12	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.13	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.14	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.15	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.16	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.17	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.18	ABB	XT2H 125	ANSI-SYM	65	20.489	31.50%
		CB-INV.19	ABB	XT2H 125	ANSI-SYM	65	20.49	31.50%
		CB-INV.20	ABB	XT2H 125	ANSI-SYM	65	20.49	31.50%
		CB-XFMR-AUX	ABB	XT1H 125 TMF	ANSI-SYM	65	20.571	31.60%
		CB-ZIG-ZAG	ABB	XT4H 250 TMF	ANSI-SYM	65	20.557	31.60%
		MCB-SWGR	ABB	E2.2 S-A 2000A	ANSI-SYM	65	18.914	29.10%
		SWGR	EMI		ANSI-SYM	65	20.571	31.60%

SECTION 6 - PROTECTIVE DEVICE COORDINATION STUDY

1. The primary function of protective devices is to detect system disturbances and isolate the disturbance by activating the appropriate circuit interrupting devices to create a safe and reliable power distribution system that will isolate any faulted region within its system, while eliminating any potential hazards to both personnel and equipment.

2. The Protective Device Coordination Study is performed to properly select and determine settings of protective devices to ensure system protection and fault clearing selectivity. The objective of a protection scheme in a power system is to minimize hazards to personnel and equipment while causing the least disruption of power service. In a properly coordinated system, a fault results in interruption of only the minimum amount of equipment necessary to isolate the faulted portion of the system. The power supply to loads in the remainder of the system is maintained. The goal is to achieve an optimum balance between equipment protection and selective fault isolation that is consistent with the operating requirements of the overall power system. A coordinated system is one in which the necessary compromises between maximized protection and optimum selectivity have been meet.

3. The Protective Device Coordination Study was performed using the computer program EASY POWER and using the results of the Short Circuit Study to establish a minimum and a maximum current level at which proper coordination must be achieved. The software includes electrical characteristics of each protective device, where a time current characteristic curve (TCC) is generated from the software library for each protective device examined.

4. The protective device TCCs are represented graphically with device operating time versus current magnitude to show the protective device tripping characteristics and coordination between devices. Several devices are included on the same TCC within a protective zone to show graphically the magnitude of protection and coordination that exists between each piece of equipment selected within a zone.

5. In developing the device settings, consideration was given to both isolation of faults and protection of equipment and circuit elements. Efforts were made to provide the best coordination possible with the existing protective devices. It should be understood that selective coordination between two instantaneous trip units cannot be achieved for fault levels above the instantaneous pickup of the upstream device. There is some overlapping of curves that cannot be avoided.

6. The results of the Protective Device Coordination Study indicate that most protective devices are somewhat coordinated with existing device sizes and trip settings. Improved coordination is possible for some adjustable device settings. The ability to improve coordination is dependent on exact equipment and the range of adjustment available for specific protective devices. For example, trip elements in molded case circuit breakers may not include the functions or adjustment range available with solid-state trip devices

used in metal-clad switchgear breakers. Therefore, coordination between upstream or downstream devices may be limited.

7. Where devices are adjustable type, the recommended settings have been chosen to provide the optimum protection and selectivity to coordinate with upstream and downstream devices. Settings for these circuit breakers have been made in accordance with the National Electric Code and ANSI requirements.

8. Protective device coordination and calculations in this report are based on protective devices and trip settings contained herein. If changes in devices or trip settings are required to prevent nuisance tripping, then the Protective Device Coordination Study and Arc Flash Hazard Analysis including related calculations for the circuit must be revised to incorporate the new device settings.

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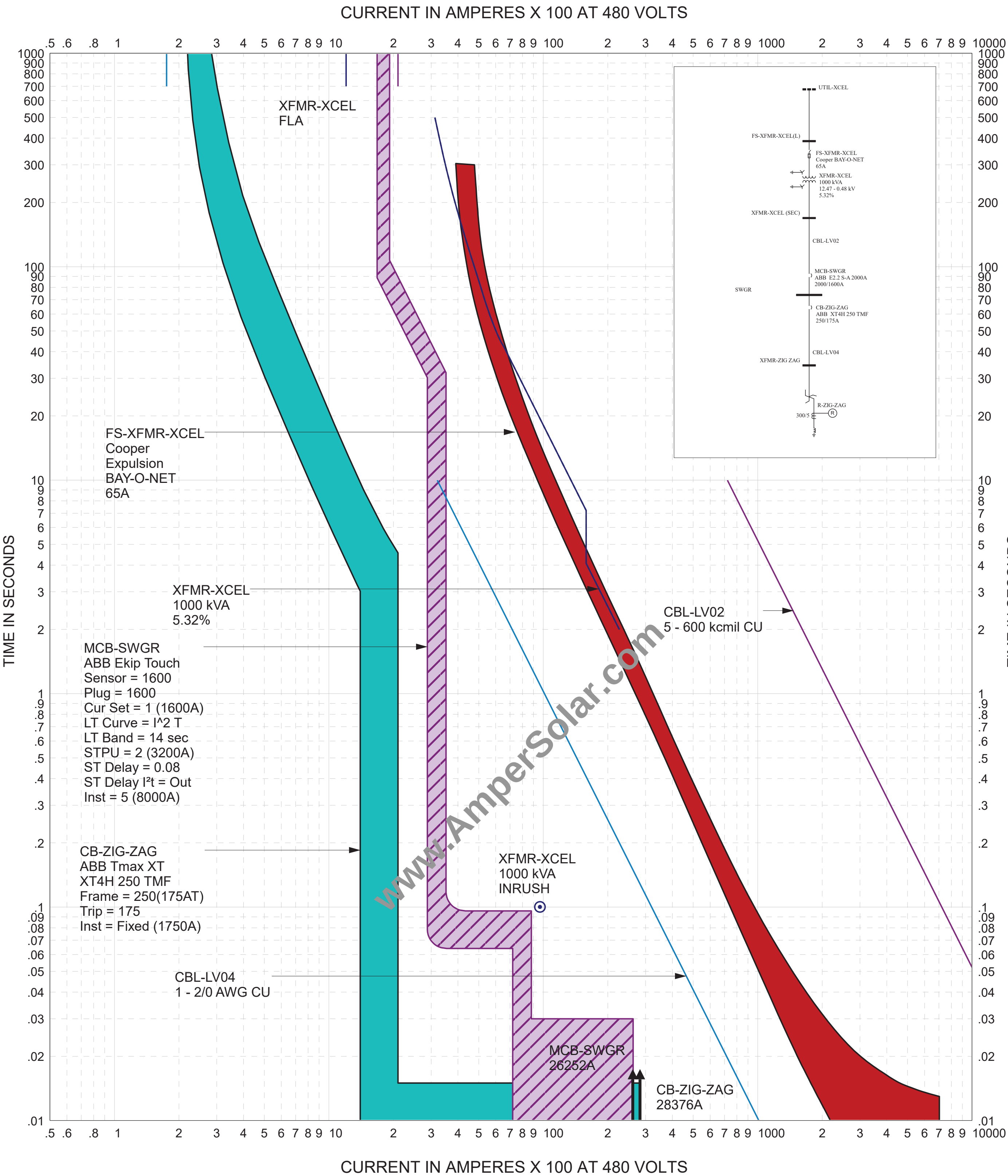
6.1 TIME-CURRENT COORDINATION CURVES (TCC)



