34.5/115 kV Solar Power Plant & Substation Senior Design Project

Senior Design Team 18 - May 2024

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BLACK & VEATCH

Agenda

- Safety Moment
- Calculations
- Equipment Updates
- AutoCAD Update
- ETAP
- Feedback

Safety Moment - Injury Treatment & Reporting

- Most common injuries:
  - Overexertion-related pain
  - Sprains, strains, and tears
  - Cuts, lacerations, and puncture wounds
- According to National Safety Council, in 2017, nearly 4.6 million medically consulter work injuries costing over $161.5 billion
- First course of action is to determine severity of injury and contact 911 if needed
- Reporting an injury:
  - After treatment, report injury to workers' compensation carrier
  - Provide as much information as possible about injury and how it occured
  - Depending on severity a report may need to be filed with OSHA

LINK

Calculations

AC Load Calculation :

Assumptions

1. 180VA load per Outlet assumed as worst case
2. The worst case scenario will be as follows:
   a) Time of day: Day (no lights on).
   b) Temperature: 90 deg F (all Transformer fans on).
   c) Battery: Deep discharge (charger on full).
3. Worst case tripping conditions shall be as follows:
   a) XXXX fault
      - (1) XXX Breaker will trip
      - (1) XXX Breakerwill trip

- Ratings estimated.

Calculations

The continuous 120/240VAC single phase loads are as follows:

		Quantity	Load/Unit(W)	Amps (ea)	Voltage(V)	Total(W)	Amps Total
AC Panel - Control Building	Breaker Recepticle and Lights	1	210	1.75	120	210	1.75
	Transformer Fans	1	24,000	100.00	240	24,000	100.00
	Transformer Sump Pump	1	2,000	8.33	240	2,000	8.33
	Control House Lighting	20	36	0.30	120	720	6.00
	Yard Lights	1	55	0.46	120	55	0.46
	HVAC System	1	10,000	41.67	240	10,000	41.67
	Fire Detection Equipment	1	150	1.25	120	150	1.25
	Exhaust Fan	1	132	1.10	120	132	1.10
				#DIV/0!		0	#DIV/0!
				#DIV/0!		0	#DIV/0!
				#DIV/0!		0	#DIV/0!
				#DIV/0!		0	#DIV/0!
				#DIV/0!		0	#DIV/0!
	Worst Case Tripping:						
				#DIV/0!		0	#DIV/0!
				#DIV/0!		0	#DIV/0!
	Total Worse Case AC Panel Load					37,267	#DIV/0!

Total Worst Case Load (+10 %)	**40,994**	**#DIV/0!**

Sizing Recommendations:
Station Service - XXkVA
MTS, Safety Switch - XXA

recommend XXXA Station Service Equipment

1. Breaker tripping load is temporary
2. 10% worst case scenario is added to the final value

https://docs.google.com/spreadsheets/d/1hwF8cv3VBiy1_Yih5wwwBzs9P8UB_BBc/edit?usp=sharing&ouid=101132689819119398819&rtpof=true&sd=true

Calculations

DC Load & Battery Sizing :

1. Fill out the DC Load Profile below. Read the assumptions and notes below the table.
2. Determine and record the current load amounts for 3 periods:
   a. Period 1: T=0min Fault occurs, relays detect. Breakers Trip due to relay operation.
   b. Period 2: T=1min Breakers are open, everything else is simply running.
   c. Period 3: T=240min Fault is cleared, relays operate to close Breakers
3. Create an account for the Enersys Battery Sizing Program https://bsp.enersys.com/bsp/index.do and enter your parameters to obtain a full battery system and PDF of the sizing report. This should give you a breakdown of the Amp-hours for the time periods determined.

Some notes on the table above and how to use it:

- Continuous load will be the above parameters NOT INCLUDING the trip coils from the breakers.
  - Keep in mind, there will be more than one of each type of relay, use your zones of protection to keep in mind how many of each there are.
    - 34.5kV Feeder position (array) –Primary SEL-411L, Backup SEL-451
    - Transformer Position – Primary SEL-487E, Backup SEL-451
    - 115kV Line Position – Primary SEL-411L, Backup SEL-311L
- There will be 3 periods of operation:
  - Period 1: T=0min Fault occurs, relays detect. Breakers Trip due to relay operation.
  - Period 2: T=1min Breakers are open, everything else is simply running.
  - Period 3: T=240min Fault is cleared, relays operate to activate the Breaker close-coils, bringing the Breakers back into the closed position for normal operation.
- Last item listed are LED Lamps. These will be placed around the substation yard to illuminate important equipment and cabinets. Assume we have 8 of these.
- Assume a 60 Cell system
- Use device cut-sheets to find SEL parameters (you will need to create an account, should be quick to create!) for the relay current-draw.

