4.3 Proposed Design

4.3.1 Overview

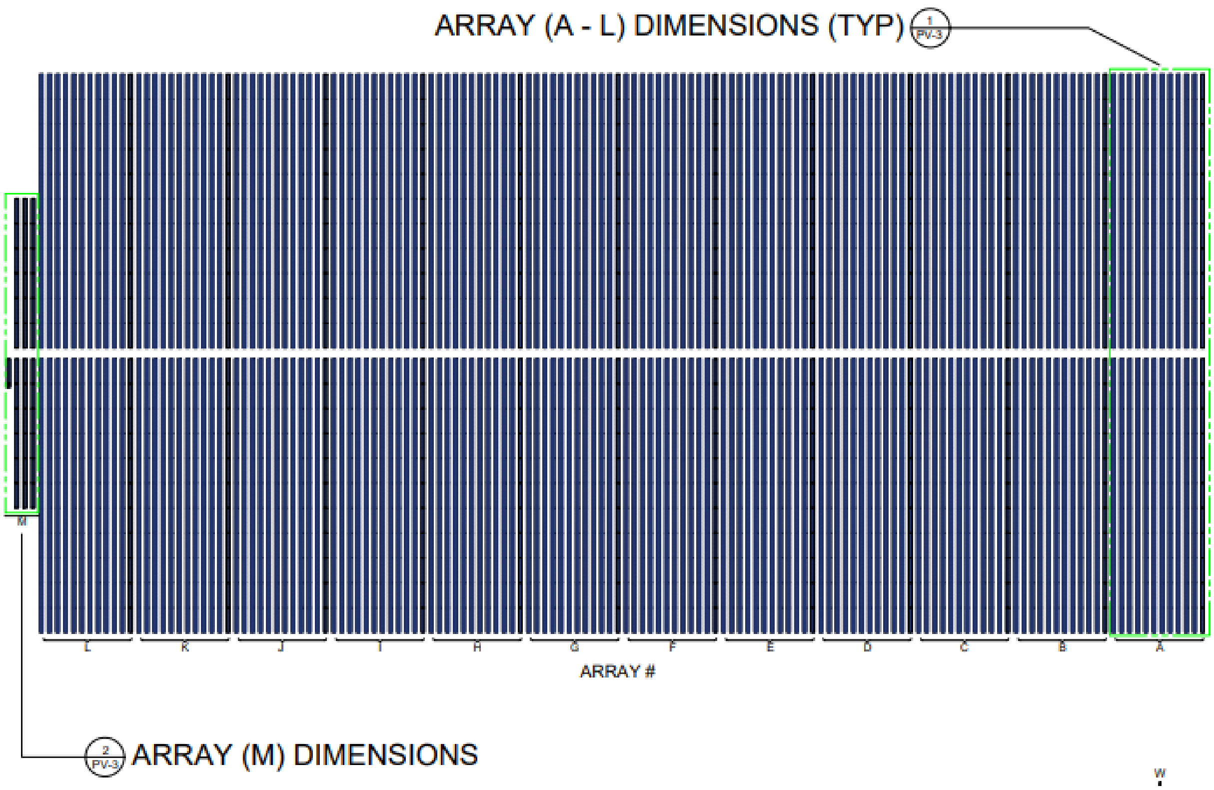
Provide a high-level description of your current design. This description should be understandable to non-engineers (i.e., the general public). Describe key components or subsystems and how they contribute to the overall design. You may wish to include a basic block diagram, infographic, or other visual to help communicate the overall design.

During the fall semester we are completely designing the solar array portion of our project. There are several aspects that make up the design; the layout, the specific gear that makes up the layout, and the data that helped us make the design decisions.

Our current solar array layout consists of 144 rows of uniformly placed panels with 4 more rows of irregular-length panel strings (as seen below). Within these rows there are 148 combiner boxes, 13 combiner boxes and over 20 thousand panels. We were able to determine the number of components to use as well as the make and model through our use of an excel spreadsheet called the Array Parameter Tool. The APT takes in data from each component datasheet and outputs component numbers, layout spacing, and solar plant output. All of this information was very useful to us because it confirmed which components would generate our desired output voltage and power as well as tell us how many components we needed and how far apart we should be spacing our rows.

Another tool that helped us solidify our solar array layout was the Voltage Drop Calculator excel spreadsheet. In systems such as these we need to worry about excess voltage drop because if the outermost panels have too high of a voltage drop (greater than 5% overall) the equipment will experience too much wear and tear and will degrade much faster than they should . When we input panel currents, voltages, string/jumper lengths, wire size, and wire impedance, we were given an overall voltage drop value. At first the voltage drop was too high, so we had to move the combiner box locations to reduce the jumper distance which gave us a voltage drop below 5%. This tool allowed us to verify our design and modify it to ensure proper functionality.

Overall, with the help of the Array Parameter Tool and the Voltage Drop Calculator, we have gotten data that has helped us make design decisions. The major design decisions have been which specific component models should be used for our solar array, and where the components need to be placed within the array to make it functional.



Solar Array Layout

4.3.2 Detailed Design and Visual(s)

Provide a detailed, technical description of your design, aided by visualizations. This description should be understandable to peer engineers. In other words, it should be clearly written and sufficiently detailed such that another senior design team can look through it and implement it.

The description should include a high-level overview written for peer engineers. This should list all sub-systems or components, their role in the whole system, and how they will be integrated or interconnected. A visual should accompany this description. Typically, a detailed block diagram will suffice, but other visual forms can be acceptable.

The description should also include more specific descriptions of sub-systems and components (e.g., their internal operations). Once again, a good rule of thumb is: could another engineer with similar expertise build the component/sub-system based on your description? Use visualizations to support your descriptions. Different visual types may be relevant to different types of projects, components, or subsystems. You may include, but are not limited to: block diagrams, circuit diagrams, sketches/pictures of physical components and their operation, wireframes, etc.