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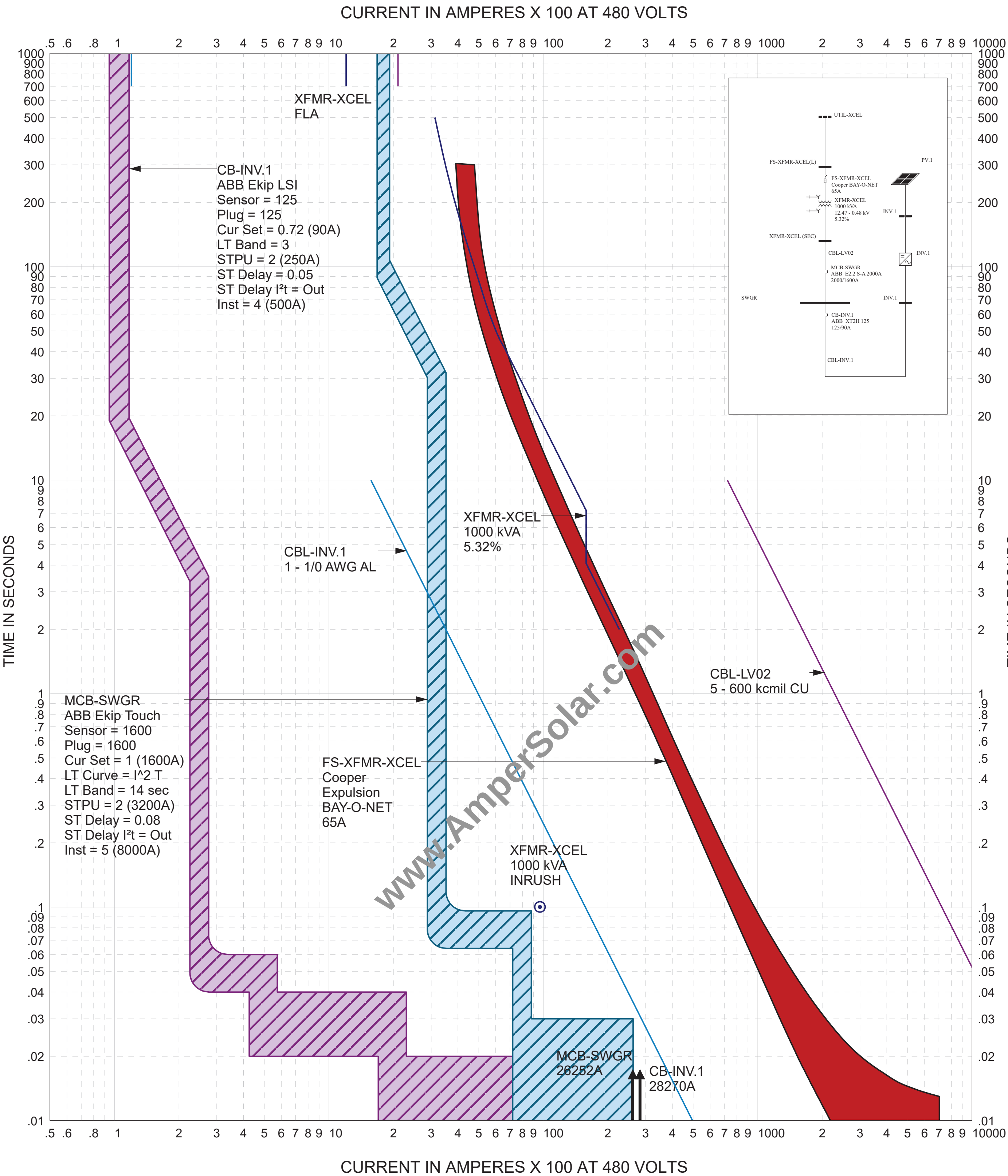
ENGINEERING | CONSULTING | ESTIMATING

