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

Senior Design Team 18 - May 2024

Siti Mohd Radzi, Baylor Clark, Eduardo Jimenez-Tzompaxtle, Chicheng Tang, Eli Schaffer, Liam Gossman

BLACK & VEATCH

Agenda

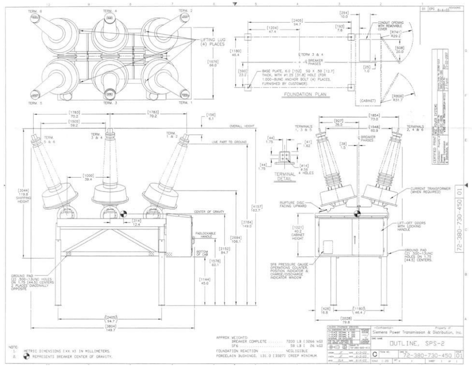
- Safety Moment
- Calculation Documents
- AutoCAD Update
- ETAP
- Feedback

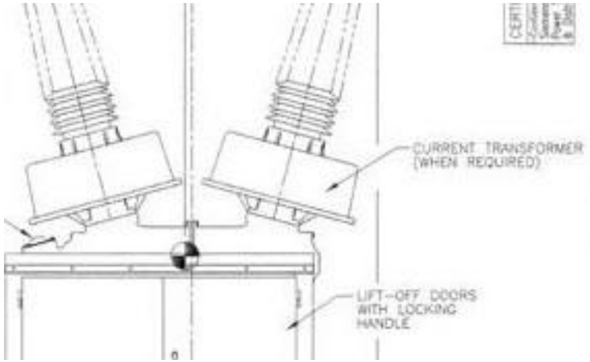
Safety Moment - Safe lifting techniques

- Back injuries are one of the five main types of workplace injuries, and 75% of workplace-related back injuries occur during a lifting task.
- To avoid back injuries, safe lifting techniques required.
  - Holding the load as close to body as possible, level with belly button.
  - Keeping shoulders in line with hips as move (don't twist your trunk).
  - Changing direction with feet and leading with hips.
  - Taking small steps and keeping a good grip with all fingers.
- To set down the heavy objects
  - Keep the load close to body and back straight or slightly arched.
  - Squat down, bending only at the knees and hips.
  - Tight stomach muscles when lower yourself.
  - Kneel on one knee if necessary.

https://www.thepromove.com/news/blog/proper-lifting-techniques-used-by-professional-movers

High Side Breaker CTs





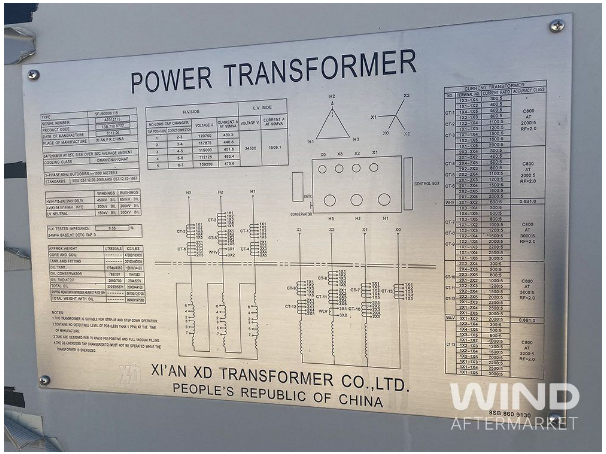
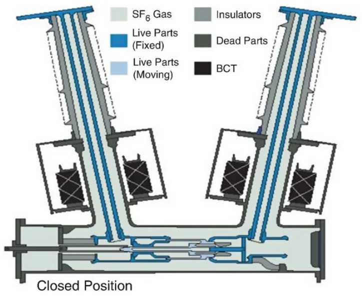


Fig. 5.3

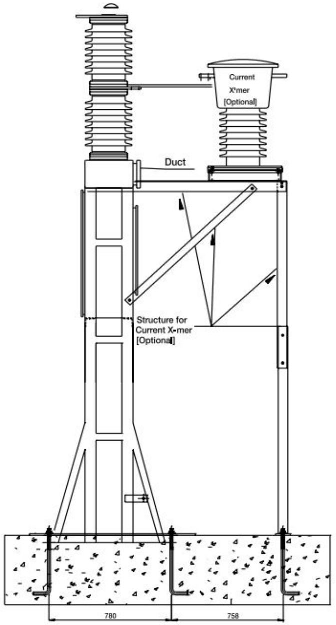


6 CTs, 1 per phase on each side of the breaker

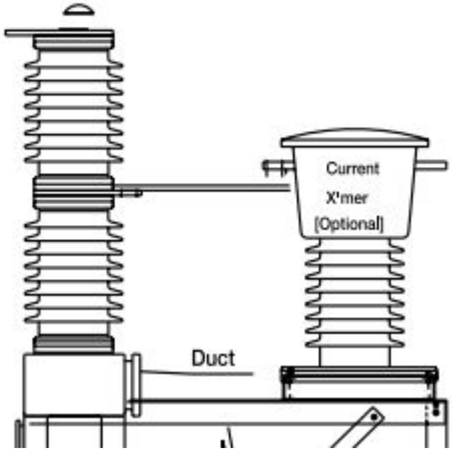
XFMR also has 12 available CTs

Image Link

Low Side Breaker CTs



Side View



Changed low side breaker to SF6 model from vacuum model

Assuming 3 CTs, 1 per phase on one side of the breaker

Relays

Changed SEL-451 to SEL-352

Intended to use SEL-451 as a breaker protection relay, however SEL-352 is specifically designed for this purpose and will require fewer instrument transformer connections (352 is also slightly cheaper).