DC Load & Battery Sizing (IEEE 485)

Extra Reference: https://ewh.ieee.org/r3/atlanta/ias/2014-2015_Presentations/2015-04-20_EEE%20IAS%20Stationary%20Battery%20Sizing.pdf

DC Load Profile

	Components	Load Current (A)	Nominal Voltage (V) DC	Inception and Active Shutout Time (Min.)	Power Requirement (remember to account for # of relays required)	Number of Components
	34.5kV Breaker:	Tripping Current: 3.3A Closing Current: 2.6A	70 – 140 90 - 140	0 -1	231 - 343W 234 - 364W	
	115kV Breaker:	Tripping Current: 3.3A Closing Current: 2.6A	70 – 140 90 - 140	239- 240	462 - 924W 324 – 504W	
	SEL-411L		125	1 - 240		
	SEL-311L		125	1 - 240		
	SEL-4207		125	1 - 240		
	SEL-487E		125	1 - 240		
	SEL-451		125	1 - 240		
	Battery Monitoring Equipment	0.024A	50 -180	1 - 240	6VA	
	DC Ammeter	0.048A	125	1 - 240	3VA	
	DC Voltmeter	0.048A	120	1 - 240	3VA	
	SACO Annunciator (L8)		125	1 - 240		
	Edwards Bell	0.012A	125	1 - 240	1.5VA	
	Power Line Indicating Lamps (LEDs)	0.017A	125	1 - 240		8

	60 cell system	Continuous Load	Discontinuous Load Current	
		T = 0	T = 1 min	T = 240 min

https://docs.google.com/spreadsheets/d/1xRuwZ2yvrR49pMpPJpyQim3Ds8Mtx1fYL_kV4MVxrck/edit?usp=sharing

Calculations

Grounding calculation:

Requirements:

1. Find the uniform soil resistivity (ρ_a) in ohm-m using the given soil resistivity measurements.
2. Find the minimum conductor size (in kcmil) for a copper, soft-drawn grounding conductor. (Although the minimum value may be significantly smaller, 4/0 AWG is typically the smallest size conductor used in a substation grounding grid)
3. Find the tolerable Step (E_{STEP}) and Touch (E_{TOUCH}) voltages with a surface layer derating factor $C_s = 0.8$. (Note that equations are 31-33 are labeled incorrectly as step equations. They are touch equations)
4. Design a square grid for the given substation area and find the maximum step (E_s) and maximum mesh/touch (E_m) voltages. Refine the ground grid design as needed so that the maximum step/touch voltages are less than the tolerable step/touch voltages that were found in problem 3. If needed, use ground rods with a length of 20'.
5. Provide a drawing of the ground grid in the proposed substation area showing grid spacing distances. Industry standard typically has the ground grid extend 3 feet outside the fence line.
6. Provide a short report that includes references, any assumptions made, and final results (please include equations and calculations, even if hand-written).

Grounding calculation (IEEE 80)

Reference https://community.ptc.com/sejnu66972/attachments/sejnu66972/PTCMathcad/175612/1/Earthing%20Exercise%20

Given parameters for grounding

Parameters	Value	Unit	Symbols
Maximum grid current	32	kA	
Fault duration for conductor sizing	1	s	
Shock duration	0.5	s	
Surface layer thickness	0.15	m	
Surface layer resistivity	3000	ohm-m	
Body weight	50	kg	
Ambient temperature	40	C	
Grounding conductor depth	0.15	m	

Parameters to calculate/find

Parameters	Value	Unit	Symbols
Number of parallel conductors			n
Spacing between n parallel conductors		m	D
grid conductor diameter		m	d
Total length of conductor in the horizontal grid		m	Lc
Perimeter length of grid		m	Lp
Area of the grid		m^2	A
Max length in the x direction		m	Lx
Max length in the y direction		m	Ly
Max distance between any two points on the grid		m	Dm

Task : Get the outer dimensions of substation fence for grounding calculation.

https://docs.google.com/spreadsheets/d/1xRuwZ2yvrR49pMpPJpyQim3Ds8Mtx1fYL_kV4MVxrck/edit?usp=sharing

Equipment

- 34.5 kV PTs and CTs available from Kuhlman Electronic Corporation

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://library.e.abb.com/public/5e984f081be0b5ccc1257b13005740d7/34500%20section_updated_050212.pdf

- 34.5 kV lightning arrestor from Hubbell Power Systems

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://hubbellcdn.com/catalogfull/70-SurgeArresters1_IEEEandIEC.pdf