EasyPower®
TIME-CURRENT CURVES

TCC-1

Recommended settings show best possible coordination

FAULT: 3 Phase
DATE: 05/20/2021
BY: D. Evrim Ercan, P.E.
REVISION: 0



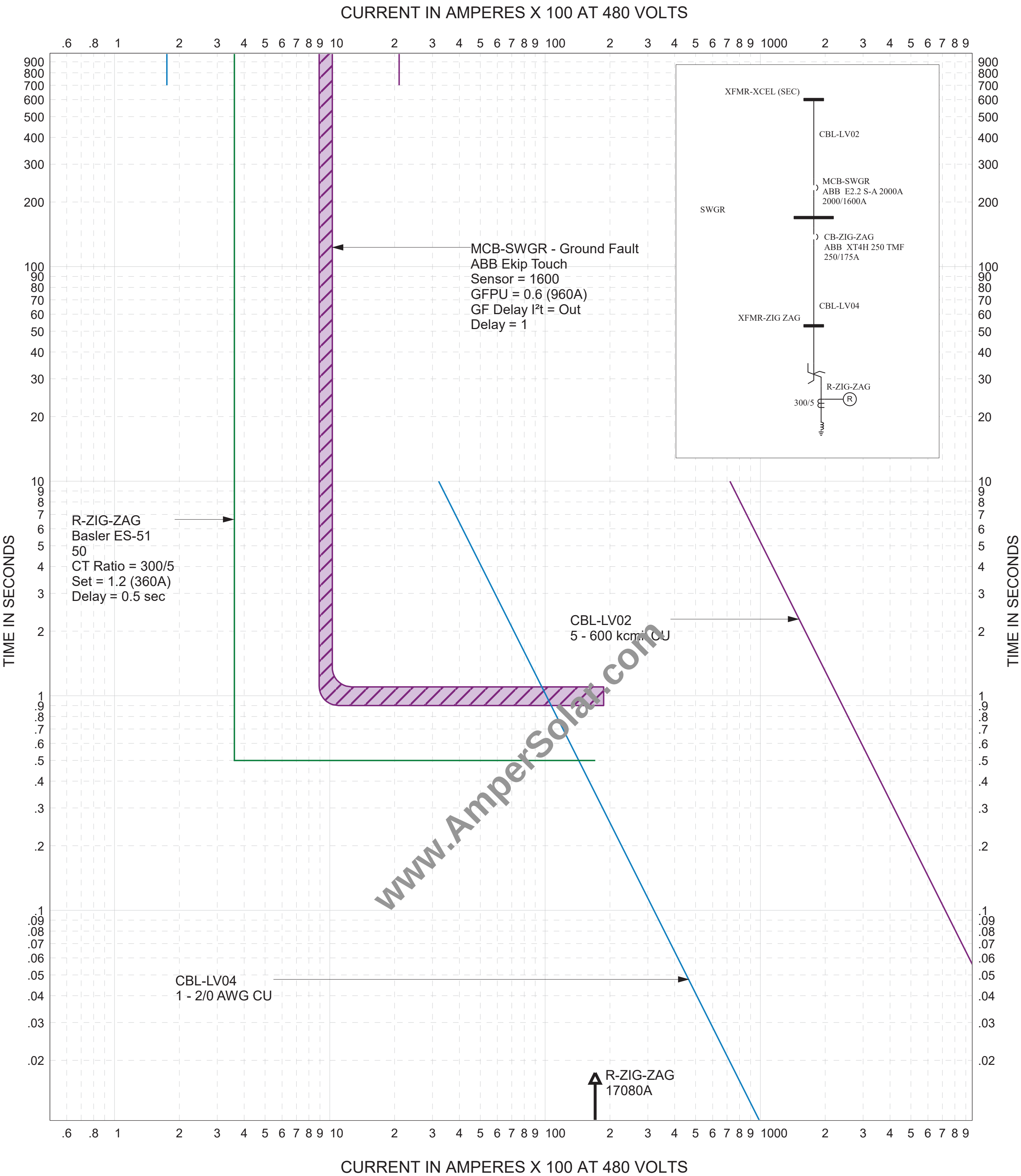
EasyPower®

TIME-CURRENT CURVES

TCC-2

Recommended settings show best possible coordination

FAULT: 3 Phase
DATE: 05/20/2021
BY: D. Evrim Ercan, P.E.
REVISION: 0



DURAK EVRIM ERCAN P.E.	*EasyPower®* TIME-CURRENT CURVES	TCC-3

Recommended settings show best possible coordination

FAULT: SLG
DATE: 05/20/2021
BY: D. Evrim Ercan, P.E.
REVISION: 0

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6.2 PROTECTIVE DEVICE SETTING SOLID STATE CIRCUIT BREAKERS

Solid State Circuit Breakers

SST					LTPU		LT Delay	STPU				Inst			Ground Trip			
ID	Manufacturer	Type	Frame/ Sensor	tap/plug	Setting	Trip (A)	Band	Setting	Trip (A)	Band	I2t	Setting	Override	Trip (A)	Pickup	Trip (A)	Delay	I2t
CB-INV.1	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.2	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.3	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.4	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.5	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.6	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.7	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.8	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.9	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.10	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.11	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.12	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.13	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.14	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.15	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.16	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.17	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.18	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.19	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
CB-INV.20	ABB	Ekip LSI	125	125	0.72	90	3	2	250	0.05	Out	4	Pickup	500				
MCB-SWGR	ABB	Ekip Touch	2000	1600	1.00	1600	14	2	3200	0.08	Out	5	Pickup	8000	0.6	1200	1	Out

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6.3 PROTECTIVE DEVICE SETTINGS – THERMAL MAGNETIC CIRCUIT BREAKERS

Thermal Magnetic Circuit Breakers							
Thermal Magnetic Breaker						Instantaneous	
ID	Manufacturer	Type	Style	Frame	Trip	Setting	Trip (A)
CB-ZIG-ZAG	ABB	Tmax XT	XT4H 250 TMF	250(175AT)	175	Fixed	1750

6.4 PROTECTIVE DECIVE SETTINGS – SOLID STATE RELAYS

Solid State Relays							
Relay					Inst		Delay
ID	Manufacturer	Type	Device Function	CT Ratio	Setting	PA	Setting
R-ZIG-ZAG	Basler	ES-51	50N	300/5	1.2	360	0.5

6.5 PROTECTIVE DEVICE SETTINGS - FUSES

Fuses						
ID	**Manufacturer**	**Type**	**Style**	**Model**	**kV**	**Size**
FS-XFMR-XCEL	Cooper	Expulsion	BAY-O-NET	Dual Sensing	15.5	65A

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SECTION 7 - ARC FLASH HAZARD ANALYSIS

1. The study report presents the arc flash results from a compilation of each of these Modes of Operations and Scenarios and is based on the worst-case arc flash values for the recommended device settings.

