

# 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
- Calculation Documents
- AutoCAD Update
- ETAP
- Feedback



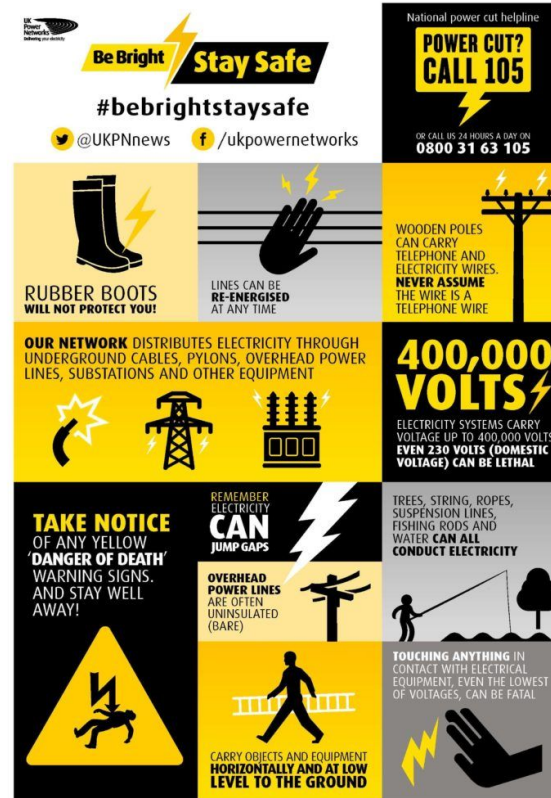
# Safety Moment - Electrical Safety

## Substation Concerns:

- Grounding
- Arc Flashes
- Equipment Failures

## Mitigation Techniques:

- Calculations on grounding
- PPE to help with arc flashes
  - Flame retardant
  - Arc-rated
  - Gloves, safety glasses
- Training for safe practices
- Maintenance and consistent inspections of equipment



# Calculations

## AC Load Calculation :

Total worst case load:  
44.3 kW or 48.7  
(10% worst case scenario added)

Note: Transformer fan current rating does seem relatively high based on examples from catalogs. Running amps are 4 - 5 A, however starting amps are much higher.

	Quantity	Load/Unit(W)	Amps (ea)	Voltage(V)	Total(W)	Amps Total	
AC Panel - Control Building	Breaker Receptacle and Lights	4	210	1.75	120	840	7.00
	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	6	55	0.48	120	330	2.75
	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
	AC Battery Charger	1		0.00	240	0	0.00
	Power Outlet	10	180	1.50	120	1,800	15.00
	Feeder Motor	2	720	3.00	240	1,440	6.00
		0	0	0.00	120	0	0.00
		0	0	0.00	120	0	0.00
	<b>Worst Case Tripping:</b>						
	High Side Breaker Motor	1	720	3.00	240	720	3.00
Low Side Breaker Motor	3	720	3.00	240	2,160	9.00	
Total Worst Case AC Panel Load					44,292	201.10	

<b>Total Worst Case Load (+10 %)</b>	<b>48,721</b>	<b>221.21</b>
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<b>Sizing Recommendations:</b>
Station Service - XXXkVA
MTS, Safety Switch - XXX

[https://docs.google.com/spreadsheets/d/1hwF8cv3VBiy1\\_Yih5wwwBzs9P8UB\\_BBc/edit?usp=sharing&ouid=101132689819119398819&rtpof=true&...](https://docs.google.com/spreadsheets/d/1hwF8cv3VBiy1_Yih5wwwBzs9P8UB_BBc/edit?usp=sharing&ouid=101132689819119398819&rtpof=true&...)  
[https://www.ziehl-abegg.com/fileadmin/Downloadcenter\\_NEW/00\\_englisch%28EN%29\\_MASTER/X02\\_Catalogues/Catalogue-Fans-for-transformer-cooling-fans/f26h](https://www.ziehl-abegg.com/fileadmin/Downloadcenter_NEW/00_englisch%28EN%29_MASTER/X02_Catalogues/Catalogue-Fans-for-transformer-cooling-fans/f26h)  
<https://www.krenzvent.com/transformer-cooling-fans/f26h>