This will fit better with our low side breakers (assuming 3 CTs per low side breaker)

Note: This will require some DC and cost recalculations, however the differences should be small enough to avoid any changes to battery calculations

https://selinc.com/products/352/

Calculations

Battery Charger Equation:

$$A = L + \frac{AHR * K}{T}$$

A = Battery charger output current (A)
L = Continuous load current (A)
AHR = Amp hours removed of the battery system (Ah)
K = Efficiency factor (1.15 for flooded lead acid, 1.4 for NiCa)
T = Recharge time (hours)

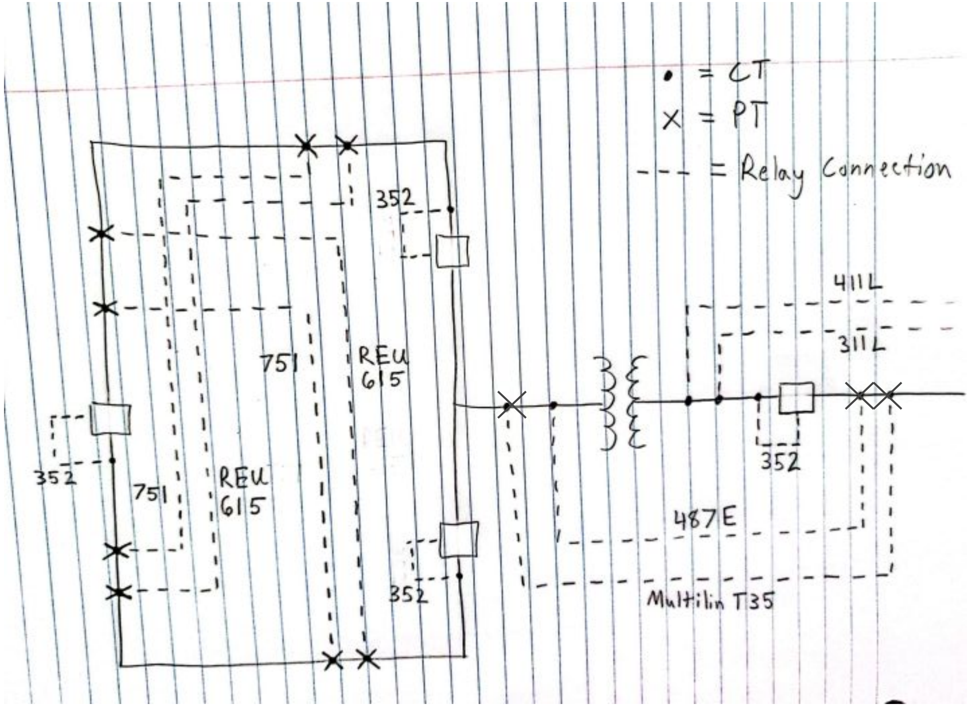
Our system has a 100 Ah capacity with 60 Ah removed, and uses flooded lead acid batteries. Our continuous load is 3.576 A. Typical recharge times are usually 8, 12, or 24 hours.

A recharge time of 8 hours results in a charger output of 12.201 A.

A recharge time of 12 hours results in a charger output of 9.326 A.

A recharge time of 24 hours results in a charger output of 6.451 A.

Relay Setup



High side:
5 sets of CTs

Low side:
13 sets of CTs
8 sets of PTs

Calculations - BOM

Solar Component

Component Type	SKU/Model Number	Quantity	Price	Datasheet Link	Total Price	Pricing Link
PV Panels	ZXM7-SHDB144-550/M	143250	$270.00	Link	$38,677,500.00	Link
Combiner Boxes	BHSZ-16-1-1500V	360	$1,921.00	Link	$691,560.00	Link
Inverters	PVS980-MWS-4000kVA-K-34.5-Dry	15	$200,000.00	Link	$3,000,000.00	Page 31
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
				Total Solar Farm Cost	$42,369,060.00	