Components:

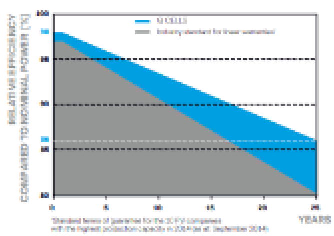
-Solar Panel Data Sheet Summary: Data Sheet Link

ELECTRICAL CHARACTERISTICS

POWER CLASS				470	475	480	485	490	495
MINIMUM PERFORMANCE AT STANDARD TEST CONDITIONS, STC[1] (POWER TOLERANCE +5 W / −0 W)									
Minimum	Power at MPP[1]	P_{MPP}	[W]	470	475	480	485	490	495
	Short Circuit Current[1]	I_{SC}	[A]	11.21	11.24	11.26	11.29	11.31	11.34
	Open Circuit Voltage[1]	V_{OC}	[V]	53.54	53.58	53.61	53.64	53.68	53.71
	Current at MPP	I_{MPP}	[A]	10.62	10.66	10.71	10.76	10.81	10.86
	Voltage at MPP	V_{MPP}	[V]	44.27	44.54	44.81	45.07	45.33	45.59
	Efficiency[1]	η	[%]	≥20.3	≥20.5	≥20.7	≥20.9	≥21.2	≥21.4
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NMOT[2]									
Minimum	Power at MPP	P_{MPP}	[W]	352.6	356.4	360.1	363.9	367.6	371.4
	Short Circuit Current	I_{SC}	[A]	9.03	9.05	9.07	9.09	9.12	9.14
	Open Circuit Voltage	V_{OC}	[V]	50.49	50.53	50.56	50.59	50.62	50.65
	Current at MPP	I_{MPP}	[A]	8.34	8.39	8.43	8.47	8.52	8.56
	Voltage at MPP	V_{MPP}	[V]	42.26	42.49	42.72	42.94	43.17	43.39

[1]Measurement tolerances P_{MPP} ±3%; I_{SC}; V_{OC} ±5% at STC: 1000 W/m², 25±2 °C, AM 1.5 according to IEC 60904-3 • [2]800 W/m², NMOT, spectrum AM 1.5

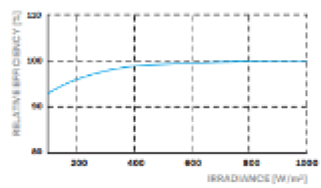
Q CELLS PERFORMANCE WARRANTY



At least 98% of nominal power during first year. Thereafter max. 0.5% degradation per year. At least 93.5% of nominal power up to 10 years. At least 86% of nominal power up to 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Q CELLS sales organisation of your respective country.

PERFORMANCE AT LOW IRRADIANCE



Typical module performance under low irradiance conditions in comparison to STC conditions (25 °C, 1000 W/m²)

TEMPERATURE COEFFICIENTS

Temperature Coefficient of I_{SC}	α	[% / K]	+0.04	Temperature Coefficient of V_{OC}	β	[% / K]	−0.27
Temperature Coefficient of P_{MPP}	γ	[% / K]	−0.34	Nominal Module Operating Temperature	NMOT	[°F]	109±5.4 (43±3 °C)

PROPERTIES FOR SYSTEM DESIGN

Maximum System Voltage V_{SYS}	[V]	1500 (IEC) / 1500 (UL)	PV module classification	Class II
Maximum Series Fuse Rating	[A DC]	20	Fire Rating based on ANSI / UL 61730	TYPE 1
Max. Design Load, Push / Pull[3]	[lbs/ft²]	75 (3600 Pa) / 42 (2000 Pa)	Permitted Module Temperature on Continuous Duty	−40 °F up to +185 °F (−40 °C up to +85 °C)
Max. Test Load, Push / Pull[3]	[lbs/ft²]	113 (5400 Pa) / 63 (3000 Pa)		

[3]See Installation Manual

-Combiner Box Data Sheet Summary: Data Sheet Link

TECHNICAL INFORMATION	STG.DCB.xx.C400dCG.BesN[a]	STG.DCB.xx.C400dCC.BesN[a]	STG.DCB.xx.C400dCB.BesN[a]	STG.DCB.xx.C400dCO.BesN[a]
Max. System Voltage	1500 VDC	1500 VDC	1500 VDC	1500 VDC
Rated Output Current	400A	400A	400A	400A
Rated Input Current	25.6A	25.6A	25.6A	25.6A
Max. Overcurrent Protection	32A	32A	32A	32A
Number of Input Circuits	Up to 18	Up to 18	Up to 24	Up to 32
Positive Input Wire Size	6-14 AWG	6-14 AWG	6-14 AWG	6-14 AWG
Negative Input Wire Size	4-14 AWG	4-14 AWG	4-14 AWG	4-14 AWG
Positive Output Wire Size	Up to (1) 600 MCM or (2) 500 MCM	Up to (1) 800 MCM or (2) 700 MCM	Up to (1) 900 MCM or (2) 750 MCM	Up to (1) 1000 MCM or (2) 800 MCM
Negtive Output Wire Size	Up to (1) 600 MCM or (2) 500 MCM	Up to (1) 800 MCM or (2) 700 MCM	Up to (1) 900 MCM or (2) 750 MCM	Up to (1) 1000 MCM or (2) 800 MCM
Ground Wire Size	2/0-14 AWG	2/0-14 AWG	2/0-14 AWG	2/0-14 AWG
Enclosure Rating	NEMA 4X	NEMA 4X	NEMA 4X	NEMA 4X
Max. Ambient Temp. Rating	50°C	50°C	50°C	50°C
Enclosure Size (H x W x D)	24" x 24" x 10"[b]	30" x 24" x 10"[b]	24" x 30" x 10"[b]	30" x 36" x 10"[b]
Approximate Weight	70 lbs	75 lbs	80 lbs	110 lbs