# Calculations

DC Load & Battery Sizing :  
Look into EnerSys battery sizing  
and CA series lead acid batteries

60 cell system	Continuous Load	Discontinuous Load Current
	3.896	9.9

Power Supply Burden (W)	T = 0	T = 1 min	T = 240 min
	20.396	3.896	15.296

T1= 0, Discontinuous load (trip current)  
& continuous load  
T2= 1 min, Total continuous load  
T3= 240 min, Discontinuous load  
(closing current) & continuous load

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	Total Load Current (A)
34.5kV Breaker:	Tripping Current: 3.3A Closing Current: 2.6A	70 - 140 90 - 140	0 - 1	231 - 343W 234 - 364W	3	Tripping Current: 9.9 A Closing Current: 7.8 A
115kV Breaker:	Tripping Current: 6.6A Closing Current: 3.6A	70 - 140 90 - 140	239- 240	462 - 924W 324 - 504W	1	Tripping Current: 6.6A Closing Current: 3.6A
SEL-411L (Line)	0.28	125	1 - 240	35 W	1	0.28
SEL-311L (Line)	0.2	125	1 - 240	25 W	1	0.2
SEL-487E (XFMR)	0.28	125	1 - 240	35 W	1	0.28
GE Multilin T35 (XFMR)	0.7	125	1 - 240	87.5 W	1	0.7
SEL-751 (Bus/Feeder)	0.2	125	1 - 240	25 W	2	0.4
ABB REU615 (Bus/Feeder)	0.144	125	1 - 240	18 W	2	0.288
SEL-451 (Breaker)	0.28	125	1 - 240	35 W	4	1.12
Battery Monitoring Equipment	0.024	50 - 180	1 - 240	3VA	1	0.024
DC Ammeter	0.048	125	1 - 240	6VA	1	0.048
DC Voltmeter	0.048	120	1 - 240	6VA	1	0.048
SACO Annunciator (L8)	0.12	125	1 - 240	15 W	3	0.36
Edwards Bell	0.012	125	1 - 240	1.5VA	1	0.012
Power Line Indicating Lamps (LEDs)	0.017	125	1 - 240	2.125 W	8	0.136

EnerSys : <https://bsp.enersys.com/bsp/index.do>  
[https://docs.google.com/spreadsheets/d/1xRuWZ2yrrR49pMpPjyQim3Ds8Mtx1fYL\\_kv4MVxrck/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1xRuWZ2yrrR49pMpPjyQim3Ds8Mtx1fYL_kv4MVxrck/edit?usp=sharing)



# Calculations

## DC Load & Battery Sizing : Look into EnerSys battery sizing and CA series lead acid batteries

Batteries Sizing > Size Battery

Range	Product	Technology	Products / String	Strings	Total Products	Nb of Cells	Margin *	Select
PowerSafe OGi Americas	6 OGi 110	PLANEPLATE	10	1	10	60	25.0%	<input type="radio"/>
PowerSafe OGi Americas	6 OGi 60	PLANEPLATE	10	2	20	120	25.0%	<input type="radio"/>
PowerSafe CA-M	CA-07M	PLANEPLATE	20	1	20	60	48.3%	<input type="radio"/>
PowerSafe CA-M	CA-03M	PLANEPLATE	20	3	60	180	48.3%	<input type="radio"/>
PowerSafe CC-M	CC-07M	PLANEPLATE	20	1	20	60	48.4%	<input type="radio"/>
PowerSafe CC-M	CC-03M	PLANEPLATE	20	3	60	180	48.4%	<input type="radio"/>
PowerSafe ESG	ESG-05	PLANEPLATE	30	1	30	60	82.5%	<input type="radio"/>
PowerSafe CA-M	CA-05M	PLANEPLATE	20	2	40	120	97.7%	<input type="radio"/>
PowerSafe CC-M	CC-05M	PLANEPLATE	20	2	40	120	97.8%	<input type="radio"/>
PowerSafe DSG	DSG-05	PLANEPLATE	15	1	15	60	194.5%	<input type="radio"/>
PowerSafe EA-M	EA-05M	PLANEPLATE	60	1	60	60	104.2%	<input type="radio"/>
PowerSafe EC-M	EC-05M	PLANEPLATE	60	1	60	60	105.0%	<input type="radio"/>
PowerSafe GC-M	GC-09M	PLANEPLATE	30	1	30	60	747.4%	<input type="radio"/>
PowerSafe OPzS	4 OPzS 200	TUBULAR	60	1	60	60	118.7%	<input type="radio"/>
PowerSafe Vb Single Cell	Vb 2408	PLANEPLATE	60	1	60	60	847.3%	<input type="radio"/>