Substation Component

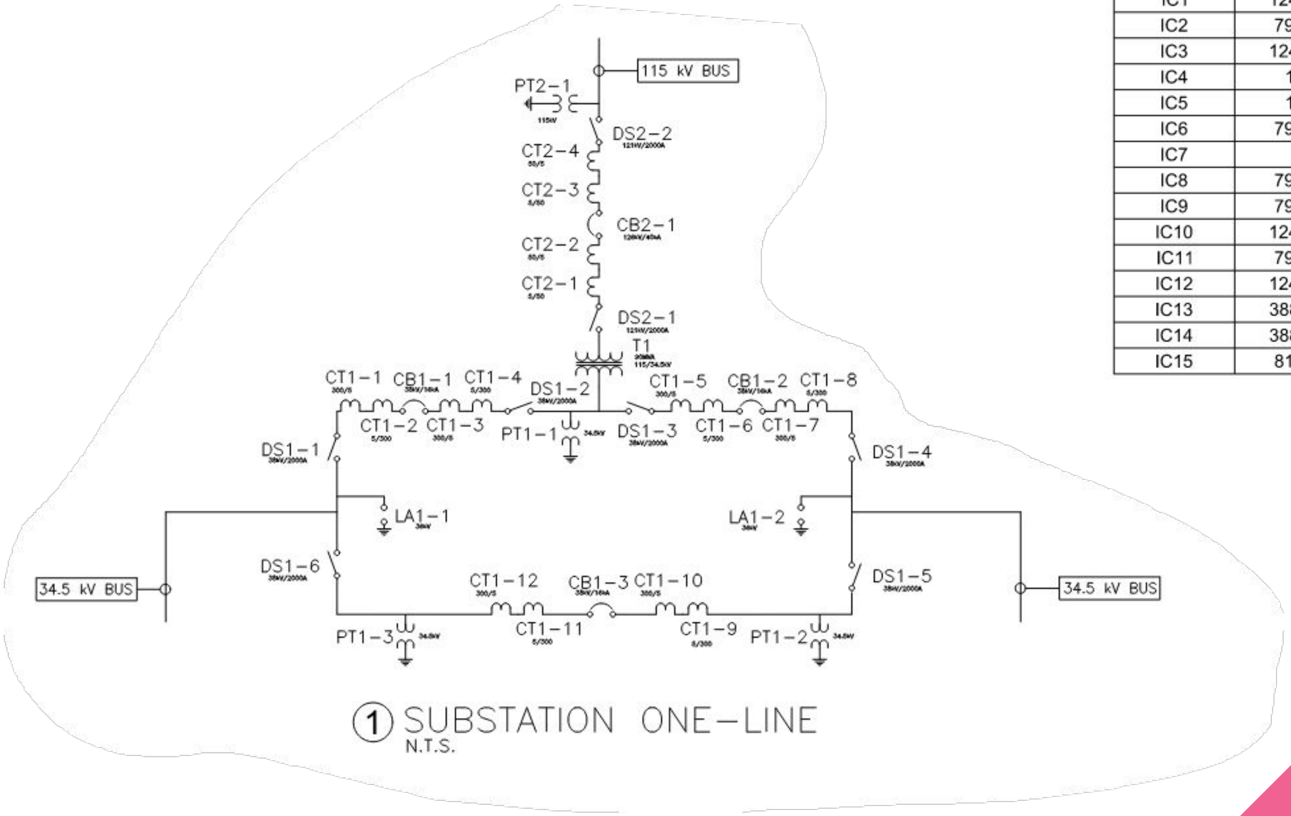
Component Type	SKU/Model Number	Quantity	Price	Datasheet/Website Link	Total Price	Pricing Link
SEL-411L		1	$11,170.00		$11,170.00	
SEL-311L		1	$6,920.00		$6,920.00	
SEL-487E		1	$8,860.00		$8,860.00	
GE Multilin T35		1	$4,500.00		$4,500.00	
SEL-751		2	$1,270.00		$2,540.00	
ABB REU615		2	$750.00		$1,500.00	
SEL-451		4	$5,520.00		$22,080.00	
CB1		3	$35,000.00	SEE TO THE RIGHT	$105,000.00	Circuit Breaker (35 kV)
CB2	SPS2-123-40-2	1	$95,500.00	Link	$95,500.00	Link
DS1			$7,000.00	Link	$0.00	Discon. Switch (34.5 kV)
DS2			$20,000.00	Link	$0.00	Discon. Switch (138 kV)
LA1			$500.00	Link	$0.00	Surge Arrestor (34.5kV)
LA2			$2,000.00	Link	$0.00	Surge Arrestor (138kV)
T1 (Power XFMR)	SF-9000000/15	1	$2,000,000.00	Link	$2,000,000.00	Page 7
T2 (Station Power)	MT-PML-R50-1P-GMA-50KVA-SZ-LT-DF-Z6-BB-CS-2BZ-M1	1	$18,641.04	Link	$18,641.04	Link
CT1				Link	$0.00	
CT2			$15,000.00	Link	$0.00	Current XFMR (138kV)
PT1			$2,000.00	Link	$0.00	Volt XFMR (34.5kV)
PT2			$7,000.00	Link	$0.00	Cap Volt XFMR (138kV)
Battery MTS	GF224NR	1	$842.73	Link	$842.73	Link
Battery Backup	6-OGi-100	10	$450.00	Link	$4,500.00	Link
				Total Substation Cost	$2,282,053.77	

Misc Component

Component Type	SKU/Model Number	Quantity	Price	Datasheet/Website Link	Total Price	Pricing Link
Land	406 Acres	1	$609,000.00	Link	$609,000.00	
Conduit					$0.00	
10 AWG					$0.00	
Bus Bars					$0.00	
400 MCM					$0.00	
Fence					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
					$0.00	
				Total Misc Cost	$609,000.00	