2. The calculations made in this arc flash hazard analysis conform to IEEE-1584 and NFPA 70E. Actual heat and radiation exposure may be more or less than reflected in the analysis and depend on a variety of factors including but not limited to operational condition of the power system and equipment, magnitude of the fault current, type of fault and event leading to the fault.

3. The calculation of arc flash incident energy is based on the results of the Short Circuit Study from which two fault currents are calculated:

    a. Bolted Fault Current: Which is the fault current generated by a three-phase fault assuming zero impedance at the point of the fault.

    b. Arcing Fault Current: Which is the current flowing through the electrical arc plasma. This fault is normally less than the bolted fault current since it is opposed by the arc resistance.

4. Calculations are based on IEEE-1584, using an arc flash boundary which is equivalent to 1.2 cal/cm² of incident energy. Although the arc flash calculation procedure is based upon NFPA 70E and IEEE-1584 equations and methods. The values produced by the analysis software are based on laboratory values, in which arc current incident energy was measured and recorded under a specific set of test conditions. The calculations are derived from theory and research involving arc current incident energy measurements conducted under the test conditions. Therefore, calculation results under this study can be considered statistical in nature as the actual incident energy from an arc flash may be more or less severe than indicated by these models and then the hazard presented by an actual arc flash exposure. Additionally, the arc flash calculations do not consider hazards associated with the splattering of molten metal, explosively propelled pieces of equipment and air pressure shock waves.

5. The incident energy associated with an arc flash is dependent upon the following parameters that are required to make the calculation:

    a. The maximum "bolted fault" three-phase and single-line to ground short circuit current available at the equipment and the minimum fault level at which the arc will self-sustain.
    b. The total protective device clearing time (upstream of the prospective arc location) at the maximum short circuit current and the minimum fault level at which the arc will self- sustain.

    c. The distance of the worker from the prospective arc for the task to be performed.

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6. Arc flash boundaries are required around electrical equipment when an individual works on or in the proximity of exposed energized components. This includes conducting activities such as examination, visual verification of the state of disconnecting devices, adjustment, servicing, maintenance or troubleshooting and during lockout/tag out procedures. Research has shown that permanent injury results from an arc flash that causes an incident energy of 1.2 cal/cm² or greater at the skins surface.

    a. The Limited Approach Boundary listed in NFPA 70E can be defined as the closest an unqualified person can get to an exposed, energized conductor of circuit part.

    b. The Flash Protection Boundary is the distance from an exposed, energized conductor or circuit part where a person would receive the onset of a second degree burn on unprotected skin, if not properly protected by flame resistant (FR) clothing. This is the closest that anyone may approach without the use of PPE. This boundary is the distance from the arc source where there is potential heat energy of 1.2 calories/cm² falling on the surface of the skin for 0.1 seconds.

    c. Whichever of these boundaries is furthest from the exposed, energized element is where barriers and signs need to be placed.

7. Results are calculated based on bus gaps and enclosure sizes and worst-case busbar configuration as identified in the table below.

Equip Type	Lower Voltage Limit	Upper Voltage Limit	Busbar Config (Worst Case)	Busbar Gap (mm)	Box Height (mm)	Box Width (mm)	Box Depth (mm)	Working Distance (in)
Control Panel	50	600	VCB/VCBB	25	355.6	304.8	264.2	18
Panelboard	50	600	VCB/VCBB	25	355.6	304.8	264.2	18
Switchboard	50	600	VCB/VCBB/HCB	32	508	508	508	18
Transformer Terminal	50	600	VCB	32	508	508	508	18

8. The Arc Flash Hazard Analysis considers each system location within the scope of the study.

9. The power analysis software determines the available fault currents for each location from the Short Circuit Study and the clearing time of the device protecting the same location from the Protective Device Coordination Study. The time duration of the arc is determined by calculating the arcing fault current through the protective device that will clear the fault. From these determinations, the potential incident energy is calculated for each location.

10. Accurate fault currents and device clearing times are extremely important in deriving reliable results. A conservative (high) fault current value could yield a faster clearing time of a protective device, and the calculated incident energy may actually be less than

the incident energy calculated for a lower magnitude of fault current and a longer clearing time.

11. The time duration of the arc is determined by calculating the arcing fault current through the protective device that will clear the fault. It is important to calculate the arcing current as accurately as possible to determine the protective device total clearing time correctly. The bolted short circuit calculations should not be conservative (high magnitude). Actual values for utility fault levels, conductor lengths and motor contribution were determined as accurately as possible. Conservative fault levels may indicate that the operating time of a protective device is faster than it would be if the actual fault level were used. The clearing time of the upstream protective device from the potential arc location is included in the incident energy equation.

12. The short circuit calculations that were performed based on the maximum and minimum short circuit contributions from sources. The first case assumes the worst-case condition which included the assumption that all motors (known and assumed) were connected to the system and running. The second case is based on minimum short circuit contribution from sources, where no generators or motor are contributing to the fault.

13. The amount of arcing current and incident energy is directly related to the calculated short circuit current. Sources of short circuit current to a fault include the utility supply, generators, motors, and PV Modules.

14. The fault current at the DC side of a PV inverter is calculated based on the sum of the maximum short-circuit currents of the PV strings connected to it. PV inverters contribution to the AC short-circuit is limited to 1.25 times the full-load current of the inverter according to the manufacturer literatures.