-Inverter Data Sheet Summary: Data Sheet Link

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Technical data and types

Product Type designation, PVS980-58	PVS980-58 4.3 MVA -4348kVA-I	PVS980-58 4.6 MVA -4565kVA-J	PVS980-58 4.8 MVA -4782kVA-K	PVS980-58 5.0 MVA -5000kVA-L
Input (DC)				
Maximum recommended input power ($P_{PV,max}$) [1]	8696 kWp	9130 kWp	9564 kWp	10000 kWp
Maximum dc short circuit current	16 kA			
Maximum operational dc current	5700 A			
Maximum operational DC voltage ($U_{max (DC)}$) [2]	1500 V			
DC voltage range for maximum power ($U_{DC, mpp}$) @ -20 to +25 °C	850 to 1350 V	893 to 1350 V	935 to 1350 V	978 to 1350 V
DC voltage range for maximum power ($U_{DC, mpp}$) @ 35 °C	850 to 1250 V	893 to 1250 V	935 to 1250 V	978 to 1250 V
DC voltage range for maximum power ($U_{DC, mpp}$) @ 50 °C	850 to 1100 V	893 to 1100 V	935 to 1100 V	978 to 1100 V
Number of MPPT trackers	1			
Number of protected DC inputs [3]	20-36 (+/-)			
Output (AC)				
Power @ 25 °C	4348 kVA	4565 kVA	4782 kVA	5000 kVA
AC current @ 25 °C	4184 A			
Power @ 35 °C	4229 kVA	4441 kVA	4652 kVA	4864 kVA
AC current @ 35 °C	4070 A			
Power ($S_{N (AC)}$) @ 50 °C	3845 kVA	4037 kVA	4229 kVA	4421 kVA
AC current ($I_{N (AC)}$) @ 50 °C	3700 A			
Nominal output voltage ($U_{N (AC)}$) [4]	600 V	630 V	660 V	690 V
Output frequency [5]	50/60 Hz			
Harmonic distortion, current [6]	< 3%			
Maximum AC short circuit current from network	80 kA (1 s RMS)			
Distribution network type [7]	TN and IT			
Efficiency				
Maximum [8]	98.8%			
Euro-eta [8]	98.6%			
CEC efficiency [8]	98.5%			
Power consumption				
Maximum own consumption in operation	4000 W			
Maximum standby operation consumption	460 W			
Auxiliary voltage type	external [10]			

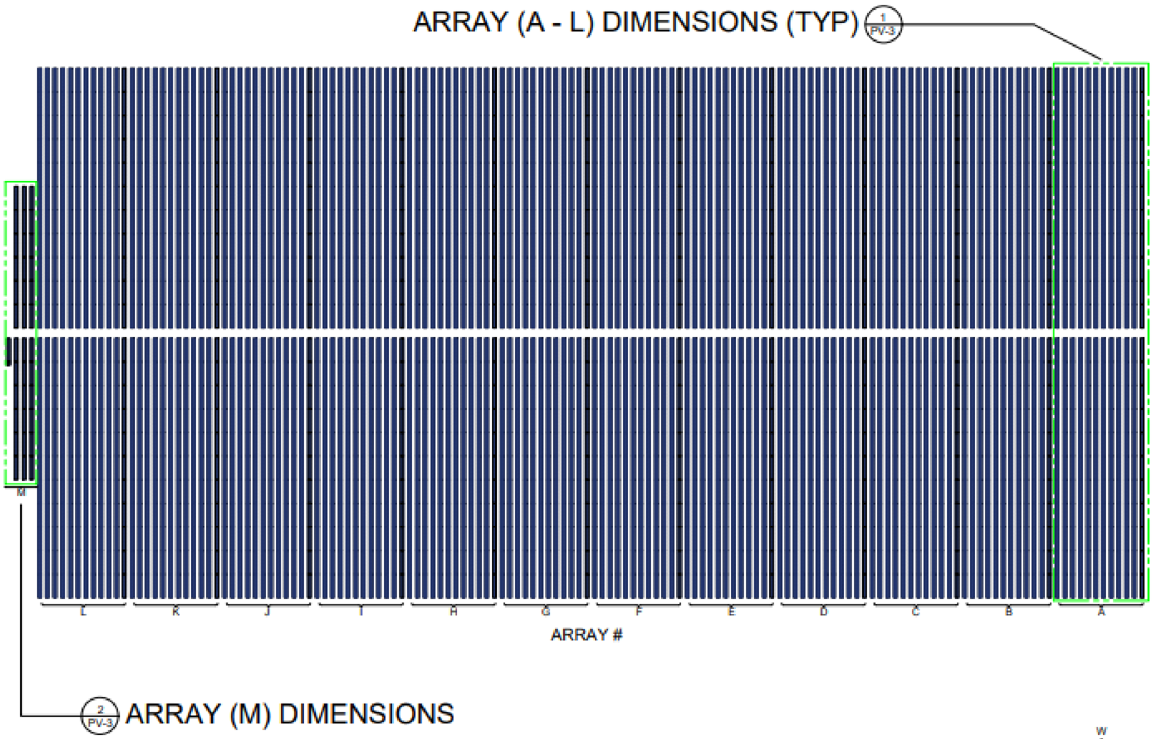
Components left to confirm:

Racking system for the solar panels and fencing around the perimeter of the array.

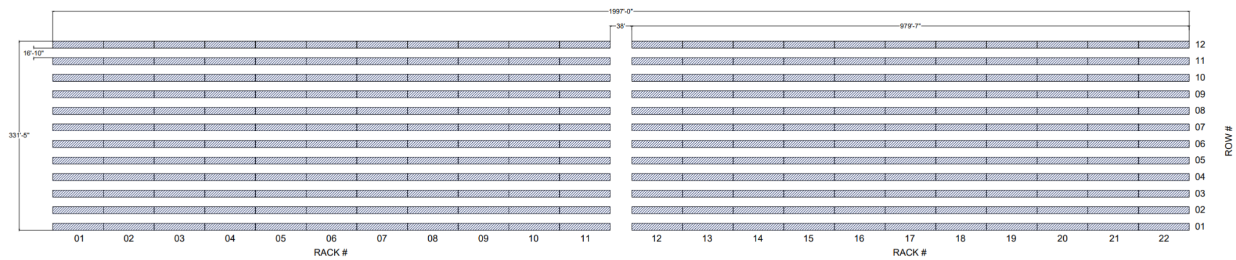
CAD Layout of Design:

CAD designs are still in progress and other details such as voltage drop are still being added. Shown below is the current version of the drawing plans. Full documentation will be provided with final submission.

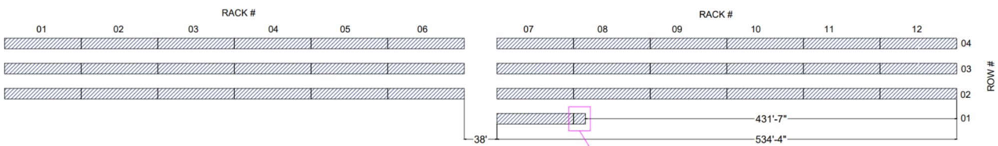
Layout:



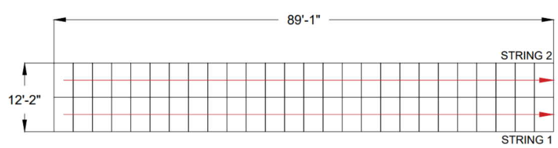
ARRAY (A - L) DIMENSIONS (TYP)
1
PV-3
M
L
K
J
I
H
G
F
E
D
C
B
A
ARRAY #
2
PV-3
ARRAY (M) DIMENSIONS



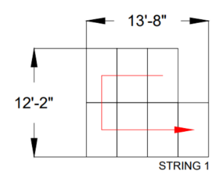
1 PV-3 ARRAY (A) DIMENSIONS (TYPICAL)
NOT TO SCALE



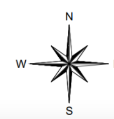
2 PV-3 ARRAY (M) DIMENSIONS
NOT TO SCALE

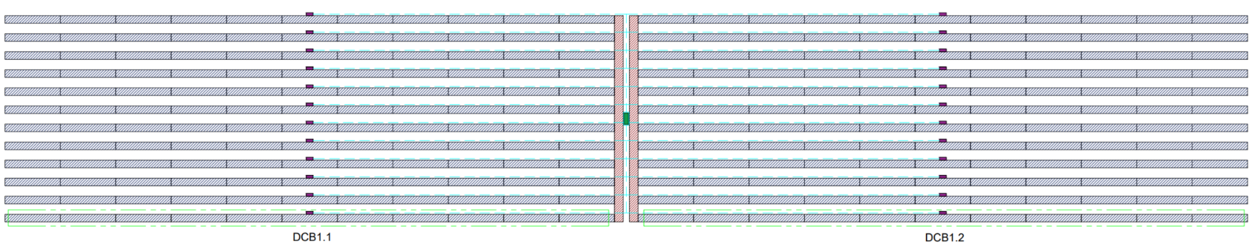


3 PV-3 RACK/STRINGING DETAIL (TYPICAL)
NOT TO SCALE



4 PV-3 RACK/STRINGING DETAIL
NOT TO SCALE

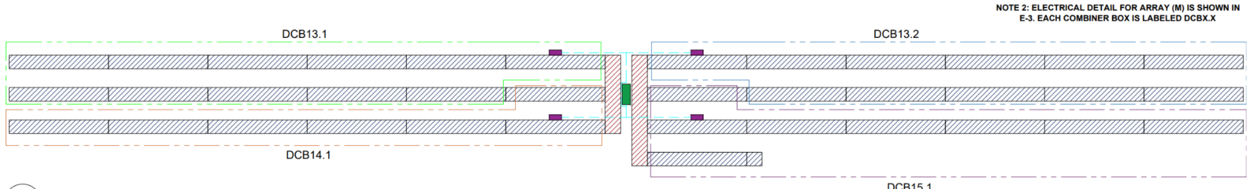




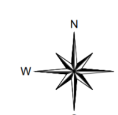
1 PV-4 ARRAY (A) COMPONENT LAYOUT (TYPICAL)
NOT TO SCALE

NOTE 1: ELECTRICAL DETAIL FOR ARRAY (A) IS SHOWN IN E-1 & E-2. EACH COMBINER BOX IS LABELED DCBX.X

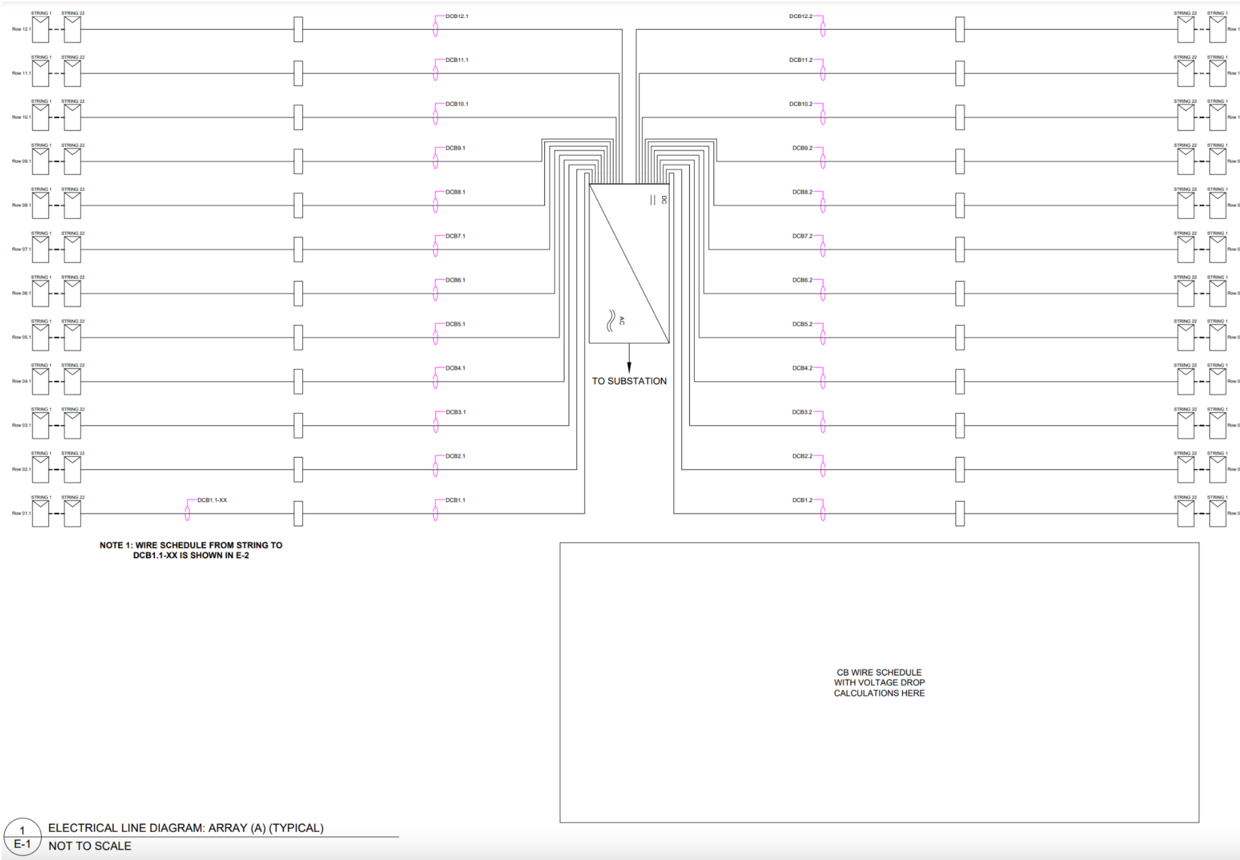
NOTE 2: ELECTRICAL DETAIL FOR ARRAY (M) IS SHOWN IN E-3. EACH COMBINER BOX IS LABELED DCBX.X



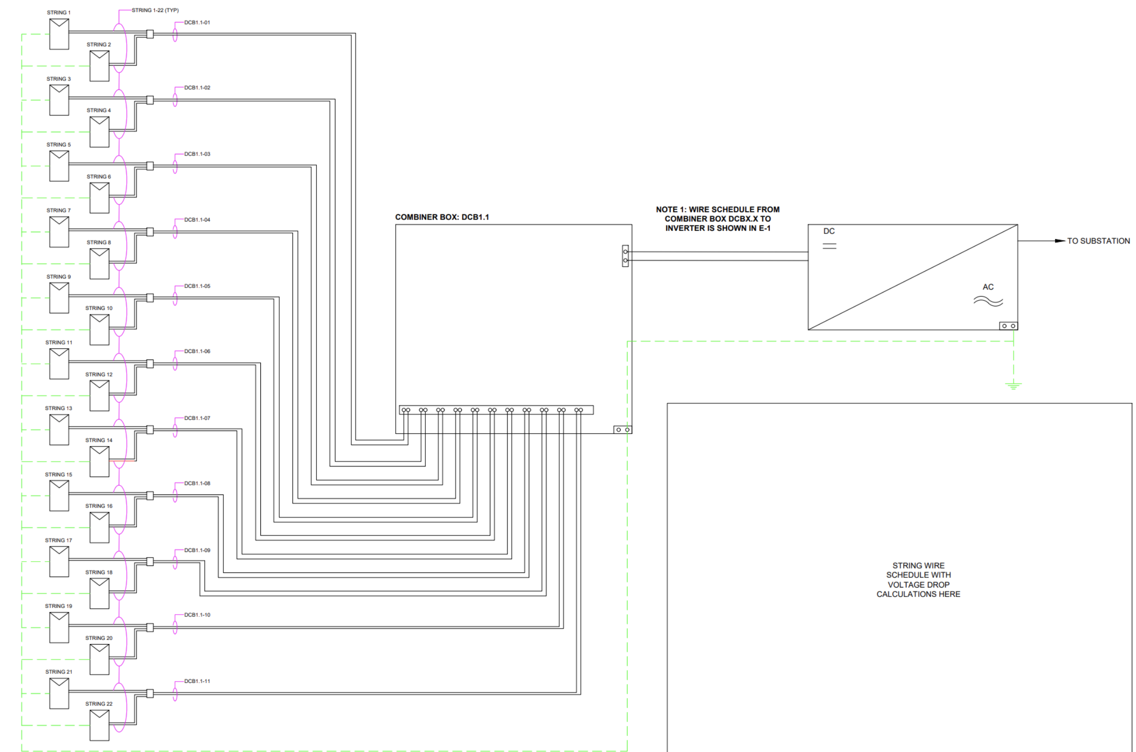
2 PV-4 ARRAY (M) COMPONENT LAYOUT
NOT TO SCALE



Wiring:



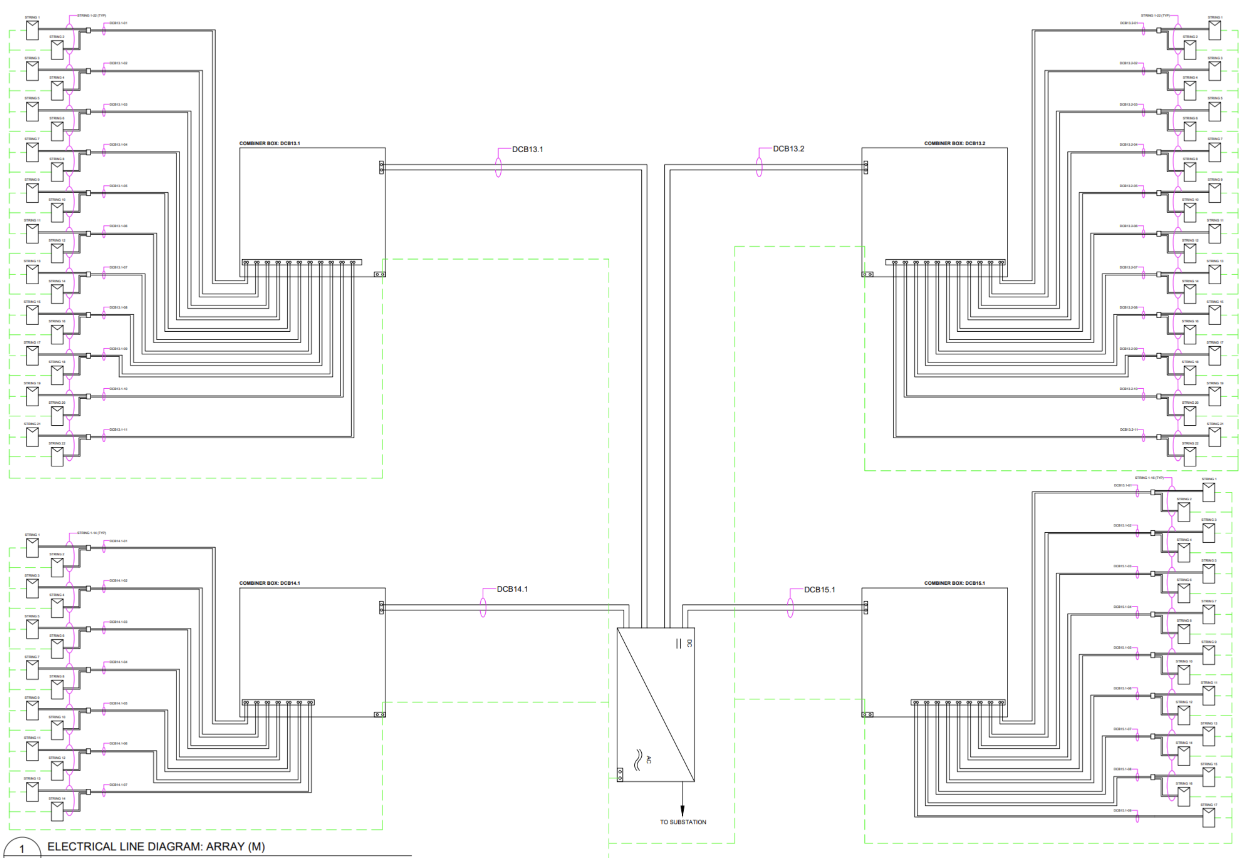
NOTE 1: WIRE SCHEDULE FROM STRING TO DCB1.1-XX IS SHOWN IN E-2
TO SUBSTATION
CB WIRE SCHEDULE WITH VOLTAGE DROP CALCULATIONS HERE
1
E-1
ELECTRICAL LINE DIAGRAM: ARRAY (A) (TYPICAL)
NOT TO SCALE



STRING WIRE SCHEDULE WITH VOLTAGE DROP CALCULATIONS HERE

1 / E-2 ELECTRICAL LINE DIAGRAM: ARRAY (A) ROW 01.1 (TYPICAL)

NOT TO SCALE



1 / E-3 ELECTRICAL LINE DIAGRAM: ARRAY (M)

NOT TO SCALE

Voltage Drop Calculations:

Normal Array

Wire Type	Aluminum - THWN														
DCB	Strings per Rack	IMP for String	String Length	String wire size	String Conductor resistance	String resistance	Voltage Drop of String	IMP for Jumper	Jumper Length	Jumper wire size	Jumper resistance	Jumper resistance	Voltage Drop of Jumper		
DCB#-##	per rack	Amp	feet	AWG	Ohm/kft	Ohm	Volts	Amp	feet	AWG	Ohm/kft	Ohm	Volts		
DCB1-01	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	490	6	0.8080	0.7664184	16.945376		
DCB1-02	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	400.95	6	0.8080	0.6270696	13.86581328		
DCB1-03	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	311.9	6	0.8080	0.4877208	10.78625056		
DCB1-04	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	222.85	6	0.8080	0.348372	7.70668784		
DCB1-05	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	133.8	6	0.8080	0.2090232	4.62712512		
DCB1-06	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	44.75	6	0.8080	0.0696744	1.5475624		
DCB1-07	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4	44.75	6	0.8080	0.072	1.5475624		
DCB1-08	2	10.7	85.7	10	2.0000	0.331681	3.66796	21.4	133.8	6	0.8080	0.216	4.62712512		
DCB1-09	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	222.85	6	0.8080	0.36	7.70668784		
DCB1-10	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	311.9	6	0.8080	0.504	10.78625056		
DCB1-11	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	400.95	6	0.8080	0.648	13.86581328		
Combiner Name		from Array Parameter	panels in string * panel width	IMP x 1.25 AWG size above that	Table 8 NEC						Table 8 NEC				
DCB23-01	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0		
DCB23-02	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0		
DCB23-03	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0	34.9518	
DCB23-04	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0		
DCB23-05	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0		
DCB23-06	2	10.7	85.7	10	2.0000	0.3319211	3.66796	21.4		6	0.8080	0	0		

DCB	No. of Rack Inputs	IMP for DCB circuit	Feeder length	Feeder wire size	Feeder resistance	Feeder resistance			Voltage drop for feeder	Voltage drop for feeder	Voltage drop for circuit	VMP for circuit			Voltage drop for circuit
DCB#-##	#	Amp	feet	kcmil	Ohm/kft	Ohm			Volt	per cent	Volt	Volt			per cent
DCB1.1	11	235.40	641	600	0.0353	0.0438			10.65293284	1.10%	48.33758241	1165.00			4.15%
DCB1.2	11	235.40	641	600	0.0353	0.0438			10.65293284	1.10%	48.33758241	1165.00			4.15%
DCB2.1	11	235.40	612	600	0.0353	0.0418			10.17097488	1.05%	48.17692976	1165.00			4.14%
DCB2.2	11	235.40	612	600	0.0353	0.0418			10.17097488	1.05%	48.17692976	1165.00			4.14%
DCB3.1	11	235.40	583	600	0.0353	0.0399			9.68901692	1.00%	48.01627711	1165.00			4.12%
DCB3.2	11	235.40	583	600	0.0353	0.0399			9.68901692	1.00%	48.01627711	1165.00			4.12%
DCB4.1	11	235.40	553	600	0.0353	0.0377			9.19043972	0.95%	47.85008471	1165.00			4.11%
DCB4.2	11	235.40	553	600	0.0353	0.0377			9.19043972	0.95%	47.85008471	1165.00			4.11%
DCB5.1	11	235.40	524	600	0.0353	0.0358			8.70848176	0.90%	47.68943205	1165.00			4.09%
DCB5.2	11	235.40	524	600	0.0353	0.0358			8.70848176	0.90%	47.68943205	1165.00			4.09%
DCB6.1	11	235.40	494	600	0.0353	0.0338			8.20990456	0.84%	47.52323965	1165.00			4.08%
DCB6.2	11	235.40	494	600	0.0353	0.0338			8.20990456	0.84%	47.52323965	1165.00			4.08%
DCB7.1	11	235.40	494	600	0.0353	0.0338			8.20990456	0.84%	47.52323965	1165.00			4.08%
DCB7.2	11	235.40	494	600	0.0353	0.0338			8.20990456	0.84%	47.52323965	1165.00			4.08%
DCB8.1	11	235.40	524	600	0.0353	0.0358			8.70848176	0.90%	47.68943205	1165.00			4.09%
DCB8.2	11	235.40	524	600	0.0353	0.0358			8.70848176	0.90%	47.68943205	1165.00			4.09%
DCB9.1	11	235.40	553	600	0.0353	0.0377			9.19043972	0.95%	47.85008471	1165.00			4.11%
DCB9.2	11	235.40	553	600	0.0353	0.0377			9.19043972	0.95%	47.85008471	1165.00			4.11%
DCB10.1	11	235.40	583	600	0.0353	0.0399			9.68901692	1.00%	48.01627711	1165.00			4.12%
DCB10.2	11	235.40	583	600	0.0353	0.0399			9.68901692	0.12%	48.01627711	1165.00			4.12%
DCB11.1	11	235.40	612	600	0.0353	0.0418			10.17097488	0.13%	48.17692976	1165.00			4.14%
DCB11.2	11	235.40	612	600	0.0353	0.0418			10.17097488	0.13%	48.17692976	1165.00			4.14%
DCB12.1	11	235.40	641	600	0.0353	0.0438			10.65293284	0.14%	41.46647041	1165.00			3.56%
DCB12.2	11	235.40	641	600	0.0353	0.0453			10.65293284	0.14%	36.84453265	1165.00			3.16%
		sum total of combiner box current		IMP x 1.25 AWG size above that	Table 8 NEC							Voltage your strings/racks are rated at	st-case DCB voltage drop:		4.05%

Small Array

Wire Type	Aluminum - THWN														
DCB	Strings per Rack	IMP for String	String Length	String wire size	String Conductor resistance	String resistance	Voltage Drop of String	IMP for Jumper	Jumper Length	Jumper wire size	Jumper resistance	Jumper resistance	Voltage Drop of Jumper		
DCB#-##	per rack	Amp	feet	AWG	Ohm/kft	Ohm	Volts	Amp	feet	AWG	Ohm/kft	Ohm	Volts		
DCB13.x-01	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	396	6	0.8080	0.619328	13.6946304		
DCB13.x-02	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	310	6	0.8080	0.4848177	10.720544		
DCB13.x-03	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	224	6	0.8080	0.3503074	7.7464576		
DCB13.x-04	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	138	6	0.8080	0.2157971	4.7723712		
DCB13.x-05	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	52	6	0.8080	0.0812868	1.7982848		
DCB13.x-06	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	43	6	0.8080	0.0667713	1.4870432		
DCB13.x-07	2	10.7	85.7	10	2.0000	0.332	3.66796	21.4	468	6	0.8080	0.756	16.1845632		
DCB13.x-08	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	382	6	0.8080	0.617	13.2104768		
DCB13.x-09	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	296	6	0.8080	0.478	10.2363904		
DCB13.x-10	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	210	6	0.8080	0.339	7.262304		end of rack 1 t
DCB13.x-11	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	74	6	0.8080	0.12	2.5590976		
DCB14.1-01	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	396	6	0.8080	0.64	13.6946304		
DCB14.1-02	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	310	6	0.8080	0.501	10.720544		
DCB14.1-03	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	224	6	0.8080	0.362	7.7464576		
DCB14.1-04	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	138	6	0.8080	0.223	4.7723712		
DCB14.1-05	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	52	6	0.8080	0.084	1.7982848		
DCB14.1-06	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	43	6	0.8080	0.069	1.4870432		
DCB14.1-07	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	74	6	0.8080	0.12	2.5590976		
DCB15.1-01	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	396	6	0.8080	0.64	13.6946304		
DCB15.1-02	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	310	6	0.8080	0.501	10.720544		
DCB15.1-03	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	224	6	0.8080	0.362	7.7464576		
DCB15.1-04	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	138	6	0.8080	0.223	4.7723712		
DCB15.1-05	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	52	6	0.8080	0.084	1.7982848		
DCB15.1-06	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	43	6	0.8080	0.069	1.4870432		
DCB15.1-07	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	74	6	0.8080	0.12	2.5590976		
DCB15.1-06	2	10.7	85.7	10	2.0000	0.343	3.66796	21.4	74	6	0.8080	0.12	2.5590976		
DCB15.1-07	1	10.7	13.7	10	2.0000	0.055	0.58636	10.7	74	6	0.8080	0.12	1.2795488		
Combiner Name		from Array Parameter	panels in string * panel width	IMP x 1.25 AWG size above that	Table 8 NEC						Table 8 NEC				
DCB23-01	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		
DCB23-02	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		
DCB23-03	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		
DCB23-04	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		
DCB23-05	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		
DCB23-06	2	10.7	88.4	10	0.8080	0.1383811	1.52854208	21.4		6	0.8080	0	0		

DCB	No. of Rack Inputs	IMP for DCB circuit	Feeder length	Feeder wire size	Feeder resistance	Feeder resistance			Voltage drop for feeder	Voltage drop for feeder	Voltage drop for circuit	VMP for circuit			Voltage drop for circuit
DCB#-##	#	Amp	feet	kcmil	Ohm/kft	Ohm			Volt	per cent	Volt	Volt			per cent
DCB13.1	11	235.40	106.5	600	0.0353	0.0073			1.76994906	0.18%	43.92989075	1165.00			3.77%
DCB13.2	11	235.40	106.5	600	0.0353	0.0073			1.76994906	0.18%	43.92989075	1165.00			3.77%
DCB14.1	7	235.40	69.5	600	0.0353	0.0047			1.15503718	0.12%	43.72492013	1165.00			3.75%
DCB15.1	9	235.40	69.5	600	0.0353	0.0047			1.15503718	0.12%	43.72492013	1165.00			3.75%
		sum total of combiner box current		IMP x 1.25 AWG size above that	Table 8 NEC							Voltage your strings/racks are rated at	st-case DCB voltage drop:		3.76%

Voltage Drop Calculations Check:

Voltage Drop Calc.

$$\frac{2(\text{jumper length})(\text{jumper resistance})(\text{Imp})}{1000} = Vd = \frac{(mV/A/m)\,Ib\,(L)}{1000}$$

DCB1-01

$$\frac{2(490)(0.8080)(21.4)}{1000} = 16.945 \quad ☑$$

DCB1-11

$$\frac{2(400.95)(0.8080)(21.4)}{1000} = 13.865 \quad ☑$$

voltage drop calc

Voltage drop for circuit / VMP for circuit × 100%

DCB1.1 $\frac{48.33758241}{1165} = 0.0415 \times 100 = 4.15\%$ ☑

DCB12.2 $\frac{36.84453265}{1165} = 0.0316 \times 100 = 3.16\%$ ☑

SMALL ARRAY

DB13.X-01 $\frac{2(396)(0.8080)(21.4)}{1000} = 13.69$ ☑

DCB12.2 $\frac{12.87269334}{1165} = 0.011049 \times 100 = 1.105\%$ ☑

4.3.3 Functionality

Describe how your design is intended to operate in its user and/or real-world context. What would a user do? How would the device/system/etc. respond? This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

Our project design is solely a design. Users will use the design as a template for how to build the physical substation and solar field. It will be used as a print of sort to show the dimensions and equipment needed when constructing both the solar field and substation. The design drawing will stay the same and be used as a visual to go off of when constructing the solar field and substation.

4.3.4 Areas of Concern and Development

How well does/will the current design satisfy requirements and meet user needs?

The current design satisfies the requirements and users needs very well because it is a clear documentation that contains all the material, dimensions, and full layout of the solar field and substation. The document includes labels and intimate details that display all aspects of the solar field. The clarity and specifics included in the design documents meet users' needs because they are easily able to understand the design, the material needed, and the cost of everything included.

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

Our primary concerns are that our design is actually applicable in the real world because everything we are designing is purely hypothetical. Based on our current design the property we are using may have some difficulties implementing the solar field as there is wetland along the edge as well as an incline.

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

We have reached out to our clients about the water and incline and they did not seem to be worried about it. We plan on doing our own research in order to understand what difficulties that might be run into if our hypothetical solar farm came to fruition.

Describe the Problem, try to gather and examine the data, and Specify and rank the problems at stake. Put a Goal Statement in Each Solution's Heading. Develop Solutions: The Plan of Action Monitor and assess whether to tackle a fresh challenge or hone an existing issue.

4.4 Technology Considerations

Describe the distinct technologies you are using in your design. Highlight the strengths, weaknesses, and trade-offs made in technology available. Discuss possible solutions and design alternatives.

- AutoCAD: This application is very applicable in the real world. CAD provides engineers with a means of demonstrating all aspects of the project. However, there is no way to collaborate on the same document in CAD. This means that only one person can really work on the CAD designs. Also, not many of us have knowledge of how to work with CAD so it makes it difficult to understand what is going on, therefore leaving a heavy workload for the individual in our group that is doing most of the CAD work.
- Array Parameter Tool: This tool is within a google sheet so the whole group can work on it at once, making it easier to keep everyone on the same page. It also already had some equations filled in for it, increasing efficiency for the team when deciding what equipment to use in the solar field. A disadvantage is you cannot compare multiple different scenarios at once, you must create a new page using the parameter tool to display different combinations of components.
- Voltage Drop Calculations Tool: This tool is within a google sheet so that the team can collaborate or make changes as necessary from wherever. This tool is set to organize the calculations for voltage

drop of the solar field for the lines between the PV and combiner boxes and then the combiner boxes and the inverters. This was used to organize the relevant inputs and streamline the calculations. One disadvantage is that the tool cannot compare different scenarios at the same time, you must create different pages within the sheet to do so. Though this tool is not designed to specifically act as a learning tool, we are using it as such as much as we are for completing the calculations. This falls short in that area as it is does not show directly how the calculations are working. As a result one team member calculated the highest voltage and lowest drops by hand to check the work of the tool and use it as a learning exercise.

- Solar Cost Analysis Tool: This is another excel tool given to us by Black and Veatch to organize our data. We have this in google sheets as well for increased access and editing ability for team members. This tool is used to organize cost data and project the cost of the project compared to the revenue of the project 10 years after project completion. One advantage of this tool is that it gives the designers and clients an estimate of project cost vs revenue, and where in the project's lifecycle it breaks even. The downside of this tool is that it does not provide as much detail in the cost breakdown of the project, but that will be supplemented by the Bill of Materials we complete later.
- BlueBeam: We have not started using this application yet as it will be used next semester for the substation design.

4.5 Design Analysis

Discuss what you have done so far, i.e., what have you built, implemented, or tested? Did your proposed design from 4.3 work? Why or why not? Based on what has worked or not worked (e.g., what you have or haven't been able to build, what functioned as expected or not), what plans do you have for future design and implementation work? For example, are there implications for the overall feasibility of your design or have you just experienced build issues?

We started with the Array Parameter Tool and analyzed different combinations of components within the solar field to find the optimal component combination. We then went through the five different options we had and picked the one that was most optimal based on the values. In this we looked at parameters such as cost, amount of equipment needed for required final output, would the required combination of outputs to reach the power output fit within the land we chose, and other parameters. Some of the parameters we looked at were determined by the standards Black and Veatch worked off of such as putting two strings in a rack and other requirements for the output of the plant. Once we chose the parts to use we worked to lay them out in a logical manner based on the requirements in the array parameter tool and the specifications of the parts (PV, combiner boxes, and inverters) themselves. Such as only connecting so many racks to the combiner boxes and not surpassing the limits on input current and voltage.

A plot of land in Ames and New Mexico were also compared based on cost, irradiance, and other qualities. We decided on a specific plot of land in Roswell, NM to place our substation and solar field. We then started creating CAD designs based on the layout given from the Array Parameter Tool. Our initial design was not correct because we did not take into consideration the total DC wattage, which was 80 MW DC. Because of this, we had to go back and create a small, irregular array that adds a specific amount of voltage to get us to almost exactly 80 MW DC.

Along with this, we did an initial voltage drop calculation, which had a voltage drop of 8.67%. Our total voltage drop needed to be under 5%, so we started by changing the wire sizes to see how that would affect the drop and they had minimal effect with our initial design. Changing the wire gauge from 12 AWG to 6 only brought the drop to 7.89%. We initially worked on the wire gauge to try and make the correct drop, as that would be a simple change to our design before reworking more of the design. Our initial design had the combiner boxes and inverters close together and in the centerline of the arrays along the access road. This was to make it more convenient for repairs and construction. However, with this set up the voltage drop would not go below the 7.89% listed above. From there we went to moving the combiner boxes closer to the arrays as the majority of the drop appeared to be between the array and the combiner boxes rather than combiner boxes and inverters. As a result, we went through and decided to move the combiner boxes to more central locations to each string, therefore decreasing the voltage drop to be within the range. Our current voltage drop of the normal part of the system is 4.05% and the small array is 3.76%. We also were able to decrease the string wire gauge to 10 AWG and the jumper wire size to 6 AWG which is cheaper than our initial plan to use all 6 AWG. The only concern we had initially with this change was that it would make maintenance more difficult as the combiner boxes would be within the arrays and not along the access road with the inverters. However, after making that change it was recognized that the spacing between the rows is approximately 16 ft which can comfortably fit a vehicle for maintenance access as long as it can drive on the terrain.

In the end, the CAD was rearranged to incorporate the new voltage drop combiner box placement along with the small specific array. To strengthen our design, we plan to complete ground calculations and finish the cost analysis to ensure the whole project is not too costly and can be sustained.