Total Project Cost	$45,260,113.77

AutoCAD - Updates

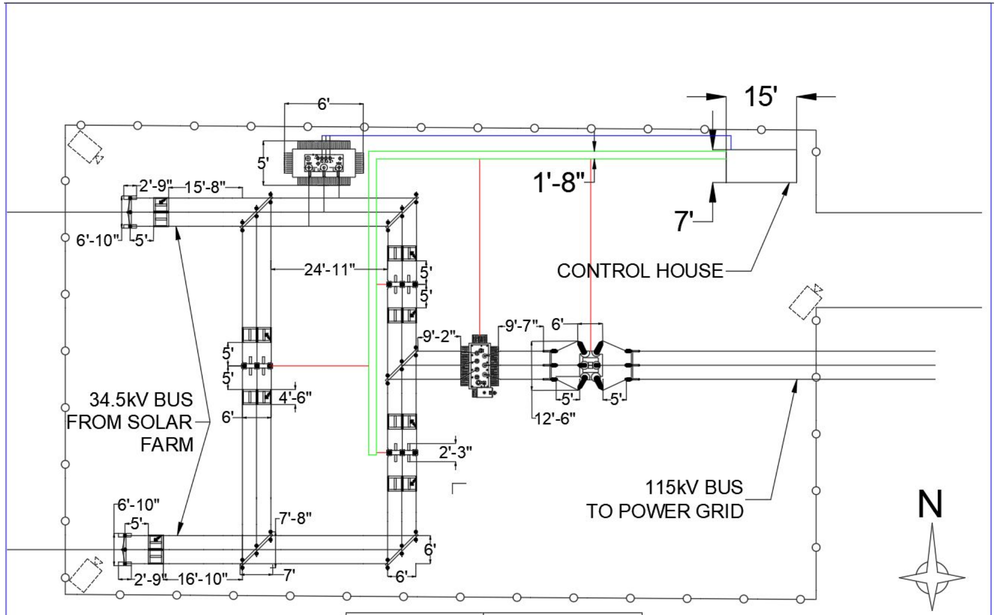


CABLE NAME	CABLE LENGTH	START	END	SIZE	CONDUIT
F1	4778' - 4"	A	SUB	600 MCM	3"
F2	3043' - 3"	B	SUB	600 MCM	3"
IC1	1242' - 6"	INV-1	F1	10 AWG	2"
IC2	791' - 8"	INV-2	F1	10 AWG	2"
IC3	1243' - 6"	INV-3	F1	10 AWG	2"
IC4	1027'	INV-4	F1	10 AWG	2"
IC5	1008'	INV-5	F1	10 AWG	2"
IC6	791' - 8"	INV-6	A	10 AWG	2"
IC7	734'	INV-7	A	10 AWG	2"
IC8	794' - 5"	INV-8	B	10 AWG	2"
IC9	794' - 5"	INV-9	F2	10 AWG	2"
IC10	1246' - 5"	INV-10	F2	10 AWG	2"
IC11	794' - 5"	INV-11	F2	10 AWG	2"
IC12	1246' - 5"	INV-12	F2	10 AWG	2"
IC13	388' - 10"	INV-13	F2	10 AWG	2"
IC14	388' - 10"	INV-14	F2	10 AWG	2"
IC15	814' - 9"	INV-15	B	10 AWG	2"

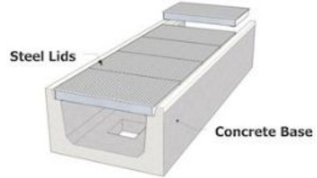
AutoCAD - Updates

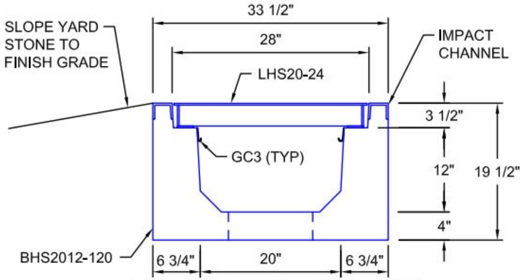
BHS2012-120

Steel Lid, 20” W x 12” D



SYMBOL	DESCRIPTION
(red line)	CONDUIT
(blue line)	CH FEEDER
(green box)	TRENCH

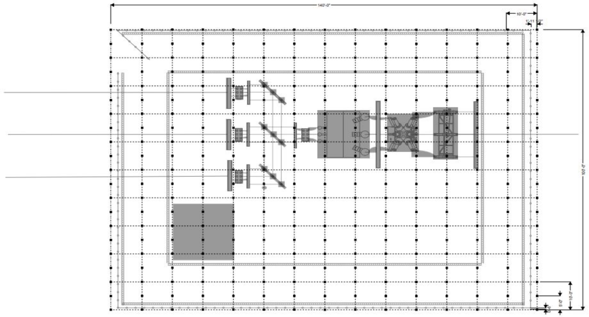




TYPICAL ROAD CROSSING
SECTION WITH STEEL LID
20"W x 12"D
SCALE: 1"=1'-0"

AutoCAD - Grounding

We have rods = total length/length each
= 765 after recalculations



SDMAY23-27 had 315 grounding rods

Mutual ground resistance between the grid and the rod bed

$$R_m = \frac{\rho}{\pi L_c}\left[\ln\left(\frac{2L_c}{L_r}\right) + \frac{k_1 \cdot L_c}{\sqrt{A}} - k_2 + 1\right]$$

$$R_1 = \frac{\rho}{\pi L_c}\left[\ln\left(\frac{2L_c}{a'}\right) + \frac{k_1 \cdot L_c}{\sqrt{A}} - k_2\right]$$

where

ρ	is the soil resistivity in $\Omega \cdot$m
L_c	is the total length of all connected grid conductors in m
a'	is $\sqrt{a \cdot 2h}$ for conductors buried at depth h in m, or
a'	is a for conductor on earth surface in m
$2a$	is the diameter of conductor in m
A	is the area covered by conductors in m^2
k_1, k_2	are the coefficients [see Figure 25(a) and (b)]

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[\ln\left(\frac{4L_R}{b}\right) - 1 + \frac{2k_1 \cdot L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right]$$

where

L_r	is the length of each rod in m
$2b$	is the diameter of rod in m
n_R	number of rods placed in area A