15. DC arc flash results on the photo-voltaic modules connected inverters side are included in the Arc Flash results table. There is currently no published IEEE 1584-2018 methodology for calculating DC arc flash incident energies. However, DC arc flash calculations where conducted in EASY POWER using the Maximum Power Method as presented in NFPA 70E. The incident energy at DC busses was based on an arcing time of 2 seconds and are found in the arc flash tables within the report.

16. Arc Flash labels for the inverters are based on higher incident energy of the either AC or DC side, whichever is greater.

17. The facility switchgear (SWGR) includes multiple vertical sections, and each section will receive the same arc flash label. The vertical sections do not include physical barriers that may otherwise prevent the propagation of an arc flash to an adjacent vertical section. It is possible that a worker could accidently contact the line-side of the main overcurrent protective device while work in an adjacent vertical section. Therefore, the arc flash incident energy for the entire switchgear is based on an incident energy calculation at the line-side of the main overcurrent protective device. The line-side calculation at the main overcurrent protective device excludes any reduction in arc flash

incident energy that may otherwise accomplished via the main overcurrent protective device. The line-side calculation method is considered a conservative method to calculate the incident energy at the switchgear (without barriered vertical construction), as well as panelboards and control panels with a main device where accidental contact with the line-side of the main overcurrent device is possible. The arc flash results for all buses with main overcurrent protective device is based on the line-side calculation method. Although the line-side calculation does not consider the main overcurrent protective device for the arc flash incident energy calculation for the equipment, the main overcurrent protective device must still be considered when analyzing protective device coordination.

18. The Arc Flash Hazard Analysis results shown in the Table below represents the worst-case arc flash hazard results and are based on a protective device clearing time that is capped at 2 seconds. This is based on IEEE-1584, Annex B, Instructions and Examples, which states.

    "If the time is longer than two seconds, consider how long a person is likely to remain in the location of the arc flash. It is likely that a person exposed to an arc flash will move away quickly if it is physically possible and two seconds is a reasonable maximum time for calculations. A person in a bucket truck or a person who has crawled into equipment will need more time to move away."

19. The fault current cannot easily be reduced; nor can the working distance be increased to lessen the incident energy. In many locations, the protective device setting can be adjusted, or the trip unit upgraded to decrease the device interrupting time that will in turn decrease the incident energy.

20. All the adjustable protective devices must be set per Section of Arc Flash Hazard Analysis Result Data table to achieve the arc flash hazard class shown in the Arc Flash Hazard Analysis Results and Arc Flash Labels provided as part of this study.

21. Each location where the hazard risk level is unacceptable to the Novel Handeland Solar, LLC PV Project 1.0 MW AC, Yellow Medicine County, Minnesota facility must be individually evaluated to determine the most effective means of reducing the incident energy while maintaining the highest degree of reliability.

22. Arc Flash tables provide a summary of the Arc Flash Study results. The following table column headings describe the results:

    a. Column #1 – Arc Fault Bus Name: The names in this column correlate to the names implemented in the software system model (reference the Study One Line within this report) These locations correspond to equipment.

    b. Column #2 – Arc Fault Bus kV: The values in this column show the nominal voltage of the equipment bus name noted in Column #1.

c. Column #3 – Upstream Device Name: The name of the protective device upstream of the faulted bus and is used to clear the fault.

d. Column #4 – Equipment Type: Type of equipment (enclosure) within which the arc flash may occur.

e. Column #5 – Electrode Configuration: The possible bus bar arrangements within the enclosure.

f. VCB: Vertical conductors or electrodes inside a metal enclosure.

g. VCBB: Vertical conductors or electrodes terminated in an insulated barrier inside a metal enclosure.

h. HCB: Horizontal conductors or electrodes inside a metal enclosure.

i. VOA: Vertical conductors or electrodes in open air.

j. HOA: Horizontal conductors or electrodes in open air.

k. Column #6 – Electrode Gap (mm): The distance between bus bars or electrodes.

l. Column #7 – Bus Bolted Fault Current (kA): The calculated bolted faulted current at the bus identified in Column #1.

m. Column #8 – Bus Arc Fault Current (kA): The calculated arcing current at the faulted bus.

n. Column #9 – Trip Time (sec): The time from the fault occurrence until the contacts of the protective device responsible for clearing the fault are completely departed.

o. Column #10 - Arc Time (sec): The time during which the arc will be sustained.

p. Column #11 - Est. Arc Flash Boundary (inches): The distance from the arc source at which the calculated incident energy is 1.2 cal/cm^2.

q. Column #12 – Working Distance (inches): The distance from the arc source to the face or chest of the worker performing the task.

r. Column #13 – Incident Energy (cal/cm^2): Arc flash thermal energy released and impressed on a surface at a certain distance from the arcing source.

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7.1 DC ARC FLASH RESULTS

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Arc Fault Bus Name	Arc Fault Bus kV	Upstream Trip Device Name	Equip Type	Electrode Configuration	Electrode Gap (mm)	Bus Bolted Fault (kA)	Bus Arc Fault (kA)	Trip Time (sec)	Arc Time (sec)	Est Arc Flash Boundary (inches)	Working Distance (inches)	Incident Energy (cal/cm2)
INV-1	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-2	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-3	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-4	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-5	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-6	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-7	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-8	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-9	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-10	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-11	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-12	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-13	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-14	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-15	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-16	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-17	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-18	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1

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Arc Fault Bus Name	**Arc Fault Bus kV**	**Upstream Trip Device Name**	**Equip Type**	**Electrode Configuration**	**Electrode Gap (mm)**	**Bus Bolted Fault (kA)**	**Bus Arc Fault (kA)**	**Trip Time (sec)**	**Arc Time (sec)**	**Est Arc Flash Boundary (inches)**	**Working Distance (inches)**	**Incident Energy (cal/cm2)**
INV-19	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1
INV-20	0.7488	[Manual Time]	Other	VCB + VCBB + HCB	32	0.101	0.05	0	2	17.1	18	1.1