- SEL-751 feeder protection relay (under/overvoltage, frequency, arc flash)

https://selinc.com/products/751/

- Possible switchgear

https://hfy-substation.en.made-in-china.com/product/MSCnhjHBGvRd/China-Kyn61-40-5-Type-Electrical-Switchgear-and-Medium-Metal-Switchgear-Zs3-2-36kv.html

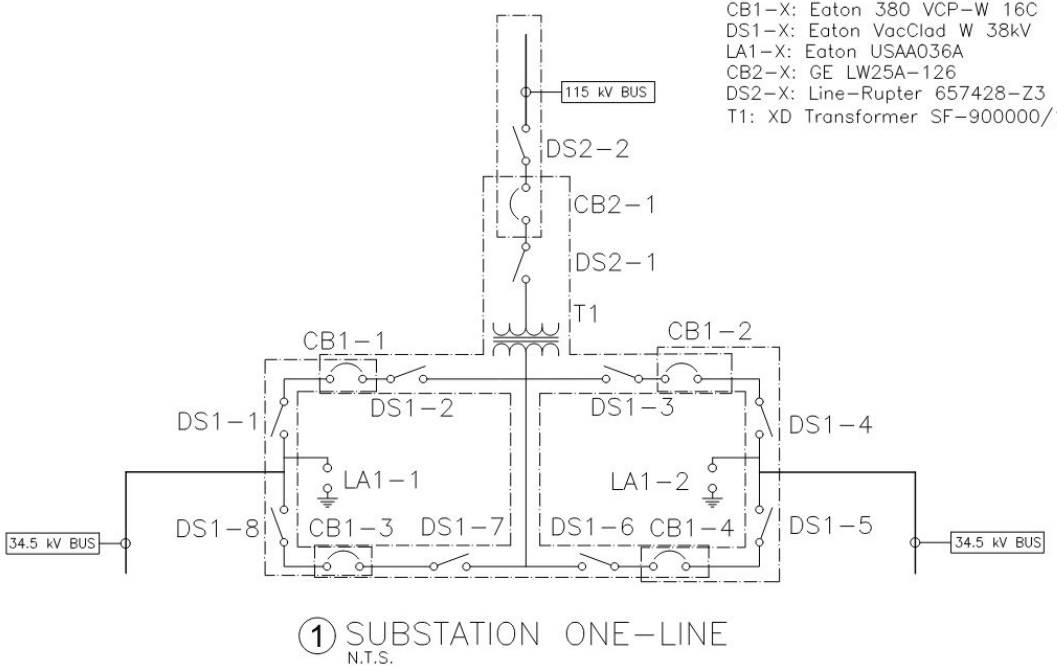
- Possible station power transformers (45 kVA - 2.5 MVA)

https://hfy-substation.en.made-in-china.com/product-group/OekaQJLMYuhH/34-5kv-Pad-Mounted-Transformer-1.html

https://www.alibaba.com/product-detail/Three-phase-pad-mounted-34-5kv_1600245187315.html

https://www.eaton.com/us/en-us/catalog/medium-voltage-power-distribution-control-systems/envirotran-three-phase-pad-mounted-transformers.html#tab-2