Smallest margin = 25%  
PowerSafe OGi  
Americas, model 6 OGi  
110

\* margin provides general fit only and should not be used for calculations

Customer Name	Iowa State University
Location	Lovington, New Mexico
Project	115/34.5kV Solar Power Plant & Substation

EnerSys : <https://bsp.enersys.com/bsp/index.do>  
[https://docs.google.com/spreadsheets/d/1xRuWZ2yvrR49pMpPJpyQim3Ds8Mtx1fYL\\_kv4MVxrck/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1xRuWZ2yvrR49pMpPJpyQim3Ds8Mtx1fYL_kv4MVxrck/edit?usp=sharing)



# Calculations

## DC Load & Battery Sizing :

Look into EnerSys battery sizing and CA series lead acid batteries



### Summary Margin Report

**Customer:** Iowa State University  
**Location:** Lovington, New Mexico  
**Project:** 115/34.5kV Solar Power Plant & Substation  
**Date Prepared:** 3/21/24  
**Prepared By:** Siti Nabila Mohd Radzi  
**Phone:** 515-7081944  
**E-Mail:** bellaahn@iastate.edu

**Sizing Parameters**  
**Application:** Utility  
**Lowest Temp (°F):** 77.00  
**Min. Voltage (Vpc):** 1.75  
**Design Margin:** 1.10  
**Aging Factor:** 1.25

Line	Cell Model	Margin
1	6 OGi 110	25.0%
2	6 OGi 60 (2 Strings)	25.0%
3	CA-07M	48.3%
4	CA-03M (3 Strings)	48.3%
5	CC-07M	48.4%
6	CC-03M (3 Strings)	48.4%
7	ESG-05	82.5%
8	CA-05M (2 Strings)	97.7%
9	CC-05M (2 Strings)	97.8%
10	DSG-05	194.5%
11	EA-05M	104.2%
12	EC-05M	105.0%
13	GC-09M	747.4%
14	4 OPzS 200	118.7%
15	Vb 2408	847.3%

**Battery Load Details**  
**Number of Cells:** 60  
**Total Time (Minutes):** 241.00  
**Amp Hour Removed:** 61.25

Period	Time (Mins.)	Load
1	0.00	20.40 A
2	1.00	3.90 A
3	240.00	15.30 A



### Sizing Report Using IEEE-485 Method

**Customer Name:** Iowa State University  
**Location:** Lovington, New Mexico  
**Project:** 115/34.5kV Solar Power Plant & Substation  
**Email:** bellaahn@iastate.edu  
**Prepared by:** Siti Nabila Mohd Radzi  
**Phone:** 515-7081944  
**Date:** 3/21/24