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7.2 AC ARC FLASH RESULTS

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Arc Fault Bus Name	Arc Fault Bus kV	Upstream Trip Device Name	Equip Type	Electrode Configuration	Electrode Gap (mm)	Bus Bolted Fault (kA)	Bus Arc Fault (kA)	Trip Time (sec)	Arc Time (sec)	Est Arc Flash Boundary (inches)	Working Distance (inches)	Incident Energy (cal/cm2)
INV.1	0.48	CB-INV.1	Control Panel	VCB + VCBB	25	4.846	3.784	0.02	0.02	6.4	18	0.2
INV.2	0.48	CB-INV.2	Control Panel	VCB + VCBB	25	5.368	4.203	0.02	0.02	6.8	18	0.2
INV.3	0.48	CB-INV.3	Control Panel	VCB + VCBB	25	6.034	4.743	0.02	0.02	7.4	18	0.2
INV.4	0.48	CB-INV.4	Control Panel	VCB + VCBB	25	6.852	5.41	0.02	0.02	8	18	0.3
INV.5	0.48	CB-INV.5	Control Panel	VCB + VCBB	25	7.95	6.315	0.02	0.02	8.8	18	0.3
INV.6	0.48	CB-INV.6	Control Panel	VCB + VCBB	25	8.633	6.881	0.02	0.02	9.3	18	0.4
INV.7	0.48	CB-INV.7	Control Panel	VCB + VCBB	25	10.373	8.335	0.02	0.02	10.5	18	0.5
INV.8	0.48	CB-INV.8	Control Panel	VCB + VCBB	25	12.83	10.406	0.02	0.02	12.1	18	0.6
INV.9	0.48	CB-INV.9	Control Panel	VCB + VCBB	25	13.109	10.641	0.02	0.02	12.3	18	0.6
INV.10	0.48	CB-INV.10	Control Panel	VCB + VCBB	25	10.568	8.499	0.02	0.02	10.7	18	0.5
INV.11	0.48	CB-INV.11	Control Panel	VCB + VCBB	25	8.773	6.997	0.02	0.02	9.4	18	0.4
INV.12	0.48	CB-INV.12	Control Panel	VCB + VCBB	25	8.071	6.414	0.02	0.02	8.9	18	0.3
INV.13	0.48	CB-INV.13	Control Panel	VCB + VCBB	25	6.943	5.485	0.02	0.02	8.1	18	0.3
INV.14	0.48	CB-INV.14	Control Panel	VCB + VCBB	25	6.081	4.781	0.02	0.02	7.4	18	0.2
INV.15	0.48	CB-INV.15	Control Panel	VCB + VCBB	25	5.405	4.234	0.02	0.02	6.9	18	0.2
INV.16	0.48	CB-INV.16	Control Panel	VCB + VCBB	25	4.862	3.796	0.02	0.02	6.4	18	0.2
INV.17	0.48	CB-INV.17	Control Panel	VCB + VCBB	25	4.642	3.621	0.02	0.02	6.2	18	0.2
INV.18	0.48	CB-INV.18	Control Panel	VCB + VCBB	25	4.222	3.286	0.02	0.02	5.9	18	0.2

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Arc Fault Bus Name	**Arc Fault Bus kV**	**Upstream Trip Device Name**	**Equip Type**	**Electrode Configuration**	**Electrode Gap (mm)**	**Bus Bolted Fault (kA)**	**Bus Arc Fault (kA)**	**Trip Time (sec)**	**Arc Time (sec)**	**Est Arc Flash Boundary (inches)**	**Working Distance (inches)**	**Incident Energy (cal/cm2)**
INV.19	0.48	CB-INV.19	Control Panel	VCB + VCBB	25	3.881	3.015	0.02	0.02	5.6	18	0.1
INV.20	0.48	CB-INV.20	Control Panel	VCB + VCBB	25	3.591	2.29	0.04	0.04	5.8	18	0.2
SWGR	0.48	FS-XFMR-XCEL	Switchboard	VCB + VCBB + HCB	32	21.831	15.526	5.933	2	254.6	18	169.1
XFMR-ZIG ZAG	0.48	CB-ZIG-ZAG	Transformer Terminal	VCB	32	19.94	14.873	0.015	0.015	11.3	18	0.6

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7.3 ARC FLASH LABELING PROCEDURES

1. Changes to the power system configuration, addition and/or changes to loads and/or equipment, any changes to devices or changes to settings of adjustable devices invalidates this Arc Flash Hazard Analysis and the information contained on arc flash labels.

2. The labels will be self-adhesive, be UV resistant vinyl labels conforming to ANSI-Z535 and approximately 4” x 6” thermal transfer type label of high adhesion polyester for each equipment analyzed as noted within this report with large print.

3. Arc flash labels will be field applied for equipment as identified in the study and the respective equipment access areas per the following:

    a. Floor Standing Equipment: Labels shall be provided on the front of each individual section. Equipment requiring rear and/or side access shall have labels provided on each individual section access area.

    b. Wall Mounted Equipment: Labels shall be provided on the front cover or a nearby adjacent surface, depending upon equipment configuration.

4. Arc flash labels will be provided in the following manner:

    a. For each low voltage switchgear and motor control center, one (1) arc flash label should be field applied for each vertical section on the front and rear of the equipment. Labels were applied on the rear of the switchgear only when there is possible access to the equipment.

    b. For each low voltage switchboard, one (1) arc flash label should be field applied for each vertical section.

    c. For each distribution panel, one (1) arc flash label should be field applied.

    d. For each panelboard, one (1) arc flash label has should be applied.

    e. For each facility transformer, one (1) arc flash labels should be field applied.

    f. For each enclosed disconnect switch or circuit breaker external to electrical distribution equipment, one (1) arc flash label should be field applied.