AutoCAD - One Line

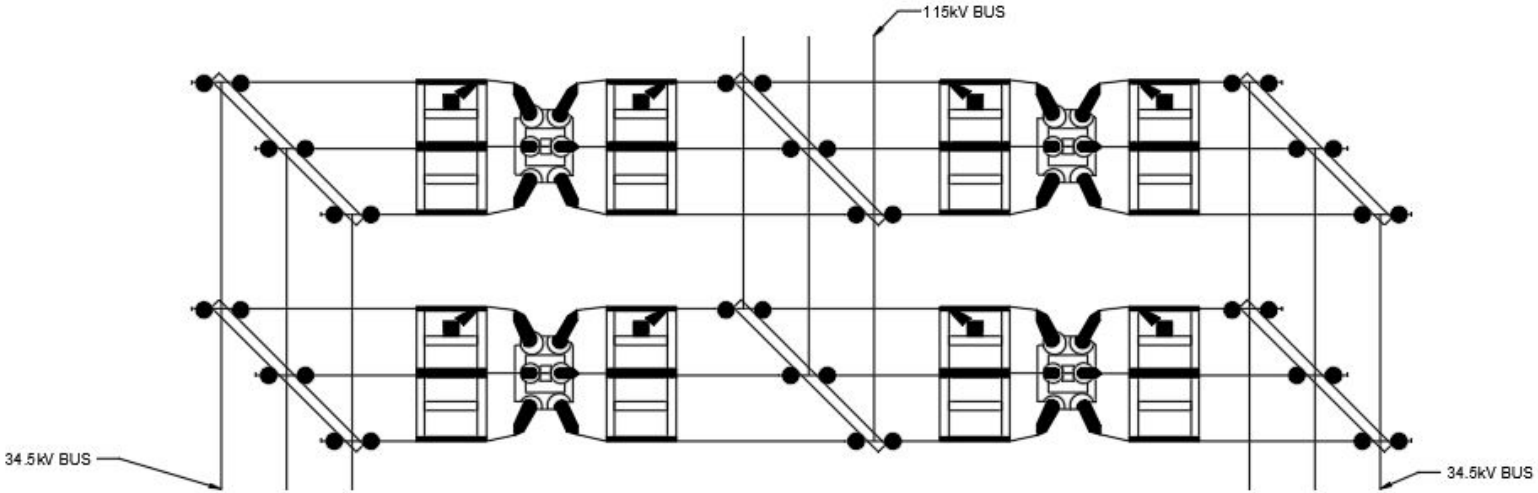


- Added lightning arrestors
- Found datasheets and nameplates for equipment

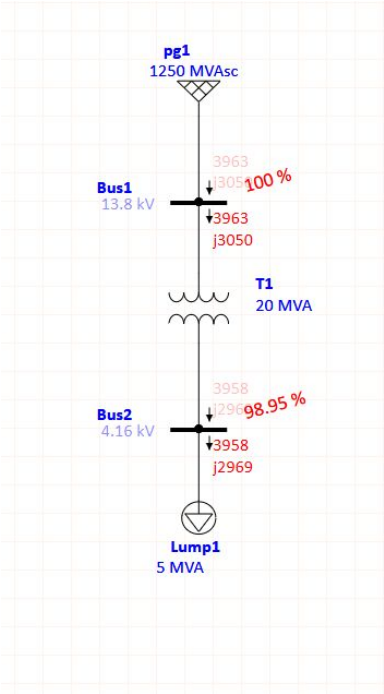
SHEET LIST TABLE

SHEET NUMBER	SHEET TITLE	SHEET NUMBER	SHEET TITLE
E100	PROJECT TITLE	SS100	SUB DESIGN SYMBOLS
S100	SITE PLAN	SS101	SUB ONE-LINE
S101	SITE KEYPLAN	SS102	SUB KEY PLAN
S102	SITE WIRING	SS103	SUB ONE-LINE DETAILS
PV100	SOLAR KEY PLAN	SS104	SUB GROUNDING INFO
PV101	OVERALL ARRAY LAYOUT	SS105	SUB LIGHTNING INFO
PV102	ARRAYS 1 - 12 LAYOUT	SS106	SUB ONE-LINE PLAN VIEW
PV103	ARRAYS 13 - 15 LAYOUT	SS107	FUTURE
PV104	WIRING ARRAYS 1 - 12	SS108	FUTURE
PV105	WIRING ARRAYS 13 - 15	SS109	FUTURE
PV106	SOLAR DESIGN DETAILS	SS110	CB1-X DATASHEET
PV107	AC ONE LINE	SS111	CB2-X DATASHEET
PV108	DC ONE LINE	SS112	DS1-X DATASHEET
PV109	STRING ONE LINE	SS113	DS2-X DATASHEET
PV110	PANEL DATASHEET	SS114	LA1-X DATASHEET
PV111	COMBINER BOX DATASHEET	SS115	T1 NAMEPLATE
PV112	SKID INVERTER DATASHEET		

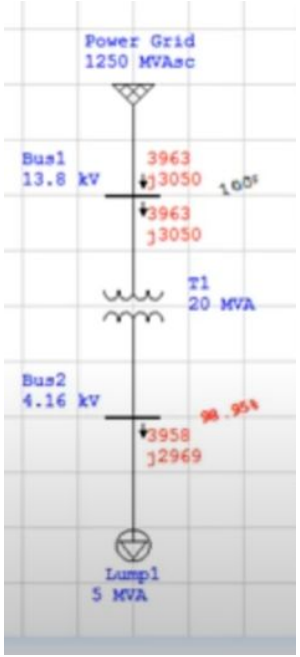
AutoCAD - One Line Plan View



ETAP - verification



Verification Result



Result from ETAP software

https://www.youtube.com/watch?v=nk3zBFGJGtw&t=86s

Questions

- Next steps?
  - Continue on calculations to find what to do
- Eli to send MM, Project context doc, drawing set

Feedback and Updates

- Tasks: Updates
  - Bell: Calculations
  - Liam: Look for other vendor relays (ex. GE), equipment pricing
  - Eli: AutoCAD Equipment Schedules
  - Baylor: Autocad, ETAP, and calculations
  - Eduardo: Conduits
  - Chicheng: ETAP