**Lowest Expected Electrolyte Temp.** 77.0 °F (25.0 °C)      **Minimum Cell Voltage** 1.75

(1) PERIOD	(2) LOAD (AMPERES)	(3) CHANGE IN LOAD (AMPERES)	(4) DURATION OF PERIOD (HH:MM:SS)	(5) TIME TO END OF SECTION (HH:MM:SS)	(6) CAPACITY AT 1 MIN RATE K FACTOR (K)	(7) REQUIRED SECTION SIZE (8) = RATED AMP HOURS	
						POS VALUE	NEG VALUE
SECTION 1 - FIRST PERIOD ONLY - IF A2 IS GREATER THAN A1. GO TO SECTION 2							
1	20.40	20.40	00:00:00	00:00:00	0.301	6.141	0.000
<b>Sub Total</b>						6.141	0.000
<b>Section 1 Total</b>						6.141	
SECTION 2 - FIRST 2 PERIOD ONLY - IF A3 IS GREATER THAN A2. GO TO SECTION 3							
1	20.40	20.40	00:00:00	00:01:00	0.379	7.736	0.000
2	3.90	-16.50	00:01:00	00:01:00	0.379	0.000	-6.258
<b>Sub Total</b>						7.736	-6.258
<b>Section 2 Total</b>						1.478	
SECTION 3 - FIRST 3 PERIOD ONLY - IF A4 IS GREATER THAN A3. GO TO SECTION 4							
1	20.40	20.40	00:00:00	04:01:00	4.477	91.310	0.000
2	3.90	-16.50	00:01:00	04:01:00	4.477	0.000	-73.868
3	15.30	11.40	04:00:00	04:00:00	4.461	50.856	0.000
<b>Sub Total</b>						142.165	-73.868
<b>Section 3 Total</b>						68.297	

MAXIMUM SECTION(8) 68.30 + RANDOM SECTION SIZE(9) 0.00 = UNCORRECTED SIZE - (US)(10) 68.30  
 (US)(11) 68.30 x TEMP CORR(12) 0.947 x DESIGN MARGIN(13) 1.10 x AGING FACTOR(14) 1.25 = (15) 88.93  
 WHEN THE CELL SIZE IS GREATER THAN A STANDARD CELL SIZE, THE NEXT LARGER CELL IS REQUIRED.  
 REQUIRED CELL SIZE(16) = 111 AH (PRODUCT RATING PER STRING IS 111 AH)

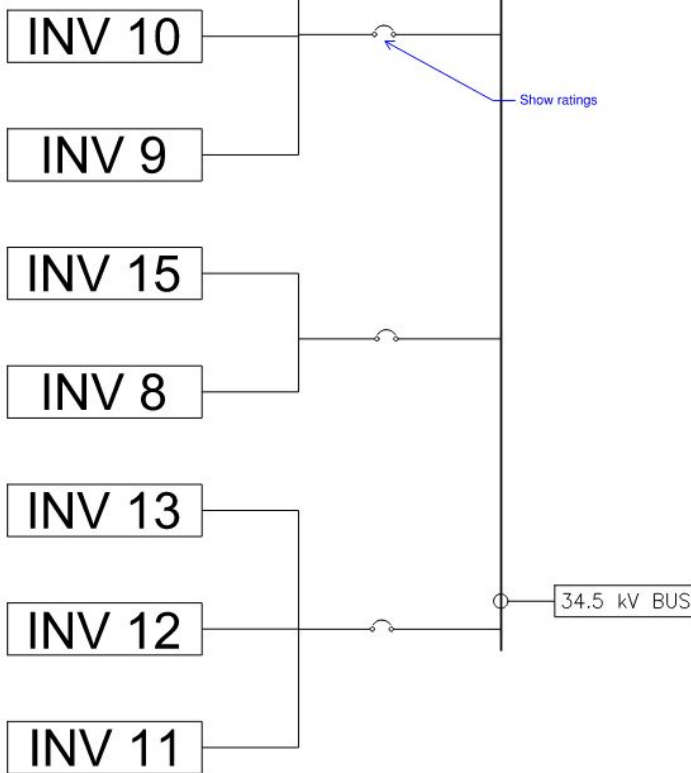
**THEREFORE 1 STRING OF (10) 6 OGI 110 IS RECOMMENDED**  
**Margin : 25.0%**  
**Total AH Removed for System: 61**      **Number of Cells for System: 60**

The 6 OGI 110 battery uses proprietary temperature correction values. Therefore, the temperature correction value used in this IEEE Sizing Report differs from the temperature correction value from the applicable IEEE Standard.