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7.4 SAMPLE ARC FLASH LABELS

WARNING

ARC FLASH AND SHOCK HAZARD
APPROPRIATE PPE REQUIRED

3’ -8”	Arc Flash Boundary	
18”	Working Distance	
6.4 cal/cm^2	Arc Flash Incident Energy	
3’-6”	Limited Approach	
1’-0”	Restricted Approach	
14.47 kA	Available Fault Current	
480 VAC and 1000 VDC	Volt Shock Hazard When Cover is Removed	
Equipment ID:	**XXXXXXX**	
Project Name:	XXXXX XXXXX XXXXX	Report – Rev.0
AE Job Number:	XXXX-XX	
Study Provided By:	Durak Evrim Ercan, P.E.	info@AmperEngineering.com
Date:	XX/XX/2021	

DANGER

NO SAFE PPE EXISTS
ENERGIZED WORK PROHIBITED

17’ -1”	Arc Flash Boundary	
18”	Working Distance	
167.9 cal/cm^2	Arc Flash Incident Energy	
3’-6”	Limited Approach	
1’-0”	Restricted Approach	
21.68 kA	Available Fault Current	
480 VAC and 1000 VDC	Volt Shock Hazard When Cover is Removed	
Equipment ID:	**XXXXXXX**	
Project Name:	XXXXX XXXXX XXXXX	Report – Rev.0
AE Job Number:	XXXX-XX	
Study Provided By:	Durak Evrim Ercan, P.E.	info@AmperEngineering.com
Date:	XX/XX/2021	

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SECTION 8 - RECOMMENDATIONS

1. Regular equipment cleaning, inspection, and testing should be scheduled for disconnect switches, circuit breakers, and trip devices. Reliable operation of protective devices cannot be assured unless regular periodic maintenance is performed according to equipment manufacturer requirements. Regular maintenance of equipment and protective devices will ensure that faults are cleared within tolerance of manufacturers published time-current curves, thereby constraining Arc Flash Hazards to calculated levels. Any variation in the values of current trip set points or clearing times will affect the magnitude of Arc Flash Hazards.

2. Only qualified electricians who are familiar with the installation and maintenance of electrical distribution equipment should perform work associated with such products. All recommendations of the manufacturer, warnings and cautions relating to the safety of personnel and equipment should be followed. All applicable health and safety laws, codes, standards, and procedures including all equipment should be de-energized prior to any maintenance or service. OSHA 1910.333 requirements and all guidelines of NFPA 70E should be followed, and in particular appropriate Personal Protective Equipment (PPE) must be provided and worn.

3. Even if work is not being performed directly on energized equipment, it is important that the proper PPE be used during some load interruption actions, during visual verification of the state of disconnecting devices, and during lock out/tag out procedures.

4. NFPA 70E-2018, Article 110.3 states that an electrical safety program shall identify a hazard/risk evaluation procedure to be used before work is started on or near energized parts operating at 50 volts or more or where an electrical hazard exists. Article 130.7 (A) of NFPA-70E states that employees working in areas where electrical hazards are present shall be provided with, and shall use, Personal Protective Equipment (PPE) that is designed and constructed for the specific part of the body to be protected and for the work to be performed.

5. NFPA 70E requires that an employer provide appropriate PPE clothing and equipment, and the employee is to wear and use when within the arc flash boundary. The selection of PPE clothing is based on the level of incident energy the individual will be exposed to in the event of an arc flash.

6. IEEE-1584 provides equations and methods to calculate the arc flash boundary and incident energy at specific locations within a facility's electrical system. These results are used to determine the safe approach distance, incident energy, and personal protective equipment (PPE) requirements for each location. Any location where work may be performed on energized parts and circuits or near energized equipment is subject to the arc flash standards. Personal protective equipment used to guard against arc flash hazard should be considered the last line of defense. It is also important to note that the use of PPE is not intended to prevent all injuries from an arc flash. The goal of determining PPE levels using the arc flash hazard approach is to identify the level of protection required to limit the injury to the onset of a second degree burn in the event

of an arc flash while avoiding the use of more protection than is needed to minimize hazards of heat stress, reduced visibility and limited body movement. An incident energy of 1.2 cal/cm2 represents the onset of a second-degree burn.

7. The results of the arc flash hazard analysis are not intended to imply that personnel be permitted to work on exposed energized equipment or circuits. OSHA 1910.333 restricts the situations in which work is to be performed near or on energized equipment or circuits. Based on OSHA requirements, a worker must be able to select the appropriate voltage detector, meter or tester and be able to inspect it to ensure it is safe to use, and then must be able to use it safely and properly. Therefore, if a circuit is not in an electrically safe work condition, it must be worked on as if it were energized.

8. Perform maintenance testing procedures annually. Based on the size, type and configuration of the power system an infrared scan of equipment including bus connections and cable terminations would be the minimum recommended annual test procedure. To perform this infrared scan properly, the equipment typically remains energized and is necessary to expose energized equipment. This could possibly be overcome by the addition of UL rated view port in the equipment enclosure.

9. The Arc Flash Hazard Analysis be revised and updated immediately following any modification or renovation to the facility power system and equipment. Any changes to the power system or equipment invalidates the results of this report and arc flash warning labels.

10. The Arc Flash Hazard Analysis should be reviewed within three (3) years from the date of the report to account for changes in the electrical distribution system.

11. All bus duct (bus way) locations are to be considered dangerous even though the incident energy may be noted as a lower value. When working on bus duct the worker is often within a man lift and work clearance is restricted. It is strongly recommended to never work on or near energized bus duct for any activity.

12. Post a copy of the facility one-line diagram in each electrical room associated with the equipment within that room. We also recommend a copy of the facility overall one-line diagram representing how the electrical equipment within the room is fed from the overall power distribution system.