R2=

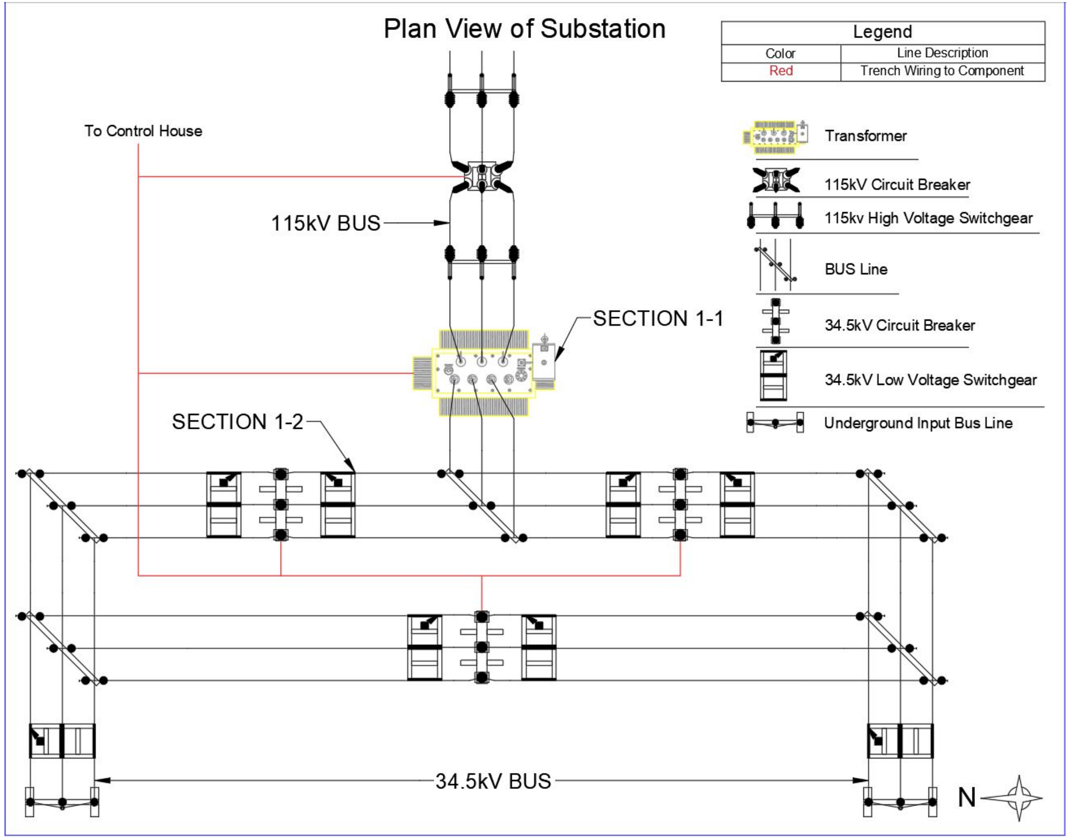
nR=

$$R_g = \frac{R_1 R_2 - R_m^2}{R_1 + R_2 - 2R_m} \quad (53)$$

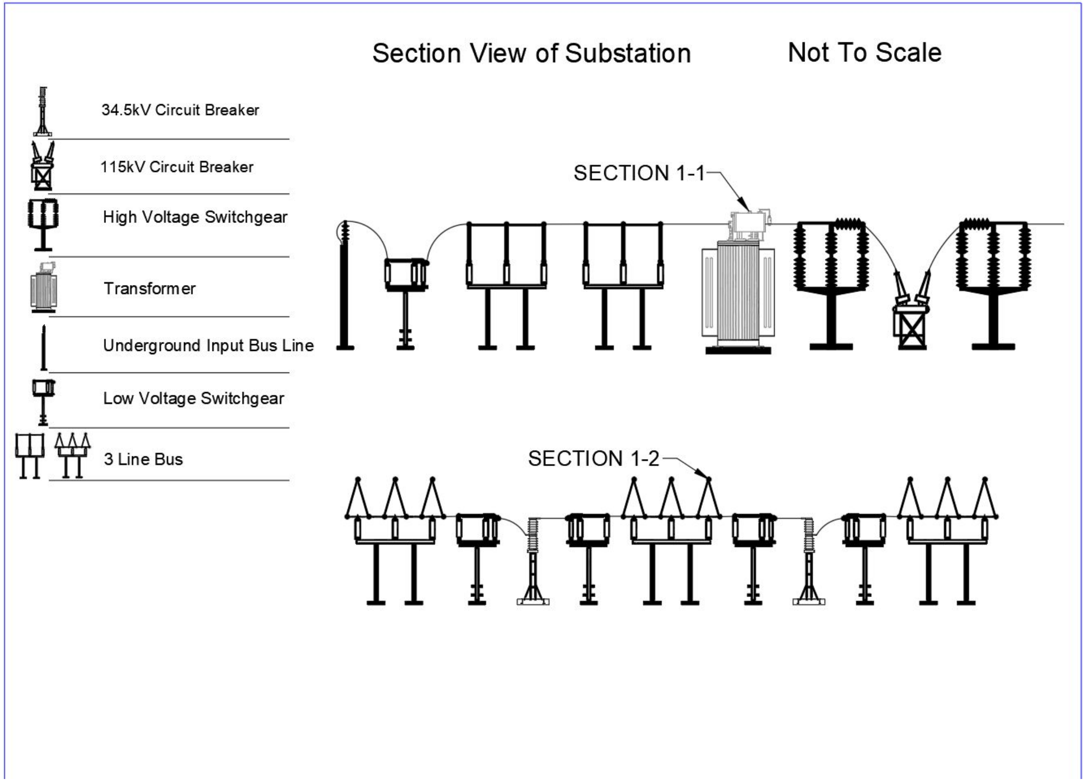
where

R_1	ground resistance of grid conductors in Ω
R_2	ground resistance of all ground rods in Ω
R_m	mutual ground resistance between the group of grid conductors, R_1, and group of ground rods, R_2 in Ω.