Task pending : Flooded System Configuration Report (for racking) : Search Lovington seismic rating

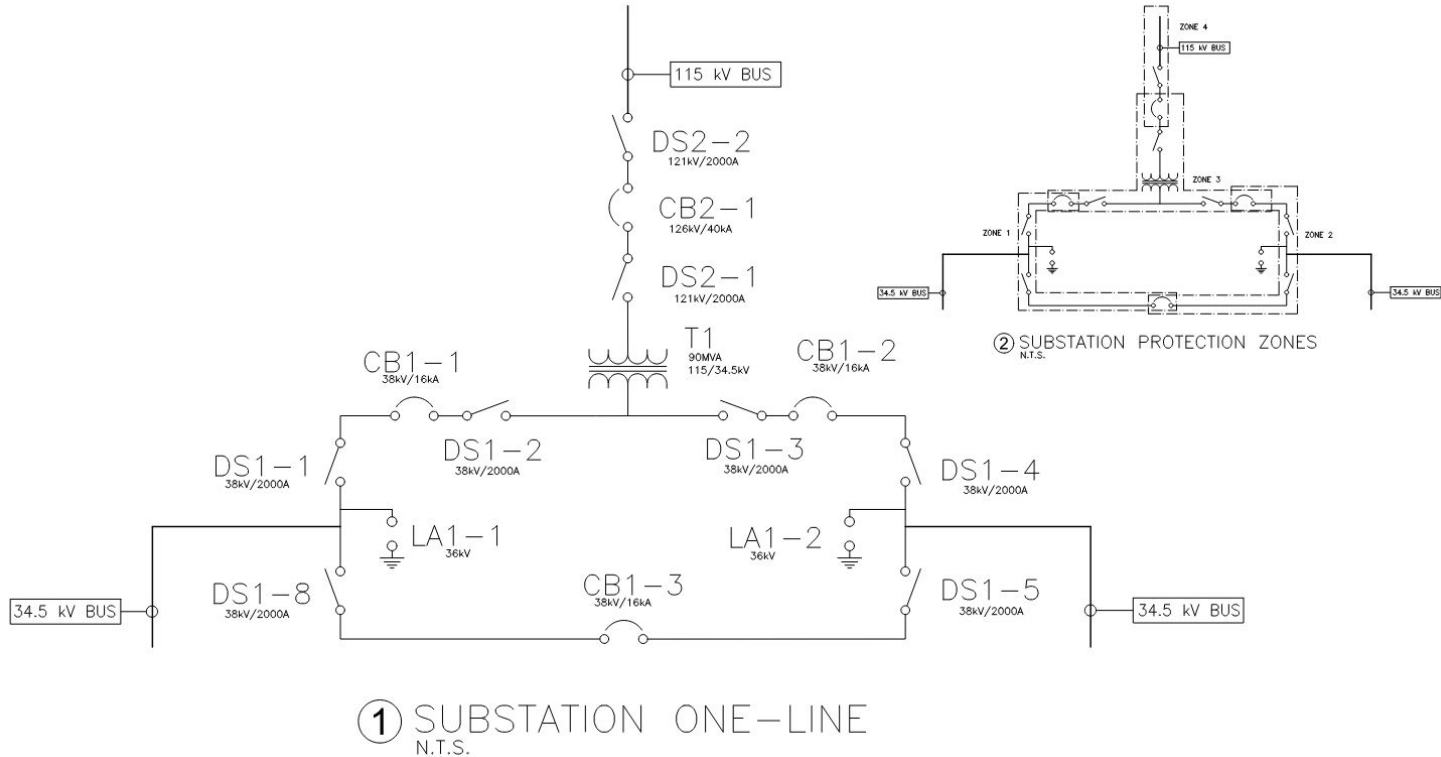


# AutoCAD - Updates

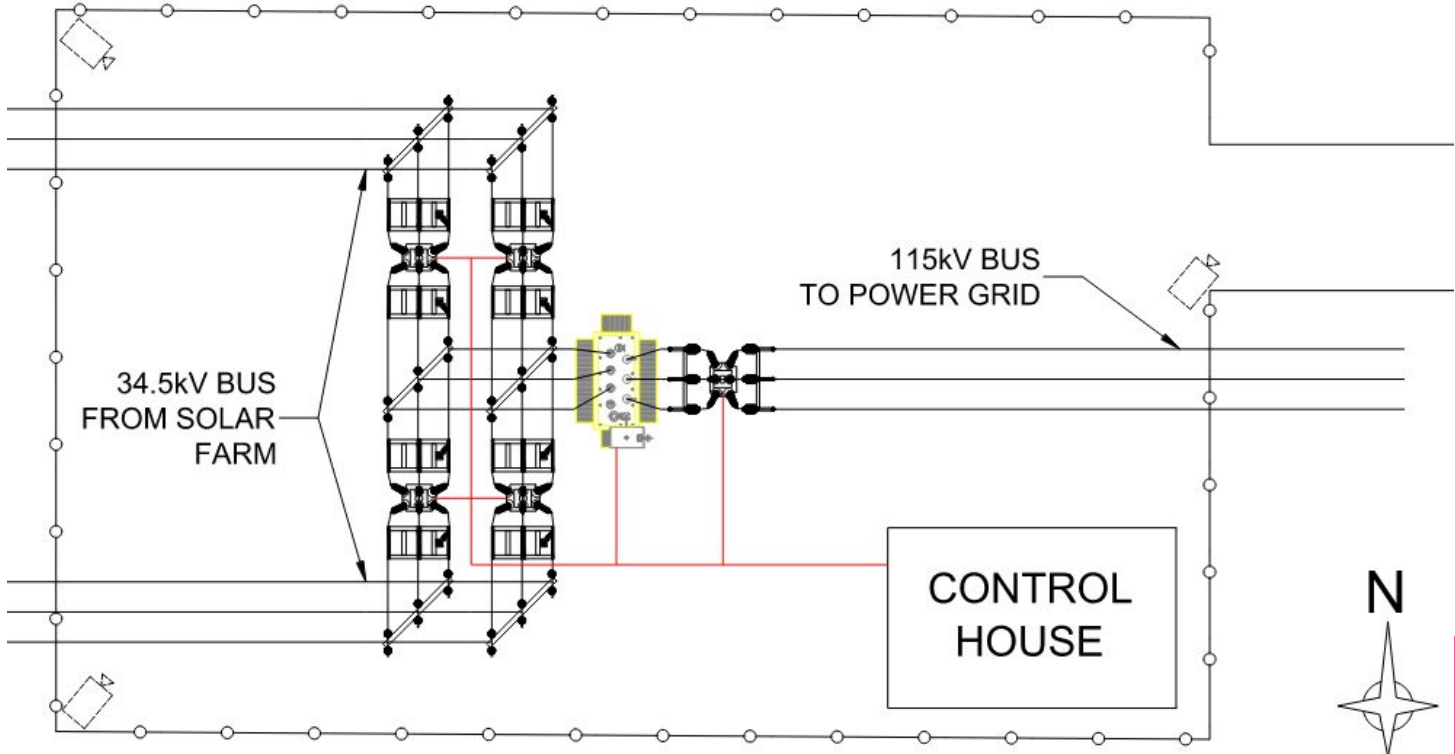




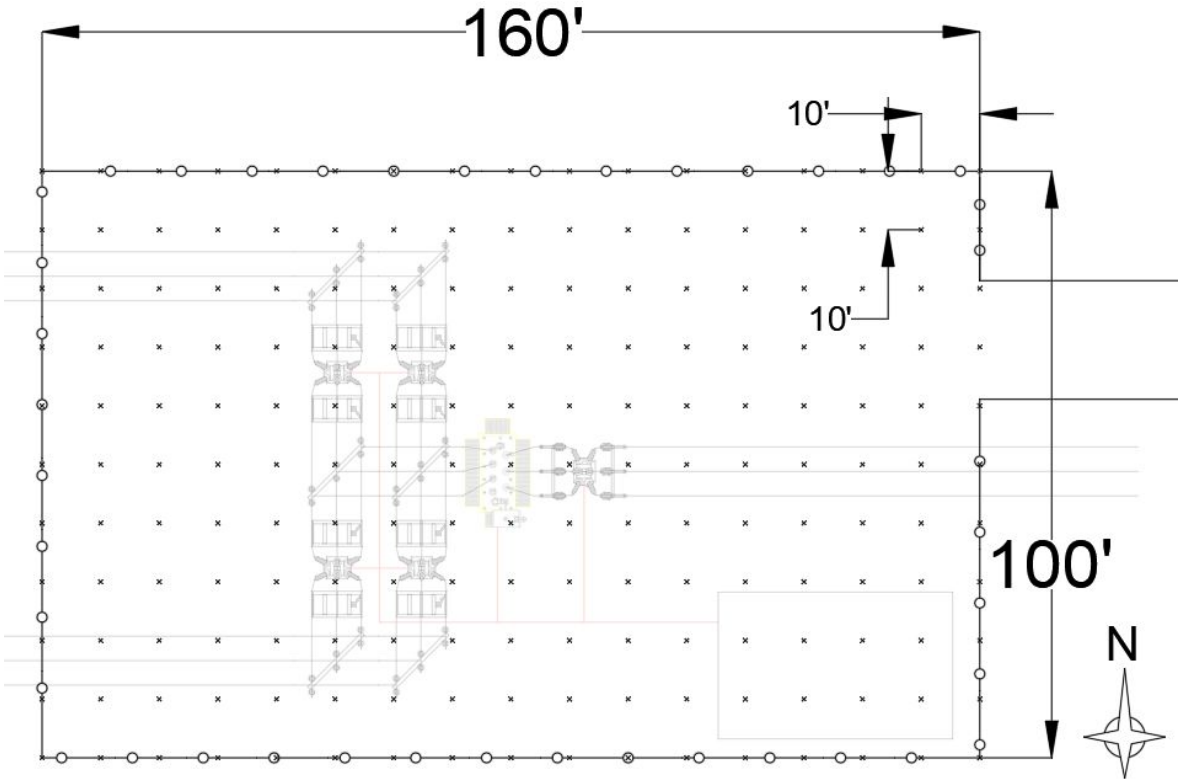
# AutoCAD - Updates



# AutoCAD - Updates

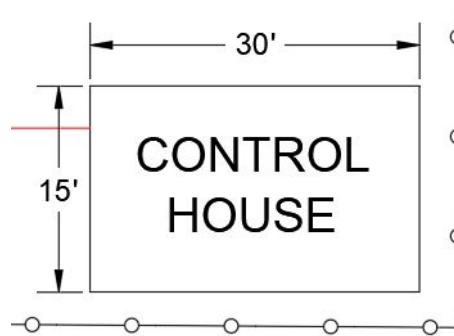


# AutoCAD - Updates



# AutoCAD - Updates

From data sheet a relay can be put in a 19" rack. An estimate of 13 relays will be placed in the control room which will add up to 21 feet wide. Each relay will also be about 4 feet in depth. A 30 foot by 15 foot will leave extra room for expansion or other necessary equipment.



Horizontal (19" rack) - Standard

Horizontal (19" rack) - Harsh Chemical Environment Option

Vertical (3/4 size) - Standard

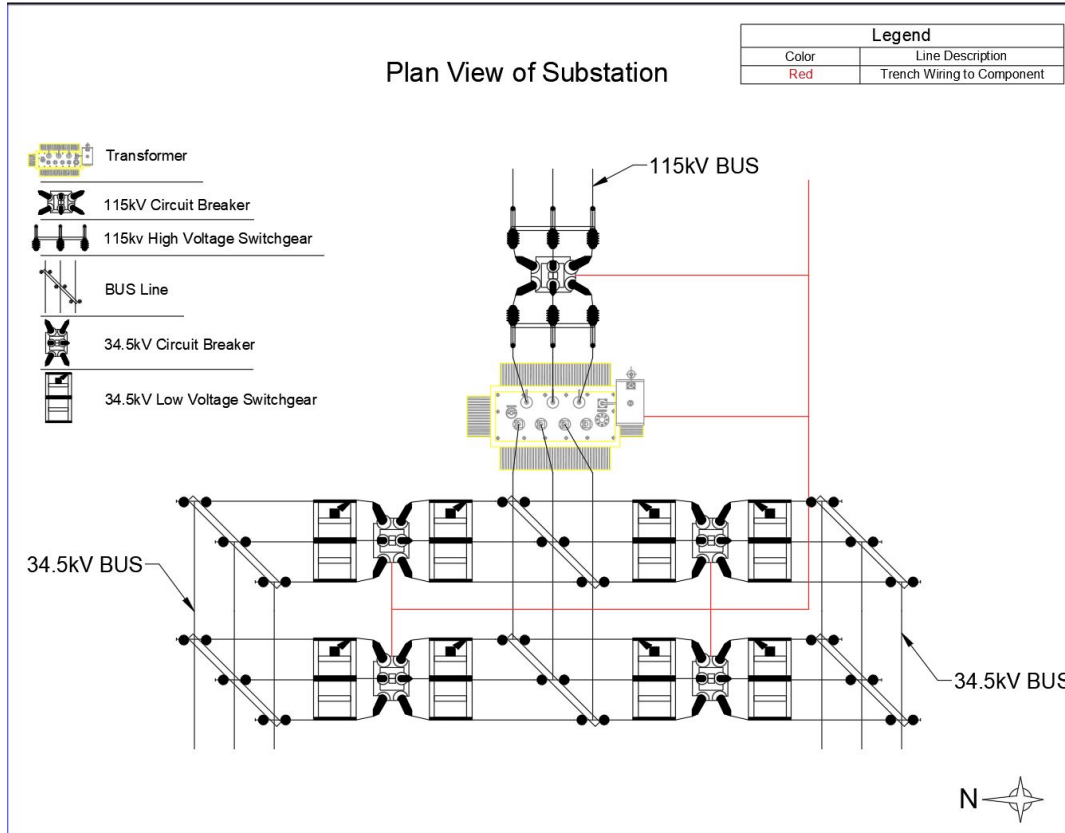
Vertical (3/4 size) - Harsh Chemical Environment Option



[Source & Picture Link](#)



# AutoCAD - Updates



# ETAP - PV Power Flow

Library Quick Pick - Cable

	Unit	Freq	Type	kV	% Class	#/C	Insul	Source	Install
320	English	60	CU	1.0	100	3/C	XLPE	Teck	Non-Mag.
321	English	60	CU	2.0	100	1/C	Rubber	*GexMarTypeP	Non-Mag.
322	English	60	CU	2.0	100	1/C	Rubber	*GexolMarine	Non-Mag.
323	English	60	CU	2.0	100	3/C	EPR	ANCNDA GC...	Non-Mag.
324	English	60	CU	2.0	100	3/C	EPR	ANCNDA GGC	Non-Mag.
325	English	60	CU	2.0	100	3/C	EPR	ANCNDA SH...	Non-Mag.
326	English	60	CU	2.0	100	3/C	EPR	ANCNDASHD...	Non-Mag.
327	English	60	CU	2.0	100	3/C	EPR	ANCNDASHD...	Non-Mag.
328	English	60	CU	2.0	100	3/C	XLPE	AmrCbl	Non-Mag.
329	English	60	CU	2.0	100	1/C	Rubber	GexMarTypeP	Non-Mag.

U/G Ampacity			A/G Ampacity		Unit	Rac Base
Ta	Tc	RHO	Ta	Tc	Length	Temp.
20	90	90	45	100	1000ft	110

Size	Phase	G/N
18		
16		
14		
12		
10		
8		

AWG/kcmil

Avail. Sizes

All Sizes

Help OK None Cancel

- Conductor Size: 10 AWG/kcmil
- Feeder Size: 600 AWG/kcmil



# Questions

- Next steps

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## Feedback and Updates

- Tasks: Updates
  - Bell: Calcs
  - Liam: Look at IEEE 485 and EnerSys for battery charger sizing, BOM
  - Eli: ACAD (Enlarged Views/Schedules), BOM
  - Baylor: ETAP, BOM
  - Eduardo: ACAD (Control House)
  - Chicheng: ETAP