13. The incident energy will define the clothing requirements in NFPA 70E. The NFPA 70E “Hazard Risk Categories” of FR clothing is based on the ability to limit the injury to curable burns at different levels of incident energy. Incident energy greater than 40 cal/cm^2 will be described in this study as “DANGER”. Working on energized equipment, circuit, components, and systems at locations designated as “DANGER” should be strictly prohibited. There is no safe PPE available for locations with over 40 cal/cm^2 incident energy.

14. Energized work should not be permitted on the line-side of Switchgear. The Arc Flash Hazard level in this area is determined by the upstream utility overcurrent protection and Durak Evrim Ercan, P.E. cannot offer a solution to lower the arc flash level for this location because the protective device is utility owned.

15. Each location where the hazard risk level is unacceptable should be individually evaluated to determine the most effective means of reducing the incident energy while maintaining the highest degree of reliability.

16. Any future loads added at the facility under this study should consider the present available fault duties and increased fault duties from additional load increases. After additions of any significant new motor load, revised short-circuit calculations should be performed to determine whether the increased available fault current will exceed equipment ratings. This concern is valid for all facility equipment, but specifically applies to equipment where the present magnitude of available fault current is close to, but may not exceed, the equipment rating.

17. If possible, plan electrical maintenance work, testing and operations to avoid possible exposure to electric arcs.

18. Label electrical equipment with arc flash incident energy. Refer to the Arc Flash Hazard tables section within the report for calculated levels of incident energy from arcing faults. We strongly recommend that all labels be consistent throughout the facility and reflective of all diagrams and references.

19. Included with equipment labeling, add reflective tape on the floor in front of each equipment with the boundary distances to scale based on the arc flash label information.

20. Provide a clothing cabinet in all electrical rooms with personal protective clothing based on the incident energy of all equipment with each respective electrical room. Provide an equipment cabinet in all electrical rooms with personal protective equipment and tools. The cabinet should include a lock with the key for the lock residing with facility management. If work is necessary on energized equipment and circuits, after an energized work form is completed and signed by management, the key is released by management to the qualified electrical worker that will perform the work.

21. Ensure that energized parts to which an employee might be exposed is put into an electrically safe work condition before an employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Financial considerations are not an adequate reason to work on or near energized circuits.

22. Minimizing exposure to arc flash by positioning the body properly. Note that the procedure of standing to the side and away as much as possible from the path of an arc flash may not be appropriate if a face shield is used. Each task must be evaluated for the body position that maximizes the protection worn.

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23. Ensure and verify all enclosure screws are attached, fastened, and secured completely in place. A loosely tightened screw could result in the enclosure cover to be blown open, exposing anyone in the room to the blast as the equipment enclosure would not contain the arc.

24. Train and stress to employees and contractors working on the electrical system that any increase in fuse sizes or the settings of breaker trip units will increase the Arc Flash Hazard potential and invalidate the study. Therefore, arbitrary changes in protective device sizes or trip settings should not be permitted.

25. Where short-circuit ratings are not adequate for calculated fault duties, and ratings cannot be increased by addition of limiters or other upgrades, a reduction in fault duty may be considered as an alternate solution for overstressed equipment.

26. Pursue available rating upgrade approaches for overstressed equipment, as identified by this report and where solutions have been proposed by manufacturers or equipment vendors. Where upgrade costs are excessive, or implementation difficult due to operational constraints, equipment replacement may be the preferred approach to achieve adequate fault ratings.

27. Develop an Electrical Safe Work Practice Policy Manual. This will assist personnel in determining the proper use and requirements for PPE during normal maintenance and repair tasks involving arc flash hazards.

28. Design future expansion to minimize the hazard with methods such as:

    a. Reduce the need for work on energized equipment.

    b. Reduce the probability of faults by including insulation on equipment buses.

    c. Reduce fault current. This can be accomplished by using multiple transformers of lesser kVA capacity rather than one large transformer to feed loads.

    d. Reduce fault duration. The use of Zone Selective Interlocking for circuit breakers will greatly reduce arc energy. Current limiting protective devices can significantly reduce the fault duration.

    e. Reduce the impact of arc flash on workers by designing installations with lower arc flash exposure such as arc-resistant switchgear which protects workers by directing arc flash energy away from the areas where the workers normally perform their work. Remote racking and operation of switchgear can increase the distance between a worker and a hazard zone.

    f. Add Arc Reduction Maintenance System (ARMS) switch for breakers rated 1200A and above and where arc flash incident energy needs further reduction.

g. Use transformer differential protection scheme where possible. This will help reducing the arc flash incident energy on the transformer load side of the equipment.

29. Adding overcurrent device protective device and properly setting them to following tie breakers and switches will reduce available short circuit current and possible arc flash hazard where these devices are existing, and settings are available.

30. For locations with unacceptable hazard levels, the fault current cannot easily be reduced, nor can the working distance be increased to lessen the incident energy. In select locations the protective device setting can be adjusted, or the trip unit upgraded to decrease the device interrupting time that will in turn decrease the incident energy.

31. In addition, there are several other methods for reducing incident energy that can be examined for locations with unacceptable hazard levels. These methods include installing:

a. Maintenance switches.

b. Remote control and/or racking.

c. Possibly using lower impedance transformers.

d. Addition of instantaneous settings to breakers and relays that do not have this function.

e. Addition or including a main device in distribution equipment.

32. The Arc Flash Hazard Analysis and the results of this report should not be considered as a substitute for safe working practices. The preferred way to avoid arc flash hazards is to perform work on de-energized equipment only. An arc flash hazard analysis by necessity is based on specific assumptions about working distance, available fault current, arc length and protective device characteristics. Actual working conditions and protective device performance may be different from those assumed for the analysis. Performing an arc flash hazard analysis does not guarantee that use of specified protective clothing will prevent injury from exposure to an electrical arc. Further, personal protective equipment intended to provide thermal protection does not provide protection against shock, flash, acoustic energy, flying particles, or force of the blast associated with an electrical arc.