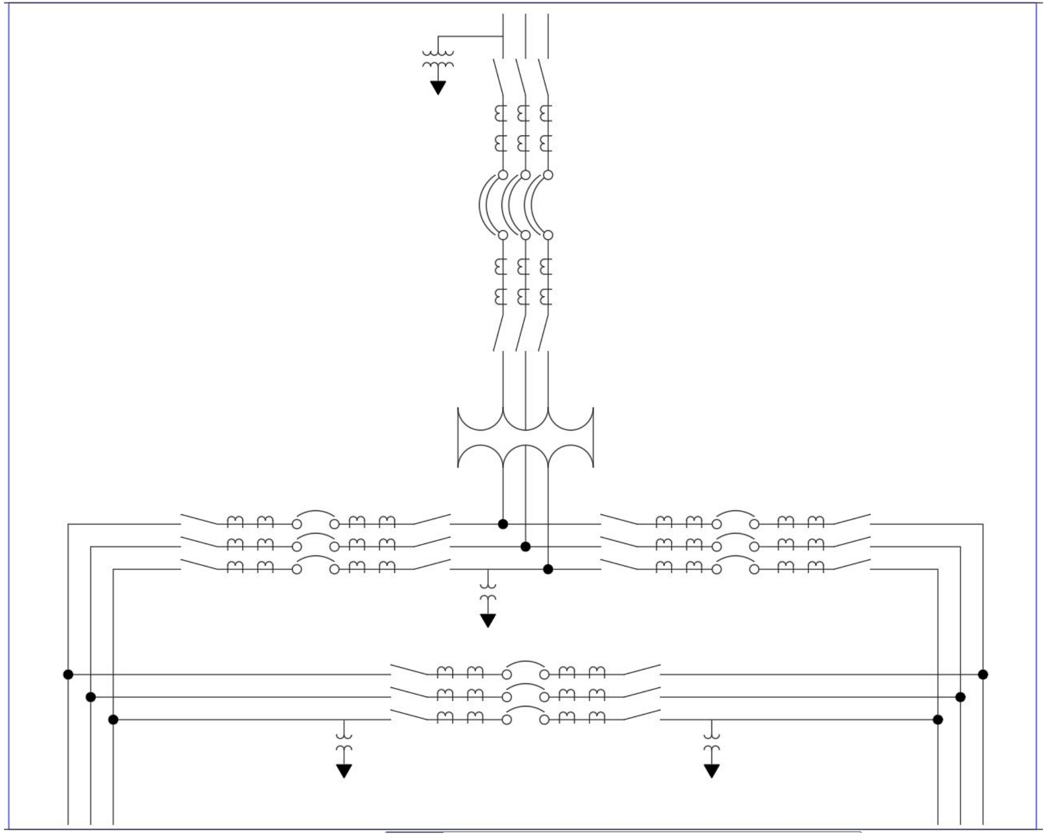
AutoCAD - Updates



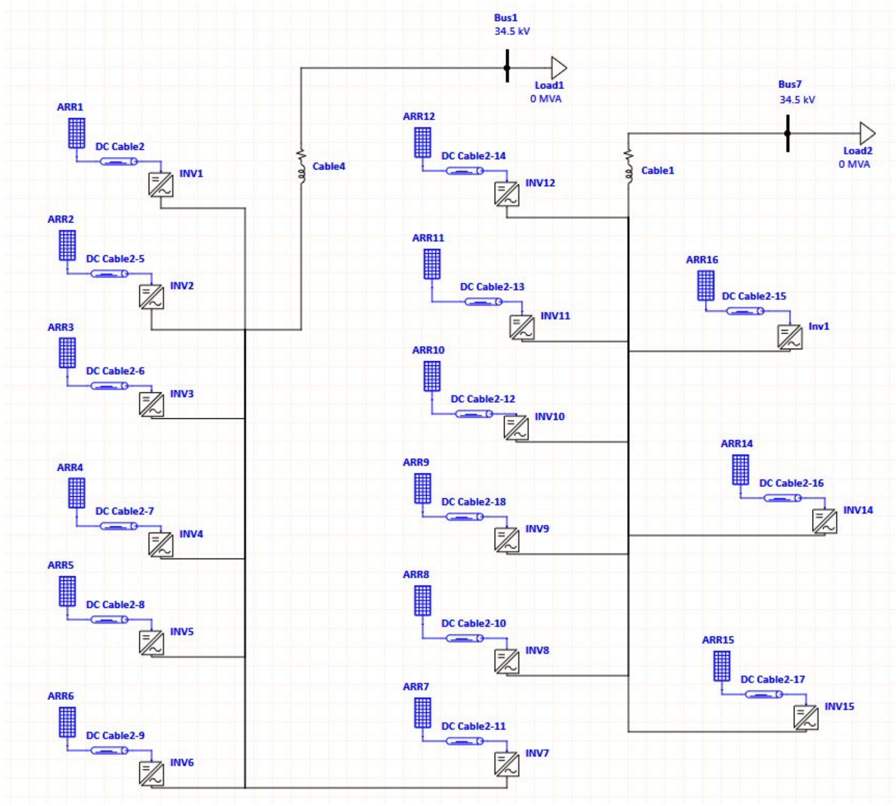
AutoCAD - Updates



AutoCAD - Updates



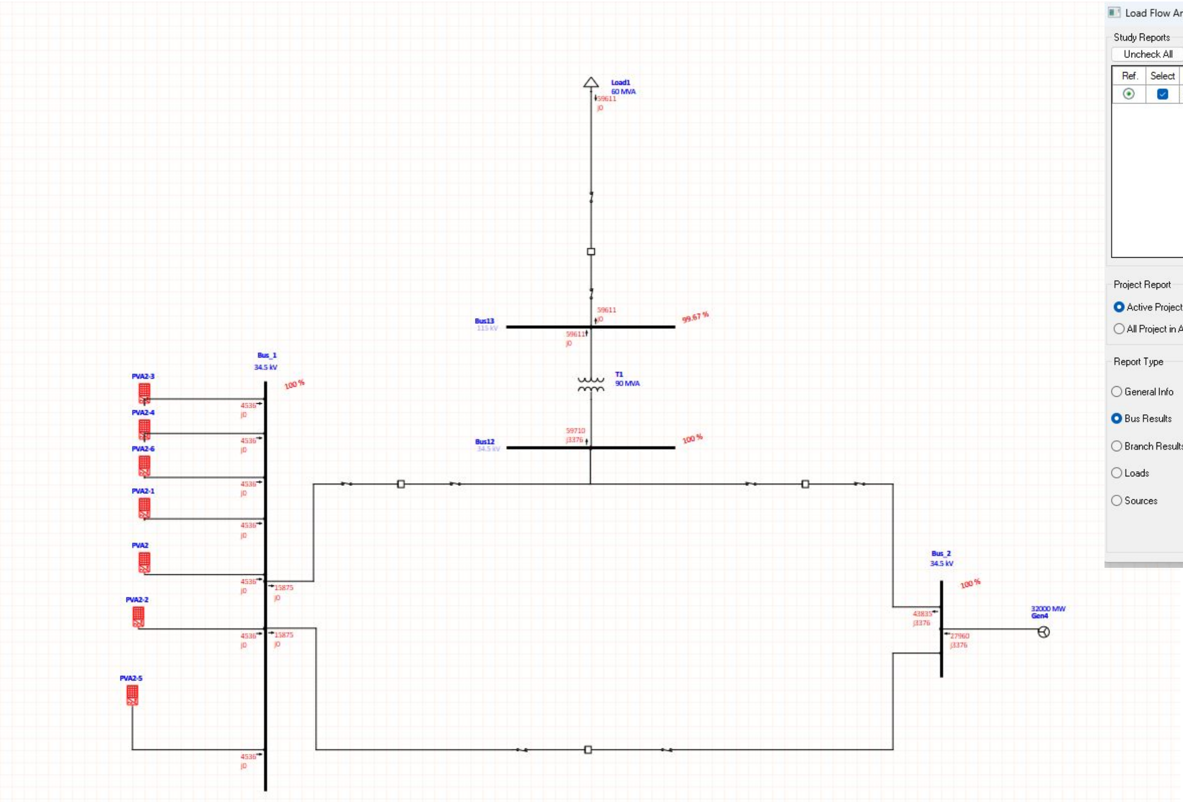
ETAP PV & Substation Power Flow Analysis

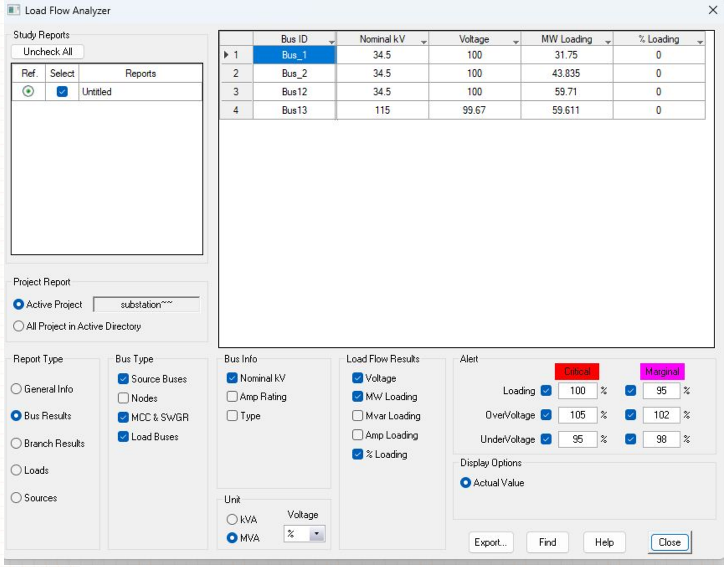


Error Codes:

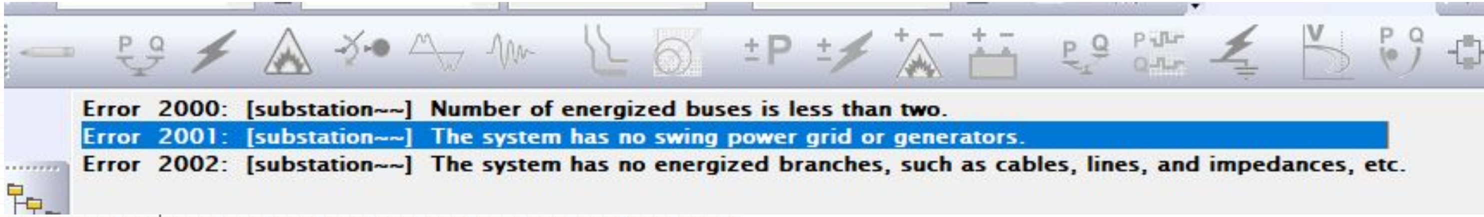
- Model could not converge in number of iterations

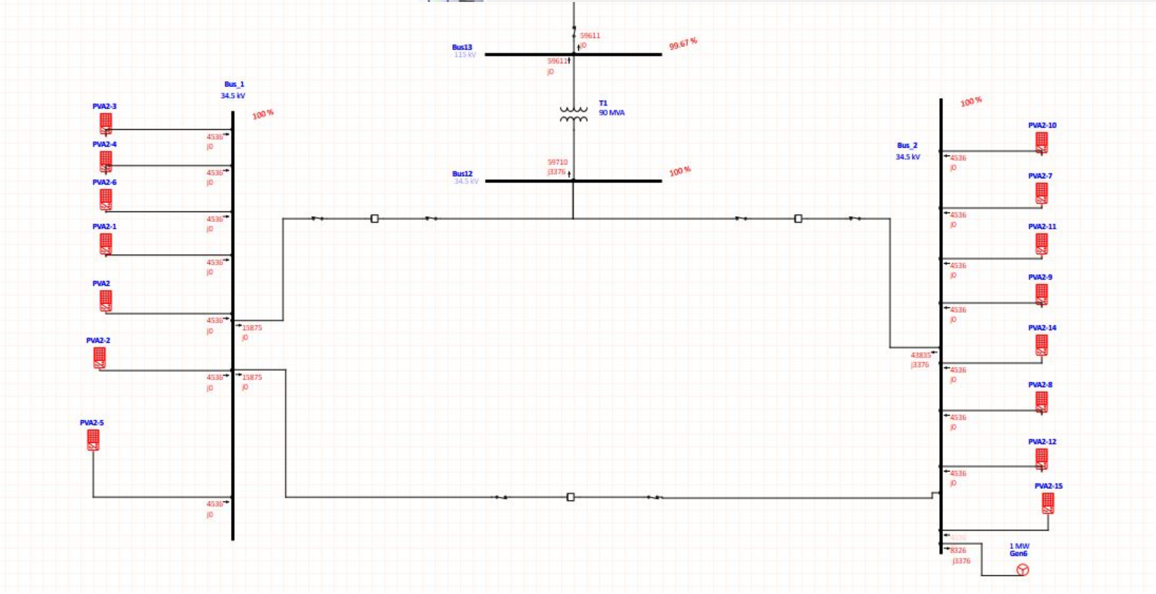
ETAP PV & Substation Power Flow Analysis



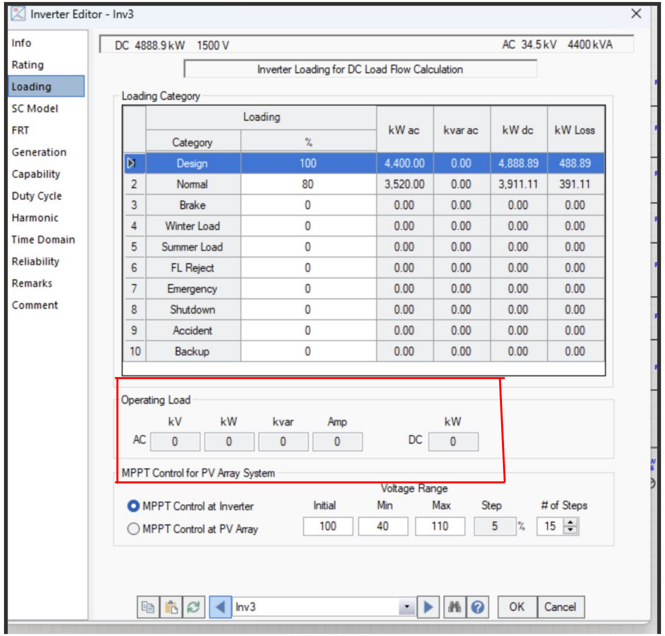


ETAP PV & Substation Power Flow Analysis

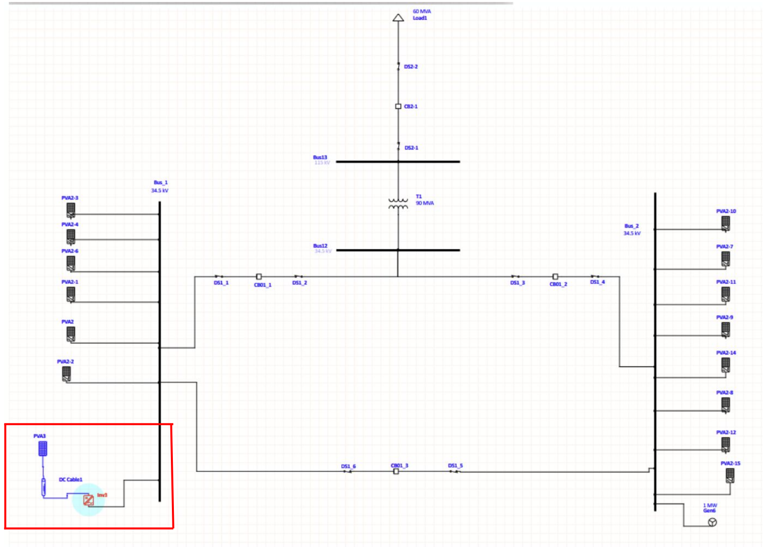




ETAP_Substation Power flow analysis



	Loading: Category	Loading: %	kW ac	kvar ac	kW dc	kW Loss
1	Design	100	4,400.00	0.00	4,888.89	488.89
2	Normal	80	3,520.00	0.00	3,911.11	391.11
3	Brake	0	0.00	0.00	0.00	0.00
4	Winter Load	0	0.00	0.00	0.00	0.00
5	Summer Load	0	0.00	0.00	0.00	0.00
6	FL Reject	0	0.00	0.00	0.00	0.00
7	Emergency	0	0.00	0.00	0.00	0.00
8	Shutdown	0	0.00	0.00	0.00	0.00
9	Accident	0	0.00	0.00	0.00	0.00
10	Backup	0	0.00	0.00	0.00	0.00



Questions

- Cybersecurity?
- Transformer Location?
- Labor Cost?

Feedback and Updates

- Tasks: Updates
  - Bell: Design documents
  - Liam: Confirm battery calcs, confirm relay/CT/PT connections, update BOM
  - Eli:
  - Baylor:
  - Eduardo:
  - Chicheng: