115 kV/34.5 kV Solar Power Plant & Substation Project

DESIGN DOCUMENT

Team Number: sdmay22-05
Client: Black & Veatch
Advisers: Venkataramana Ajjarapu

Team Members/Roles
John Jennison – Team Coordinator
Logan Miller – Test Engineer & Website Designer
Kyle Neal – Designer
Adilene Prieto –Test Engineer
Shadoe Rusk – Calculation Lead
Matthew Schindler – Design Engineer & Mentor Liaison
Aayush Shah – Researcher and Calculation Lead

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Team Website

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Executive Summary

Development Standards & Practices Used

Engineering Standards

- *IEEE 80 - Guide for Safety in AC Substation Grounding*
- *NFPA 70: National Electric Code*
- *UL1741- Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*

Summary of Requirements

Solar Panel Sizing Designs

- Equipment Selection
- Array Parameter Tool
- Cable List
- Solar Cost Analysis
- Conduit List
- BOM

Design Calculation

- Voltage Drop
- Electrical Ratings

Future Focused Research

- Trench Fill
- Lightning Protection

Design Drawings

- One Line
- Key Plan
- Equipment Plans
- Grounding Plans
- Elevation
- Drawing List

Applicable Courses from Iowa State University Curriculum

- EE 201 - Electrical Circuits
- EE 303 - Energy Systems and Power Electronics
- EE 456 - Power System Analysis 1
- IE 305 - Engineering Economic Analysis
- ENGL 314 - Technical Communication

- ME 433 - Alternative Energy

New Skills/Knowledge acquired that was not taught in courses

- Design and implementation of solar arrays
  - Parameterization of components including solar panel modules, combiner boxes, and inverter/inverter skids
- Voltage drop calculations
- AutoCad Knowledge
  - Drawings and basic

Table of Contents

List of figures/tables/symbols/definitions

Definitions:

- **VOC (Open Circuit Voltage) -** The potential difference(voltage) measured between two different points in a circuit when there is no load present/
- **ISC (Short Circuit Current) -** The current measured within a circuit when there is no load present.
- **Module** - A panel composed of many solar cells connected in series
- **String** - A set of modules connected in series
- **Rack** - A mounting system which strings are fixed to running in parallel
- **Combiner Box** - An electrical panel that combines the current produced within strings.
- **Inverter -** An electrical component that takes incoming DC voltage and converts it into AC voltage.
- **Transform** - An electrical device that takes incoming voltage and converts it to either higher or lower voltage, depending on the application.
- **Voltage Drop -** The amount of voltage consumed within a system due to wiring and component resistance when a load is not present.
- **One Line** - A simplified drawing of the working design infrastructure
- **Key Plan -** A high-level view of the overall design

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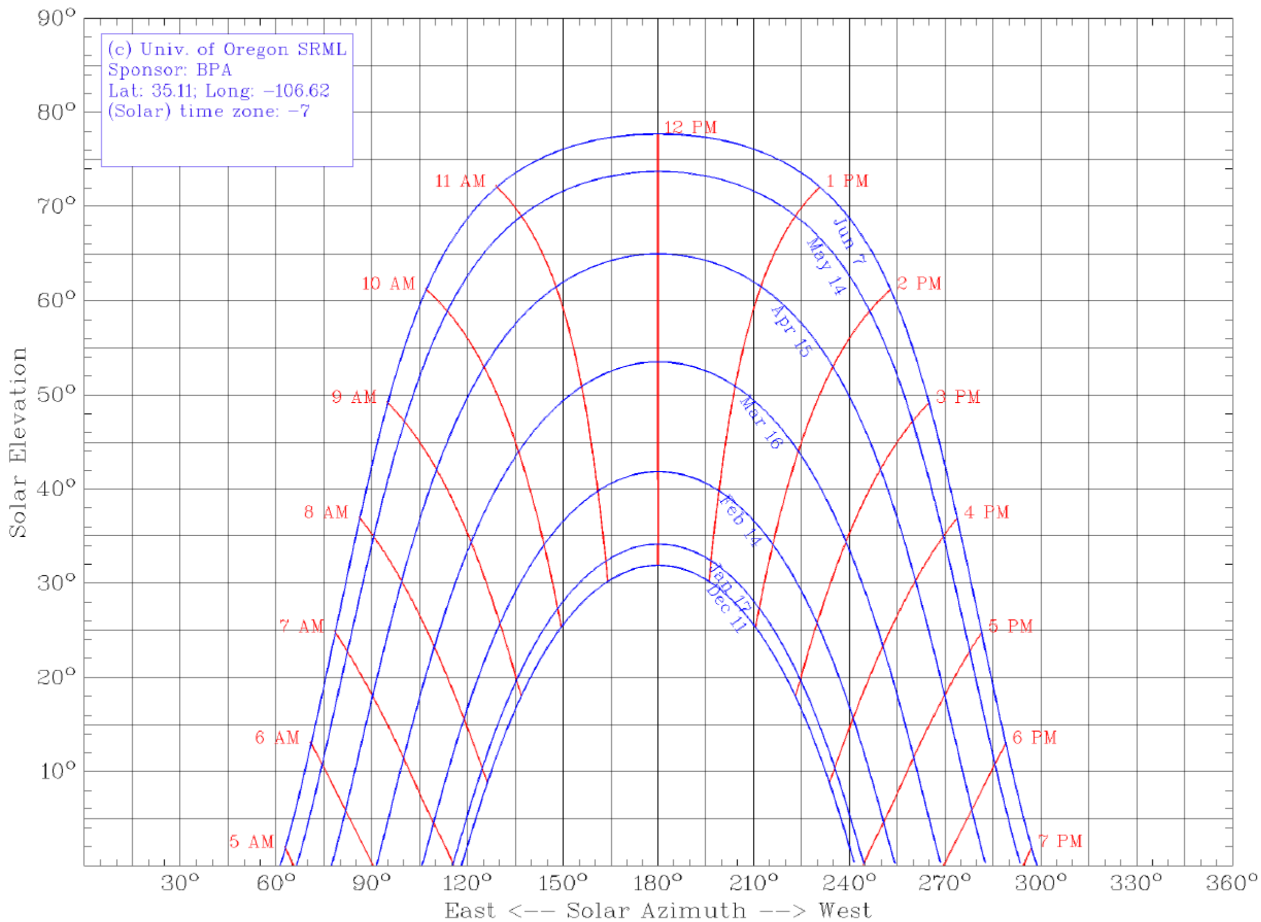
Figure 1: This New Mexico Solar Elevation/Solar Azimuth was used to determine row spacing



NEC Table 8: Conductor Properties --- Used for voltage drop calculations

Table 8 Conductor Properties

			Conductors							Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall				Copper					
Size (AWG or kcmil)	Area			Diameter		Diameter		Area		Uncoated		Coated		Aluminum	
	mm^2	Circular mils	Quantity	mm	in.	mm	in.	mm^2	$in.^2$	ohm/km	ohm/kFT	ohm/km	ohm/kFT	ohm/km	ohm/kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100
250	127	—	37	2.09	0.082	14.61	0.575	168	0.260	0.1687	0.0515	0.1753	0.0535	0.2778	0.0847
300	152	—	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
350	177	—	37	2.47	0.097	17.30	0.681	235	0.364	0.1205	0.0367	0.1252	0.0382	0.1984	0.0605
400	203	—	37	2.64	0.104	18.49	0.728	268	0.416	0.1053	0.0321	0.1084	0.0331	0.1737	0.0529
500	253	—	37	2.95	0.116	20.65	0.813	336	0.519	0.0845	0.0258	0.0869	0.0265	0.1391	0.0424
600	304	—	61	2.52	0.099	22.68	0.893	404	0.626	0.0704	0.0214	0.0732	0.0223	0.1159	0.0353
700	355	—	61	2.72	0.107	24.49	0.964	471	0.730	0.0603	0.0184	0.0622	0.0189	0.0994	0.0303
750	380	—	61	2.82	0.111	25.35	0.998	505	0.782	0.0563	0.0171	0.0579	0.0176	0.0927	0.0282
800	405	—	61	2.91	0.114	26.16	1.030	538	0.834	0.0528	0.0161	0.0544	0.0166	0.0868	0.0265
900	456	—	61	3.09	0.122	27.79	1.094	606	0.940	0.0470	0.0143	0.0481	0.0147	0.0770	0.0235
1000	507	—	61	3.25	0.128	29.26	1.152	673	1.042	0.0423	0.0129	0.0434	0.0132	0.0695	0.0212
1250	633	—	91	2.98	0.117	32.74	1.289	842	1.305	0.0338	0.0103	0.0347	0.0106	0.0554	0.0169
1500	760	—	91	3.26	0.128	35.86	1.412	1011	1.566	0.02814	0.00858	0.02814	0.00883	0.0464	0.0141
1750	887	—	127	2.98	0.117	38.76	1.526	1180	1.829	0.02410	0.00735	0.02410	0.00756	0.0397	0.0121
2000	1013	—	127	3.19	0.126	41.45	1.632	1349	2.092	0.02109	0.00643	0.02109	0.00662	0.0348	0.0106

1 Team

1.1 Team Members

John Jennison - Project Lead

Logan Miller - Test Engineer & Website Designer

Kyle Neal - Design Engineer

Adilene Prieto - Research and Test Engineer

Shadoe Rusk - Calculation Lead

Matthew Schindler - Design Engineer

Aayush Shah - Researcher and Calculation Lead

1. 2 Required Skill Sets for Your Project

- Pursuing an electrical engineering degree
- Background knowledge of power systems
- Problem solving
- Communication skills
- AutoCAD experience
- Project management
- Knowledge of solar power

1.3 Skill Sets covered by the Team

- Pursuing an electrical engineering degree - All team members
- Background knowledge of power systems - All team members
- Problem Solving - All team members
- Communication Skills - All team members
- AutoCAD experience - All team members
- Knowledge of Solar Power - Adilene, John

1.4 Project Management Style Adopted by the team

Waterfall Management Style

1.5 Initial Project Management Roles

John Jennison - Lead the team, created and held the team accountable for the gantt chart.

Logan Miller - Test Engineer

Kyle Neal - Co-Led the drawing section of the team

Adilene Prieto - Research Engineer - Brought previous background knowledge of solar power

Shadoe Rusk - Calculation Lead

Matthew Schindler - Co-Led the drawing section of the team and communicated with the advisor

Aayush Shah - Calculation Lead - Brought previous internship knowledge

2 Introduction

2.1 Problem Statement

Our team was designated to design a 60MW solar plant and a 115/34.5 kV substation for the Iowa State University client Black & Veatch. Under supervision of client contacts Adam Schroeder and Patrick Kester, we are to research and design a solar field layout, electrical layout, and their respective associated calculation and drawing deliverables to promote Black & Veatch's endeavor of a sustainable energy infrastructure. This project emphasizes the importance of renewable energy within the electrical utility industry and how solar power could be used as a viable alternative for current energy production methods.

2.2 Requirements & Constraints

The main deliverables for this project are solar panel sizing design, equipment sizing calculation, solar layout drawings, substation electrical layout drawings, grounding analysis and grounding grid development, and substation bus calculations. The following items will supplement the main deliverables.

- Grounding Plan
- Key Plan
- DC Schematics
- Wiring Diagrams
- Cable List
- Conduit Plan
- Equipment Plan
- Elevations
- Drawing List
- Vendor Drawings
    - Electrical
        - Layout/Elevations
- Controls
    - Schematics
    - Wiring Diagrams
- Lighting Plan
- Three Line
- AC Schematics
- One Line
- Bus Plan
- Calculations
    - Bus Calc
    - Grounding Calc
    - Lightning Protection
    - AC Calc
    - DC Calc
    - Trench fill
    - Cable tray fill/Trench Fill
    - Voltage drop

2.3 Engineering Standards

- This project will use the following engineering standards:
- IEEE 80 - Guide for Safety in AC Substation Grounding
    - This standard will be used to develop grounding designs for the solar power station and the substation.
- NFPA 70: National Electric Code
    - This standard will be used for general electrical designs, including, wiring, conduits, receptacles, lighting, circuit protection, etc.
- UL1741- Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
    - This standard lays out the required manufacturing and testing standards which allow a more reliable power grid management system

Additionally, the following standards will be referenced for the different parts of the design.

- Inverters
    - NEMA 3R rated UL Standards
    - EN50530 Standards
    - IEC Standards
- Service corridor
    - NEC guidelines
- Recombiner
    - NEC 2011 and 2014 compliant

2.4 Intended Users and Uses

As our project is exclusively design oriented, the main beneficiary of this project is our client Black & Veatch, a consulting company which specializes in energy system infrastructure development. With the information collected from the project, our client will be able to more effectively design future solar plants and substations. This will not only positively impact the dependency on consumable resources such as coal and natural gas through sustainable energy production, but it will allow carbon neutral production of energy for households.

3. Project Plan

3.1 Project Management/Tracking Procedures

Our group uses the waterfall management style and it has four main parts: Schedule Management, Design Report Management, Calculations Management, and Drawings Management. Each team member has a manager assignment for one part of the project. As manager of a specific part, each team member will be responsible for delegating work and ensuring quality and timeliness for that part of the project. The Schedule Manager will track all parts of the project to ensure quality and timeless of the larger project.

In order to track our progress throughout the year, our team will use Gantt charts. Each semester we work will have its own separate Gantt chart. Our project documentation is tracked and organized in a shared google drive. We use discord to set meetings, communicate online, and share any research found.

3.2 Task Decomposition

Our project is decomposed into 3 main deliverables and each deliverable is decomposed into smaller tasks. Our project tasks are decomposed in the following table.

Solar Panel String Sizing Design
Initial Equipment Selection
Array Parameter Tool
Select Solar Panels, Inverters, Combiner Boxes
Cable List
Conduit List
Deliverable: Design Report

Equipment Sizing Calculation
Bus Calc
Grounding Calc
Lightning Protection
Ac Calc
Dc Calc
Trench Fill
Cable Tray Fill
Voltage Drop
Deliverable: Record Of Calculations

Solar Layout Drawings
Grounding plan
Key plan
Wiring diagram
DC Schematics
Conduit Plan
Equipment Plan
Elevations
Controls Drawing
Lighting Plan
AC Schematics
One lines
Three lines
Bus Plan
Drawing list
Deliverable: Drawing Package

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

In the Fall semester, we are focusing on the design of a solar array, which in itself has a multitude of subtasks associated with it. Some of these milestones include:

- Equipment Calculation Record completed
- Completion of String sizing calculations with check
    - Cable List completed
    - Conduit List completed
- Completion of Solar Layout Drawings
    - Key plan Drawing
    - Drawing List
- All first drafts complete

These milestones can also be seen on the attached Gantt chart. We chose these milestones because each of these tasks are a culmination of other tasks that we will be working towards. The overall goal is to design a 60 MW Solar Panel on time and to the satisfaction of our client, Black & Veatch.

3.4 Project Timeline/Schedule

We created one Gantt chart for Fall semester work and one for Spring semester work. To create the chart, we took into account which tasks would come first, as well as how long we predicted each task would take to complete. Our solar power design delivery date is currently set to the end of the Fall semester. A Gantt chart for the design of the substation will be prepared later in this semester because it is not as important as some of the other tasks that our team has at hand.

3.5 Risks And Risk Management/Mitigation

One risk that we could foresee with this project would be mistiming some of the tasks, as that could cause us to unknowingly fall behind schedule. We believe that there is a small chance of this happening as we feel we are on/ahead of schedule.

Another risk that we could encounter would be a miscalculation in one of the parameters, causing a larger problem down the line. We also feel that this has a small chance of occurring as we have a large amount of oversight and checks to prevent this.

3.6 Personnel Effort Requirements

We have created a Gantt Chart which displays a good estimate of the amount of time each task will task us. This chart is going to be our guide to aid in the efficiency and accountability of the entire project. The

3.7 Other Resource Requirements

Resource requirements for our project will include various programs in order to assist in calculation as well as scheduling and project management; a few of these programs are Bluebeam, Microsoft Projects, Matlab, and Excel. We will also have to present the project at the end of the semester to a group of people, so it is necessary for us to utilize communication skills in order for us to thoroughly demonstrate our project and the knowledge we have obtained.

4 Design

4.1 Design Context

4.1.1 Broader Context

Our project is to design a 34.5kV/115kV solar power plant and substation. We are designing this for our client, Black and Veatch. This solar power station will be built at a to be determined location in New Mexico. We are designing this plant for our client company and that client will decide where the power will be going to specifically. Many communities that are around the area of the plant will be affected by our design as it will supply power for many of them. Our project fills two areas of need, one being reducing carbon emissions, by it being solar and the other being supplying power.

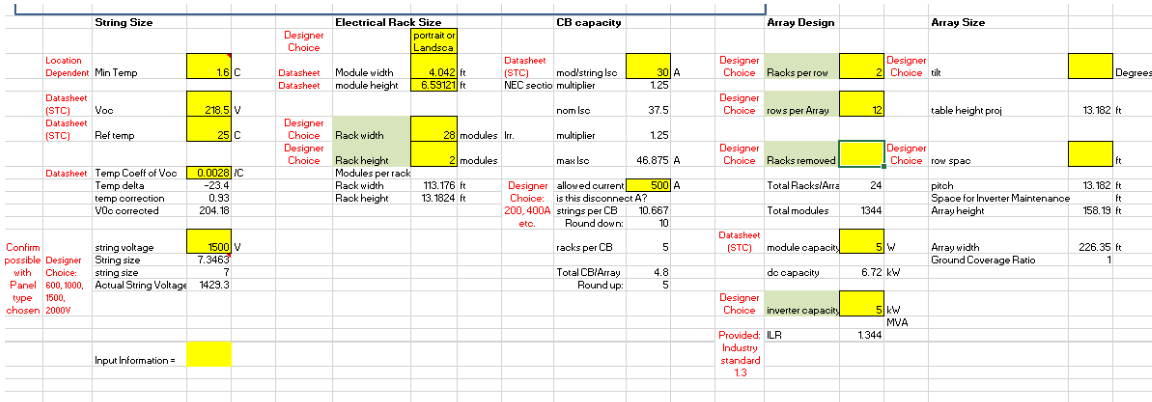
Area	Description
Public health, safety, and welfare	This plant will create jobs in the area as it will allow for more businesses to open up. In addition to that it helps reduce pollutants.
Global, cultural, and social	Our project does not violate any ethics codes or have any negative connotations that come along with it.
Environmental	Our project is very beneficial for the environment as we are creating clean energy.
Economic	This design of the plant will help create more opportunity as it will allow for a high ceiling in the power department at our location. This can lead to more businesses to open.

4.1.2 User Needs

- The average American wants their bills to cost less, so by creating more supply of power in the company, this may come to fruition.
- Our world as a whole has a lot to gain from this project as it will have its carbon emissions lower than it was before, even if it is only by a small amount.
- New Mexico citizens need a way to get power to their houses and businesses because it is a basic necessity, by building this plant we are able to help with that need.

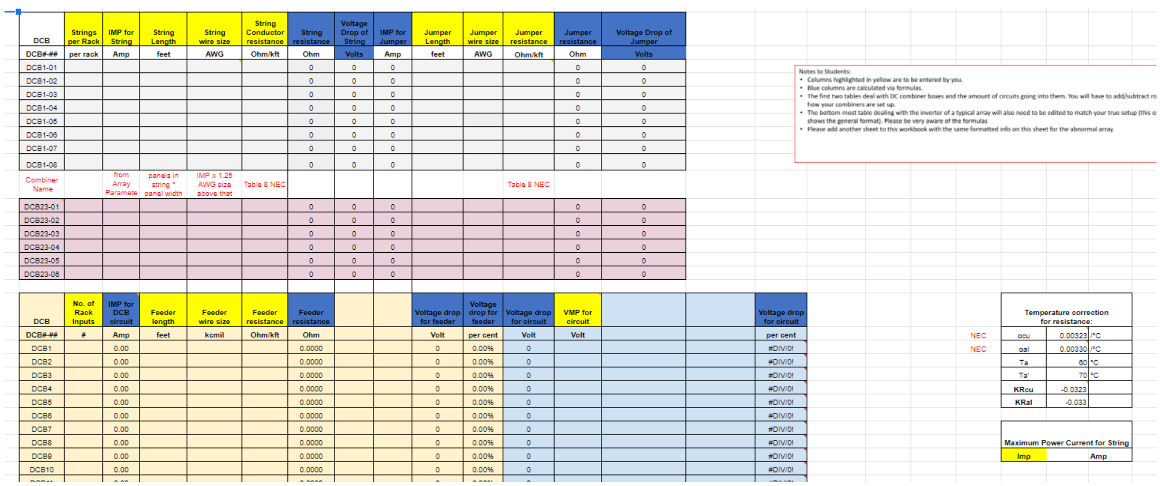
4.1.3 Prior Work/Solutions

There are identical projects in the workplace already, our client company has an entire team that work on designs like we are doing right now. The company Black and Veatch is helping us through the process of the design of the plant and the substation. As of right now we are slowly being shown different tools from our client that aid us in the overall project. Below is an array parameter sheet that helps calculate some of the parameters for the solar panel plant design. Even lower down you can see the voltage drop calculation sheet that they provided for us. By our client company aiding us in giving us calculation sheets we are able to create designs that are at an industry standard, we also have access to previous projects that pertain to our project. This gives us the ability to check some of our process and work as we progress in the project.



		String Size				Electrical Rack Size					CB capacity		
					Designer Choice		portrait or Landsca						
	Location Dependent	Min Temp	1.6	C	Datasheet	Module width	4.042	ft	Datasheet (STC)	mod/string Isc	30	A
					Datasheet	module height	6.59121	ft	NEC sectio	multiplier	1.25	
	Datasheet (STC)	Voc	218.5	V						nom Isc	37.5	
	Datasheet (STC)	Ref temp	25	C	Designer Choice	Rack width	28	modules	Irr.	multiplier	1.25	
					Designer Choice	Rack height	2	modules		max Isc	46.875	A
	Datasheet	Temp Coeff of Voc	0.0028	/C		Modules per rack						
		Temp delta	-23.4			Rack width	113.176	ft	Designer Choice: 200, 400A etc.	allowed current	500	A
		temp correction	0.93			Rack height	13.1824	ft		is this disconnect A?		
		V0c corrected	204.18							strings per CB	10.667	
										Round down:	10	
Confirm possible with Panel type chosen	Designer Choice: 600, 1000, 1500, 2000V	string voltage	1500	V						racks per CB	5	
		String size	7.3463									
		string size	7							Total CB/Array	4.8	
		Actual String Voltage	1429.3							Round up:	5	
		Input Information =										

	Array Design			Array Size		
Designer Choice	Racks per row	2	Designer Choice	tilt		Degrees
Designer Choice	rows per Array	12		table height proj	13.182	ft
Designer Choice	Racks removed		Designer Choice	row spac		ft
	Total Racks/Arra	24		pitch	13.182	ft
				Space for Inverter Maintenance		ft
	Total modules	1344		Array height	158.19	ft
Datasheet (STC)	module capacity	5	W	Array width	226.35	ft
				Ground Coverage Ratio	1	
	dc capacity	6.72	kW			
Designer Choice	inverter capacity	5	kW			
			MVA			
Provided: Industry standard 1.3	ILR	1.344				



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						0	0	0				0	0
DCB1-02						0	0	0				0	0
DCB1-03						0	0	0				0	0
DCB1-04						0	0	0				0	0
DCB1-05						0	0	0				0	0
DCB1-06						0	0	0				0	0
DCB1-07						0	0	0				0	0
DCB1-08						0	0	0				0	0
Combiner Name		from Array Paramete	panels in string * panel width	IMP x 1.25 AWG size above that	Table 8 NEC						Table 8 NEC		
DCB23-01						0	0	0				0	0
DCB23-02						0	0	0				0	0
DCB23-03						0	0	0				0	0
DCB23-04						0	0	0				0	0
DCB23-05						0	0	0				0	0
DCB23-06						0	0	0				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		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB2		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB3		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB4		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB5		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB6		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB7		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB8		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB9		0.00				0.0000			0	0.00%	0				#DIV/0!
DCB10		0.00				0.0000			0	0.00%	0				#DIV/0!

Notes to Students:
- Columns highlighted in yellow are to be entered by you.
- Blue columns are calculated via formulas.
- The first two tables deal with DC combiner boxes and the amount of circuits going into them. You will have to add/subtract ro how your combiners are set up.
- The bottom-most table dealing with the inverter of a typical array will also need to be edited to match your true setup (this e shows the general format). Please be very aware of the formulas
- Please add another sheet to this workbook with the same formatted info on this sheet for the abnormal array.

	Temperature correction for resistance:		
NEC	αcu	0.00323	/°C
NEC	αal	0.00330	/°C
	Ta	60	°C
	Ta'	70	°C
	KRcu	-0.0323	
	KRal	-0.033	

Maximum Power Current for String		
Imp		Amp

4.1.4 Technical Complexity

Our project is very large scoped and it comes with many complex pieces to it. It is broken down into main sections which then are broken down into different tasks and further to subtasks. We are creating the design of a solar power plant for section 1 and in section 2 we are creating the design for a substation. Each of these sections consists of rigorous calculations and design layout drawings that will need to be created. These different tasks are the same tasks that professional engineers at our client company Black and Veatch do when they are creating plants and substation designs for their clients.

4.2.1 Design Decisions

In the process of developing our solar power plant, Black and Veatch have requested us to go through the Array Parameter Tool they provided and create 3 or more different designs with different Combiners, Inverters, and rack parameters to compare and find the best one. With that, below are the 3 kinds of designs we have come up with and are in the process of comparing which one is the most effective in the state of New Mexico.

Something we kept in mind while designing these layouts, was that the Inverter Load Ratio (IRL) was to meet Industry Standards of 1.30. Once this condition was met, we looked at what factors in terms of inverter costs and number of racks when deciding efficiency.

Constants: Combiner Box - KACO 1500V/30A

Design 1:

CB capacity				**Array Design**			**Array Size**			
Kaco 1500V/30A										
mod/string Isc	30	A	Designer Choice	Racks per row	3	Designer Choice	tilt		37	Degrees
multiplier	1.25									
nom Isc	37.5		Designer Choice	rows per Array	65		table height proj		5.943126	ft
multiplier	1.25									
max Isc	46.875	A	Designer Choice	Racks removed	2	Designer Choice	row spac		14.5	ft
allowed current	500	A		Total Racks/Array	193		pitch		20.44312	ft
is this disconnect A?							Space for Inverter Maintenance			ft
strings per CB	10.66666			Total modules	14668		Array height		1328.803	ft
Round down:	10									
racks per CB	5		Datasheet (STC)	module capacity	410	W	Array width		644.1	ft
							Ground Coverage Ratio		0.364014	
Total CB/Array	38.6			dc capacity	6013.88	kW				
Round up:	39									
			Designer Choice	inverter capacity	4600	kW				
						MVA				
				ILR	1.307365					
			Provided: Industry standard 1.3							

Design 2:

CB capacity				**Array Design**			**Array Size**		
Kaco 1500V/30A									
mod/string Isc	30	A	Designer Choice	Racks per row	3	Designer Choice	tilt	37	Degrees
multiplier	1.25								
nom Isc	37.5		Designer Choice	rows per Array	302		table height proj	5.337600	ft
multiplier	1.25								
max Isc	46.875	A	Designer Choice	Racks removed	2	Designer Choice	row spac	11.62	ft
allowed current	500	A		Total Racks/Array	904		pitch	16.95760	ft
is this disconnect A?							Space for Inverter Maintenance		ft
strings per CB	10.66666			Total modules	23504		Array height	5121.195	ft
Round down:	10								
racks per CB	5		Datasheet (STC)	module capacity	255	W	Array width	207.9987	ft
							Ground Coverage Ratio	0.394124	
Total CB/Array	180.8			dc capacity	5993.52	kW			
Round up:	181								
			Designer Choice	inverter capacity	4600	kW			
						MVA			
				ILR	1.302939				
			Provided: Industry standard 1.3						

Design 3:

CB capacity				**Array Design**			**Array Size**		
Kaco 1500V/30A									
mod/string Isc	30	A	Designer Choice	Racks per row	3	Designer Choice	tilt	37	Degrees
multiplier	1.25								
nom Isc	37.5		Designer Choice	rows per Array	370		table height proj	6.456169	ft
multiplier	1.25								
max Isc	46.875	A	Designer Choice	Racks removed	2	Designer Choice	row spac	11.62	ft
allowed current	500	A		Total Racks/Array	1108		pitch	18.07616	ft
is this disconnect A?							Space for Inverter Maintenance		ft
strings per CB	10.66666			Total modules	13296		Array height	6688.182	ft
Round down:	10								
racks per CB	5		Datasheet (STC)	module capacity	450	W	Array width	118.638	ft
							Ground Coverage Ratio	0.447218	
Total CB/Array	221.6			dc capacity	5983.2	kW			
Round up:	222								
			Designer Choice	inverter capacity	4600	kW			
						MVA			
				ILR	1.300695				
			Provided: Industry standard 1.3						

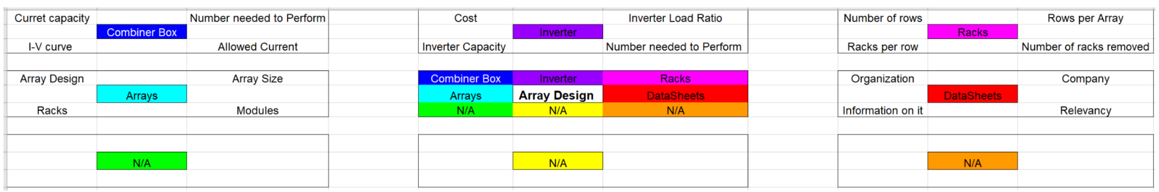
4.2.2 Ideation

When coming up with our decision, it was highly prioritized to compare the inverters. Inverters are mainly the reason why the cost of the project skyrockets. We wanted to make sure we spend the least amount of money. A single combiner box has multiple inverters and we chose the KACO 1500V/30A combiner box because it had the least amount of inverters.

Decision Option Considered:

1. Combiner Box Size
2. Number of Inverters
3. Number of Racks in the array
4. Number of Racks removed within the array
5. Module Capacity
6. Inverter Capacity

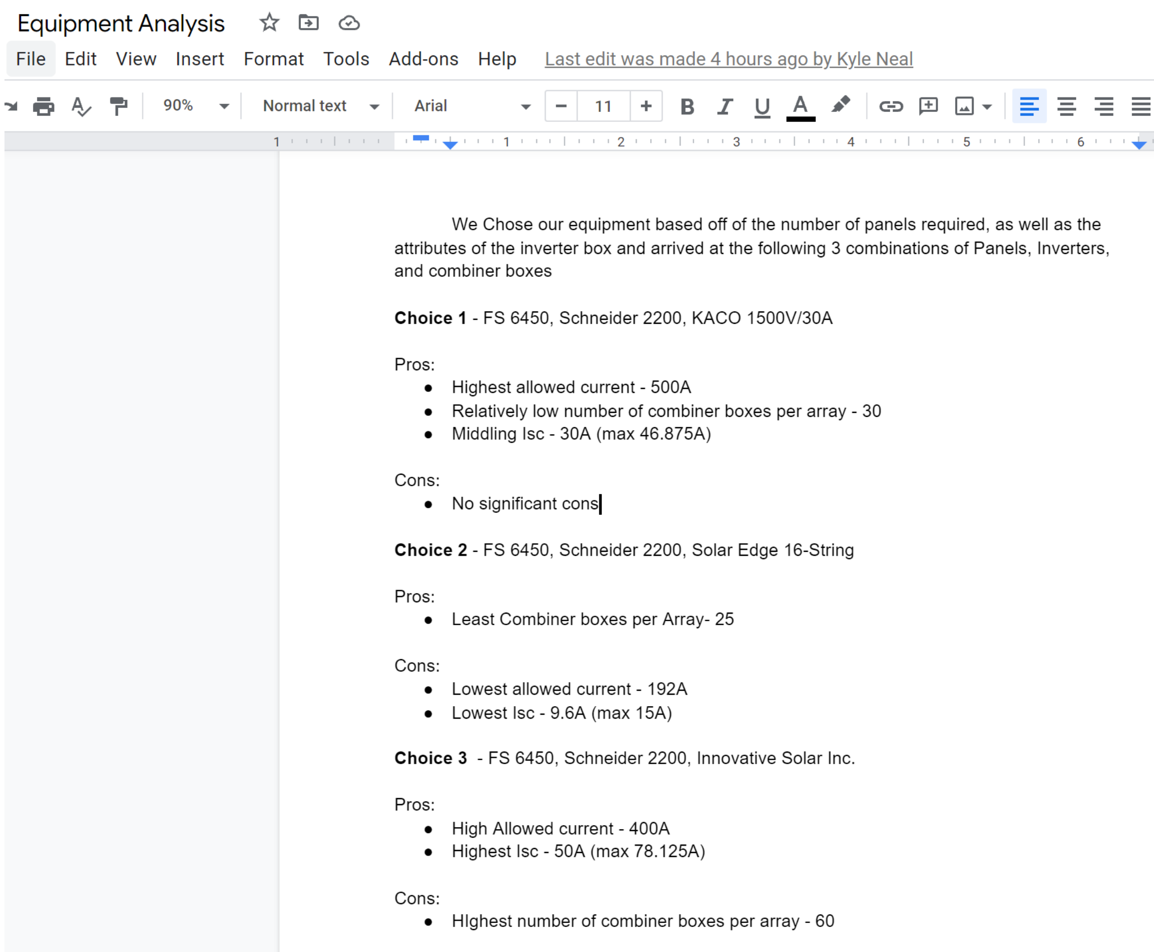
Lotus Plot



4.2.3 Decision-Making and Trade-Off

When coming up with the Pros and Cons for our designs, we had picked out relevant outputs from our Excel sheet as shown and mentioned above. With that we created a google document which listed out all the information to compare side by side and highlight the parts that were better.

With that, we decided to go with the FS 6450, Schneider 2200, KACO 1500V/30A array design due to having better pros.



We Chose our equipment based off of the number of panels required, as well as the attributes of the inverter box and arrived at the following 3 combinations of Panels, Inverters, and combiner boxes

Choice 1 - FS 6450, Schneider 2200, KACO 1500V/30A

Pros:
- Highest allowed current - 500A
- Relatively low number of combiner boxes per array - 30
- Middling Isc - 30A (max 46.875A)

Cons:
- No significant cons

Choice 2 - FS 6450, Schneider 2200, Solar Edge 16-String

Pros:
- Least Combiner boxes per Array- 25

Cons:
- Lowest allowed current - 192A
- Lowest Isc - 9.6A (max 15A)

Choice 3 - FS 6450, Schneider 2200, Innovative Solar Inc.

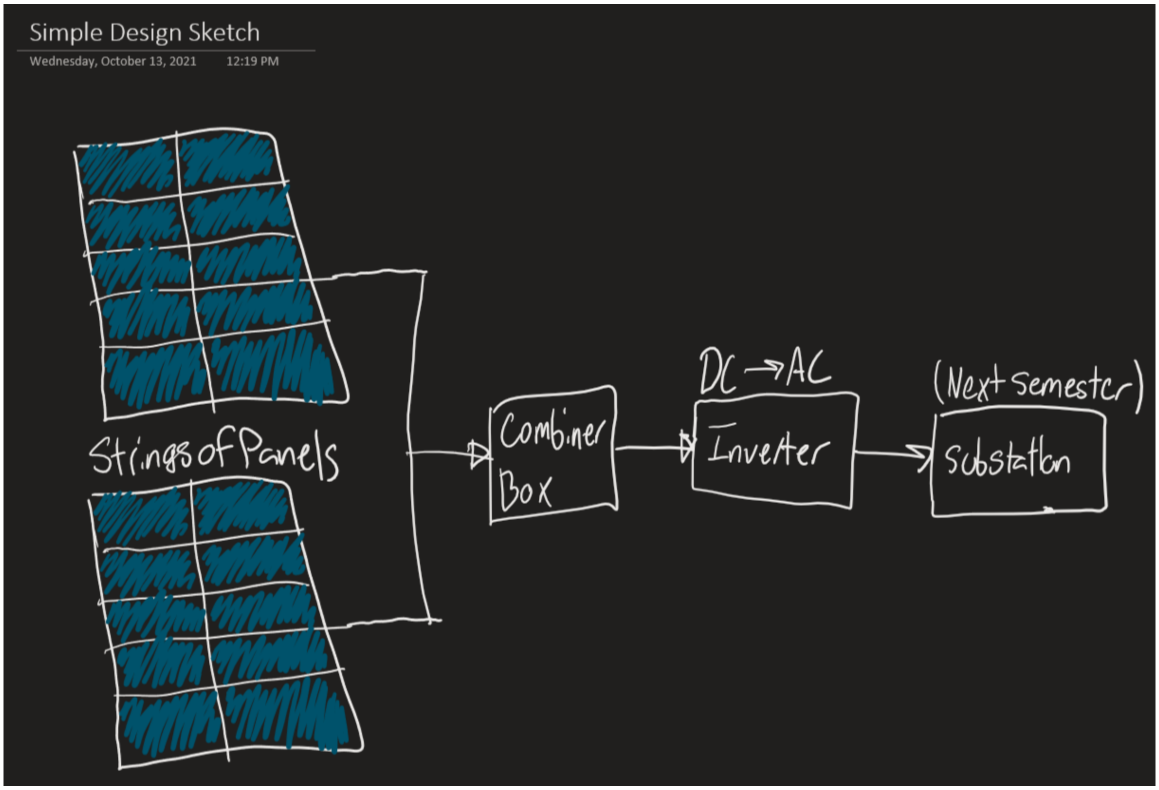
Pros:
- High Allowed current - 400A
- Highest Isc - 50A (max 78.125A)

Cons:
- HIghest number of combiner boxes per array - 60

4.2 Proposed Design

So far in our design, we have used an array parameter tool to help us select what equipment to use in the future of the project. We have also picked out a couple of locations where we could implement our design and plan out the layout of the solar array field. We will be using AutoCAD to produce a Key Plan involving the location we choose as well as the necessary amount of Solar panels and strings needed for our design.

4.3.1 Design Visual and Description



Our design is still early in its development, but the general overview of the design we are implementing can be seen above. As the image above shows, we plan to have our strings of panels connect to our combiner boxes. From the combiner boxes the energy will go to our inverters which convert the power from DC to AC before we transmit the power to our substation. As of now we plan to design the substation next semester at the suggestion of Black & Veatch.

4.3.2 Functionality

Our design will be operated by trained personnel to produce clean green power for the surrounding area. These personnel will be trained to maintain and operate the plant once it is hypothetically constructed. The influx of green energy will help to reduce the need of coal based power plants and will also reduce the overall carbon footprint of the local area as a result.

In its current state, our design is non-functional, as at the moment we have many separate pieces that we have been researching that have not yet been put together. We expect to have the first combined design within the next week.

4.3.3 Areas of Concern and Development

Our team's primary concern with delivering the system is managing our time and ensuring that we deliver each of the requested deliverables.

Another concern of our group is checking our calculations to ensure that we deliver an accurate representation of a solar array.

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

To address these concerns we are consulting with our client, Black & Veatch, on timing different tasks in our project, as they have more experience with the time needed to complete each task due to their involvement in previous projects

For our calculation concerns we will consult with our advisor due to his expertise in the power field. We also feel that he will be more available to consult for these calculation checks as he has office hours on campus where we may speak with him on these problems.

4.4 Technology Considerations

One advantage of the technology we are using is that it allows us to keep the size of our solar array Relatively compact.A trade off that we made in terms of our technology was trading out the first solar panel choice that we planned to use for our current choice in order to reduce the overall size of solar array to fit within the plot of land that we planned to build it on.

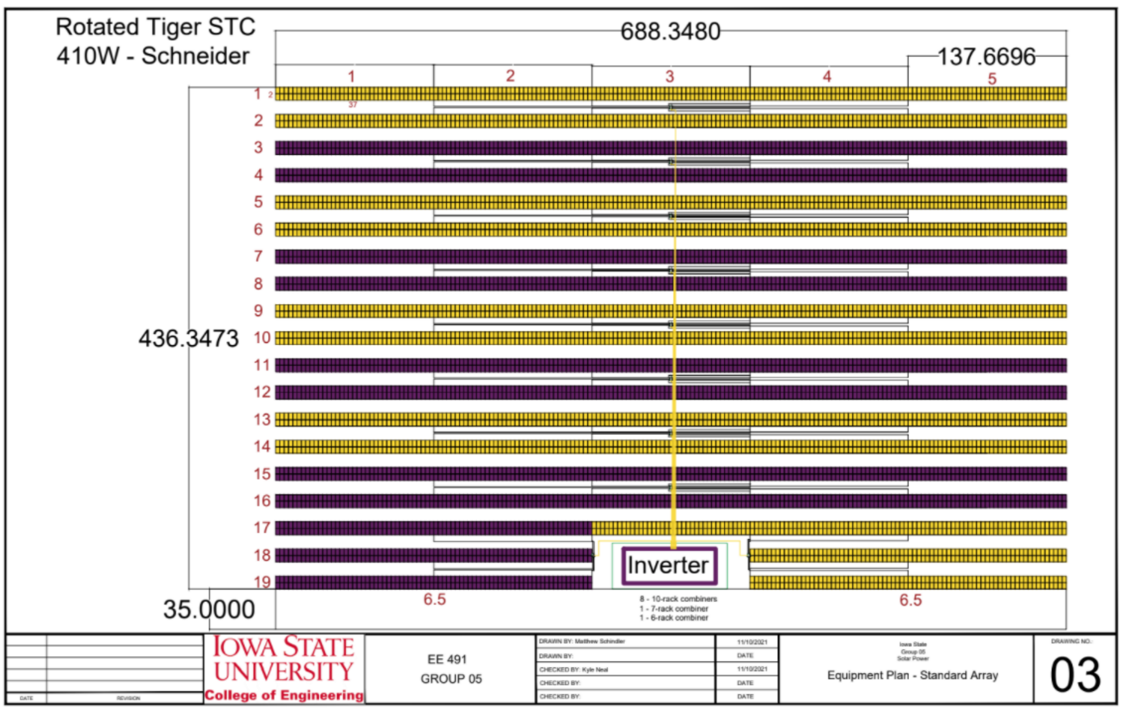
One Design alternative that we could have worked with would be if we had continued forward with our original choice of solar panel. This Would have altered how many panels we would have needed and would have made our array much larger overall due to our first choice of panel needing more space to operate properly.

4.5 Design Analysis

Our Proposed design from section 3.3 did end up working for us. This is mainly due to the fact that our design in 3.3 was simplified down to allow for us to calculate the specifics once we had each of our pieces of equipment picked out. Once we had our equipment set, we simply adjusted the number of each component until we reached our end result of an array that met our parameters. Some ideas that we modified as the design went on were the layout of our individual sub arrays that we modified in order to further reduce the space our total array would take up.

4.6 Design Plan

Our current design is based off of a 120 acre plot of land in which we are using the Tiger STC 410 W, Schneider 2200 Solar Inverters, and KACO 1500v/30A combiner boxes to gather 60 MW of power. To do this we will have 28 individual sub arrays each with a Solar Inverter and 10 combiner boxes, and Sufficient Solar modules to feed our substation which we will be designing next semester. One of our subarrays can be seen below with our up to date layout.To explain the design, the racks of solar modules each feed into a Combiner box, which then in turn feeds the collected energy into the sub-array's inverter.



5 Testing

Our project is to design a 60MW solar power plant and substation. The testing for this project will consist of using computer tools and a quality management system to ensure that our designs will work as they are intended. This report outlines some of our methods to achieve this.

5.1 Unit Testing

Unit testing on this project consists of calculation checks and quality reviews. The solar power plant and substation will be designed using software tools that are new to the design team. This software will run calculations such as voltage drop, power capacity, and other key design parameters for the system.

The design team will do dummy checks and quality reviews on the software outputs to ensure that the software inputs were correct. The team will do these checks using their knowledge about electrical calculations from their engineering courses.

5.2 Interface Testing

The user interface for this project will be engineering drawings that the team will make for the client. The engineering drawings will be reviewed at multiple points in the design process and at the end of the semester to ensure that the designs are accurate and clearly present the design of the system to the client.

Microsoft Project will also be used to aid in creating a Gantt chart. Our project's Gantt chart will be shown to the client so they can keep updated on the progress of the design. This interface will be tested for quality assurance to ensure that the client can easily understand the status of the project.

5.3 Integration Testing

Integration testing will ensure that all parts of the design will work correctly when put together. The main components that we will put together are the solar modules, the combiner boxes, the skid, and the substation. The design team will do quality control checks on the design plans to ensure that all equipment can properly integrate into the final design.

5.4 System Testing

Each component of the design will be specially chosen and designed to fit the design requirements. The design team will test that each component matches the requirements by use of calculation records. The calculation records will include the required constraint that needs to be met, and the actual designed constraint. These constraints will be compared to ensure that the system meets the design requirements.

5.5 Regression Testing

No specific regression testing has been identified for this project.

5.6 Acceptance Testing

The design team will demonstrate the design requirements through design reports, system drawings, and the design calculation records. These items will demonstrate the entire design, the design process, alternative analysis, and how the design team arrived at their conclusions. The client will review the design report, system drawings, and calculation records and these will prove the design’s acceptance to the client.

5.7 Security Testing (if applicable)

Not Applicable to this project.

5.8 Results

At this point in the project design, the design team has prepared a solar parameter calculation for the design of the solar power plant. The results of this calculation shows the number of solar modules needed to meet the design requirements. These results have been reviewed by the design team and the client for quality and accuracy. The string size calculation is included below for example.

String Size	
Min Temp	1.6
Voc	37.14
Ref temp	25
Temp Coeff of Voc	-0.0028
Temp delta	-23.4
temp correction	1.07
V0c corrected	39.5734128
string voltage	1500
String size	37.9042365 5
string size	37
Actual String Voltage	1464.2

6 Implementation

Our project is divided into two parts, design of a solar plant and design of a distribution substation. Each of which will be completed over the course of two semesters, solar plant in the fall and substation in the spring. This project will only be design based as implementation is outside of our capabilities as students.

7 Professionalism

This discussion is with respect to the paper titled "Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012
Engineering Education Vol. 28, No. 2, pp. 416–424, 2012

Table 1. The seven areas of professional responsibility in the assessment instrument

Area of responsibility	Definition	NSPE Canon
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.
Communication Honesty	Report work truthfully, without deception, and understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.
Sustainability	Protect environment and natural resources locally and globally.	
Social Responsibility	Produce products and services that benefit society and communities.	Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

7.1 Areas of Responsibility

	Description	IEEE Code of Ethics
Work Competence	Perform work that is of high quality and integrity while finishing it on time.	Members of the IEEE should uphold high standards, maintain and improve their technical competence. In addition to only taking on tasks they are qualified for and/or will disclose when they

		are not.
Financial Responsibility	Provide products and/or services at a reasonable value and cost.	Members of the IEEE should reject bribes of any form and avoid conflicts of interest and disclose them to all involved parties when they do occur.
Communication Honesty	Report truthful and understandable work to all parties involved	Members of the IEEE should be honest and realistic when stating claims or estimates based on data
Health, Safety, Well-being	Minimize risks to safety, health, and the well-being of all stakeholders	Members of the IEEE should hold paramount the safety, health, and welfare of the public with ethical designs. They should disclose factors of danger to the public and avoid injuring others, their property, and their reputation.
Property Ownership	Respect Properties, Ideas, and Information of clients and others.	Members of the IEEE should know all the policies as it regards to the property of ideas and work and follow them.
Sustainability	Meeting the needs of the present generation without compromising the ability of future generations to meet their needs	To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose factors that may go against that.
Social Responsibility	Produce products and services that benefit society and communities.	Members of the IEEE should make decisions with the safety, health, and welfare of the public/environment in mind. They should work with honesty and integrity.

7.2 Project Specific Professional Responsibility Areas

Work Competence	• Yes, this project responsibility applies to our project, as it is highly reliant on the accuracy,

<table>
<tr><td></td><td>quality and timeliness of individual calculations. Without this area of responsibility, our project would not be of much use to our client, rendering our work useless.
Team Performance: High
Our team thus far has displayed high competence both in the quality and accuracy of our work. We have also taken steps to keep on schedule and produce formal documents with professional standards</td></tr>
<tr><td>Financial Responsibility</td><td>Yes, this project responsibility applies to our project, as it is important to keep the cost of the project in mind, even if it is a hypothetical Solar array. If we were to actually implement this design in the real world, we would want the cost to be as low as possible for both our sake, and the sake of the client
Team Performance: Medium
As this is a hypothetical project, our main focus has not necessarily been on the financial side of this project. Nonetheless, we are trying to keep track using cost analysis tools provided to us by our client.</td></tr>
<tr><td>Communication Honesty</td><td>Yes, this project responsibility applies to our project, as a large portion of our project involves communicating openly with others. For instance we communicate our activities and ideas with our client, Black & Veatch, in order to get their input on problems we may run into.
Team Performance: High
We hold weekly Team meetings to communicate with teammates and set goals for the following week. On top of this we also have weekly meetings with our client to keep them appraised on our activities and any questions we may have.</td></tr>
<tr><td>Health, Safety, Well-being</td><td>Yes, this project responsibility applies to our project, as it is important to keep healthy and fit to complete this project as efficiently as possible; this semester especially with the threat of Covid still</td></tr>
</table>

	present. ● Team Performance: High 　○ In the event that one of our members falls ill, we can have the ill person assist our progress remotely. Alternatively we may shift some of the workload off of the sick individual to aid in their recovery.
Property Ownership	● Yes, this project responsibility applies to our project, since we need to keep in mind the specific ownership of various items provided to us by our client. We also need to make sure we refrain from copying the work of groups who completed this project in years prior to us. ● Team Performance: High 　○ We have all signed paperwork detailing the specifics of ownership considering the programs provided to us by Black & Veatch.
Sustainability	● Yes, this project responsibility applies to our project, as Solar energy is an important renewable energy source in today's world. Since the project is hypothetical, we will not have to consider the problem of keeping the actual construction of the plant green, however it is good practice to keep such things in mind. ● Team Performance: Medium 　○ As this project is hypothetical, the sustainability aspect of it does not take as important a role as some of the other aspects that we deal with.
Social Responsibility	● Yes, this project responsibility applies to our project, because if the plant were to be constructed, we would be producing clean, renewable energy for the foreseeable future. We also took into account the amount of land needed, opting for panels that required less total area to reduce the overall impact of our plant on the surrounding area. ● Team Performance: High 　○ Many of us may end up in the Energy production field, and that makes it important for us to keep in mind the

	positive effects that renewable energy sources have on society and the environment.

7.3 Most Applicable Professional Responsibility Area

Definition

- Perform work of high quality, integrity, timeliness, and professional competence

IEEE Members Commit to:

- uphold highest standards of integrity
- Maintain and improve their technical competence
- Only take on technological tasks for other if they are qualified, or will fully disclose their pertinent limitations

Applications to Solar Power Plant Design

- Our project is highly reliant on the accuracy, quality and timeliness of individual calculations.

- Without this area of responsibility, our project would not be of much use to our client.
- Team Performance: High
    - We have displayed high competence in quality and accuracy of our work.
    - We have also taken steps to keep on schedule and produce formal documents with professional standards
- Timeliness - Our team works on a schedule by frequently updating gantt charts with our client and having weekly meetings every Monday and Wednesday.
- Competence - Weekly meetings with our client. We fully disclose our technical limitations with the client by following a strict agenda formulated before the meeting.

8 Closing Material

8.1 Discussion

During the fall of 2021, we were tasked to design a Solar Array that met Black & Veatch's design and calculation standards as well as compared them to the industry standards in areas such as Voltage drop, Trench Fill, Irradiance, etc.

As the semester came to an end we were able to come up with a final design layout with the help of AutoCAD as well as measure the appropriate values mentioned before to make sure the design performs as efficiently as possible, with the help of Microsoft Excel.

In terms of requirements met, we made sure the area of the design fit inside a certain space, selected by the team, which was 5000 ft in length by 2000 ft in width. We took up 4800 ft in length for the entire array and left room for the substation design in the remaining 200ft, which will be completed in the Spring. In terms of Voltage Drop, we had to make sure we chose the correct cable sizes for each of the distances from the racks to the combiner boxes and then to the inverter, which was Cable size 8 and 10 respectively. The cable size affected the overall voltage drop and industry standards require it to be less than 3%.

Other requirements that we had to follow were being able to effectively communicate our work to the client and our advisor and with the help of our gantt chart and proper communication skills, we were able to efficiently conquer that step as well.

The client is super happy with our work this semester and we as a team couldn't be any happier to move forward with the project and learn more about Substation design.

8.2 Conclusion

Overall, this project was a great experience to get our hands on in terms of design work. Our goal was to meet our client, Black & Veatch's, criteria for the solar array design and with hardwork and determination we were able to get it done with high remarks. Our main goal was to make sure we understood the idea of the project and make sure that we were able to stay on track to deliver the proper work. With the help of the gantt chart and the availability of the Client on a weekly basis, we got our work done and are now moving onto the next steps of designing the substation for the power plant.

To reiterate, we used software like AutoCAD and BlueBeam to design the key plan for the solar array and get annotations for them from the client. We also used Microsoft Excel to gather data and run calculations for voltage drop, trench fill, and create a general solar parameter with the tools provided by Black and Veatch. Other tools we used were Microsoft Projects to update our gantt charts on a weekly basis as well as Microsoft PowerPoint to present our work on a weekly basis to make sure we are on track. Staying on track and communicating with our team was key in meeting our goals and we prioritized that. We were grateful that we didn't have any constraints from meeting our goals, since everyone, including Black & Veatch and our advisor, Professor Ajjarapu, prioritized the project over anything else.Next semester we plan to continue the same plan of action to meet our substation goals and currently don't see any reason to make any changes. We have completed our next semester gantt chart and according to our client, we should be able to meet our goals then too.

8.3 References

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8.4 Appendices

Reference 7.4.2 and 7.4.3 for additional drawings, charts, and additional information

8.4.1 Team Contract

Team Members:

1) John Jennison______________________

2) Aayush Shah______________________

3)Adilene Prieto______________________

4) Kyle Neal__________________________

5) Logan Miller______________________

6) Matthew Schindler_________________

7)Shadoe Rusk______________________

Team Procedures

1. Client meetings are on every Wednesday at 3:15 PM on Microsoft Teams. The team will meet in person for each video conference.
2. Team meetings will occur at least once per week to prepare for the client meeting, advisor meeting, and to delegate the weekly tasks. Meetings will be held regularly on Mondays at 3:30 PM.
3. Advisor meetings will occur weekly on Thursdays at 3PM. TA meetings will also occur weekly, promptly following client meetings at 4:30 PM on Wednesdays..
4. The team will communicate through discord and through email.
5. Team decisions will be made by majority vote.
6. Meeting agendas will be made every meeting. All team members will review the meeting agendas and arrive at each meeting prepared. Client meeting agendas will be drafted, reviewed, and emailed to the client at least 24 hours prior to each client meeting.
7. Meeting minutes will be recorded during each meeting. Meeting minute record keeping will be assigned to one individual on the team each week, and the responsibility will be assigned on a rotating basis. The meeting minutes will be reviewed after each meeting and then saved and sent to the client.

Participation Expectations

All members are expected to be at each meeting. If there are schedule conflicts, the team will be flexible to accommodate.

1. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines:
   a. Work will be divided as evenly as possible.
   b. All team members are expected to complete their work prior to their set deadline.

c. Team members that either can not complete their task by their required deadline or feel that their workload is too much are to inform the team promptly. The team shall make their best effort to relieve other members who are overloaded.

2. Expected level of communication with other team members:
    a. Each team member shall:
        i. Check their discord and email at least daily
        ii. Give a minimum 24 hour notice if their schedule conflicts with a meeting time.
        iii. Give minimum 48 hour notice if their assigned task can not be completed in time.
3. Expected level of commitment to team decisions and tasks:
    a. Each team member is expected to allocate time in their schedule to support 3 hours per week for meetings and 5 hours of individual work on the project.
    b. All team members must comply with team decisions after majority vote has been made

Leadership

1. Leadership roles for each team member:
    - Team Organizer - John Jennison
    - Client Interaction - Matthew Schindler
    - Individual Component Design -Logan Miller, Kyle Neal, Shadoe Rusk
    - Testing - Aayush Shah, Adilene Prieto
2. All members shall make an effort to be available to help each other out at all times.
3. The team will recognize the contributions of all team members during team meetings and on the discord server.

Collaboration and Inclusion

1. 6 out of 7 members are in a Power related field and 1 member is in VLSI and Electromagnetic field. All members bring in experience from extracurricular activities such as Internships, Clubs and other classes (303,411,455, 456,465).
2. The team will encourage and support each other by:
    a. Actively listening to all ideas presented by all members and open to discussing their relevance.

    b. Actively checking on each other to hold us accountable
3. The team will identify and resolve collaboration or inclusion issues by:
    a. Team members will bring issues to team meetings and include them on meeting agendas. The team will discuss the issues at the next meeting.
    b. All team members will check in with each other individually to discuss or resolve conflicts.
    c. Team members will bring issues to discussion on the discord server.

Goal-Setting, Planning, and Execution

1. Team goals for this semester:
    a. Equipment sizing calculations
    b. Solar layout drawings
    c. Solar panel string sizing design
    d. Electrical layout drawings
    e. Grounding Analysis and ground-grid developed with IEEE-80
2. Work will be assigned on a volunteer basis. Work that is unclaimed will be delegated fairly by the team.
3. The team will work will manage the project timeline by making a Gantt Chart

Consequences for Not Adhering to Team Contract

1. Conflicts within the team will be addressed by the team first. The team will make every effort to resolve the conflict themselves. If the conflict can not be resolved by the team, then the team will bring the issue to the TA, and follow up with the professor as necessary.

****

a) *I participated in formulating the standards, roles, and procedures as stated in this contract.*
b) *I understand that I am obligated to abide by these terms and conditions.*
c) *I understand that if I do not abide by these terms and conditions, I will suffer the consequences as stated in this contract.*

1) _Matthew Schindler_________________________ DATE ___9/13/21_________
2) _Adilene Prieto______________________________ DATE ___9/13/21_________
3) _Kyle Neal__________________________________ DATE ___9/13/21__________
4) _Logan Miller_______________________________ DATE ____9/13/21_________

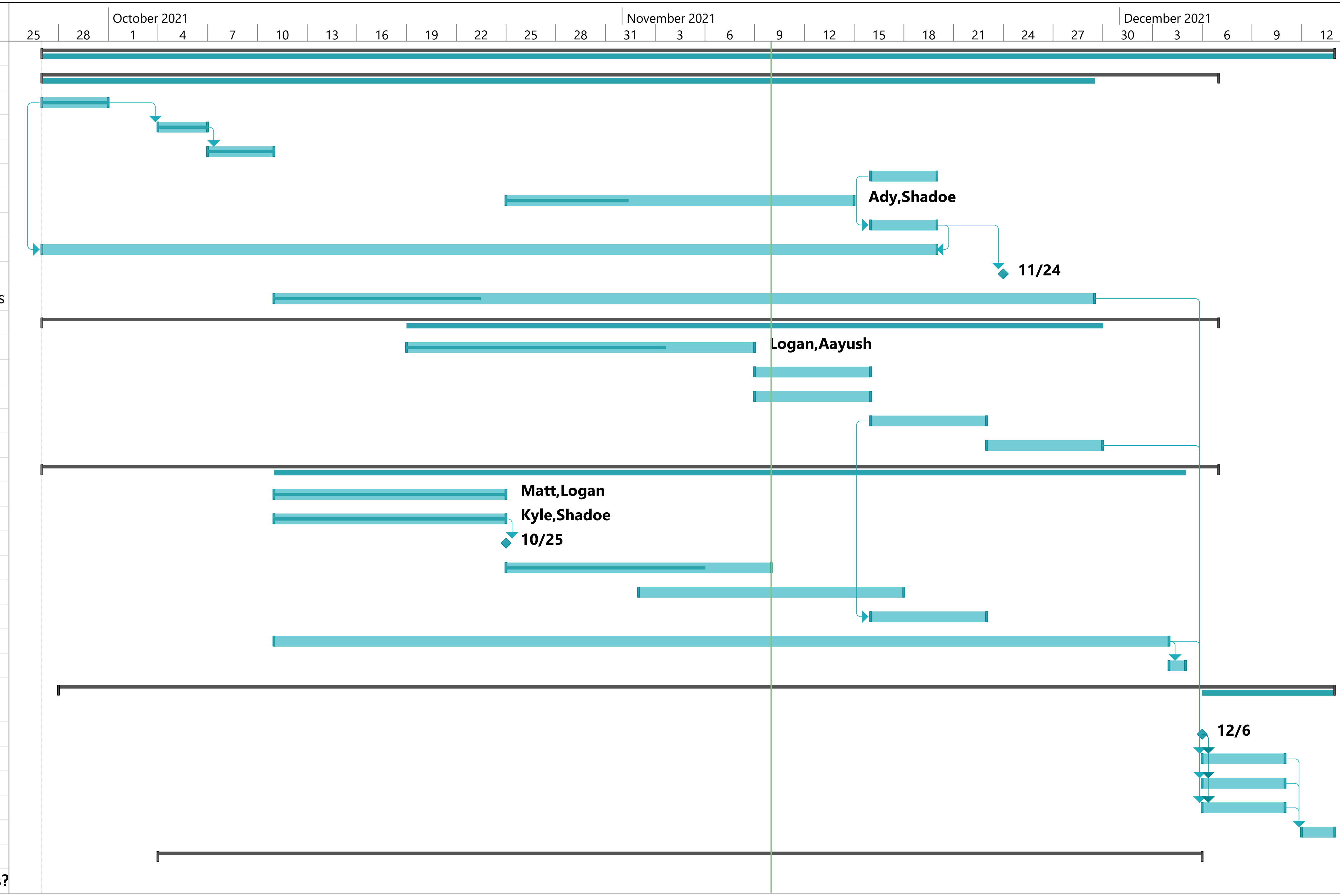
5) John Jennison DATE 9/13/21

6) Aayush Shah DATE 9/16/21

7) Shadoe Rusk DATE 9/18/21

8.4.2 Gantt Chart

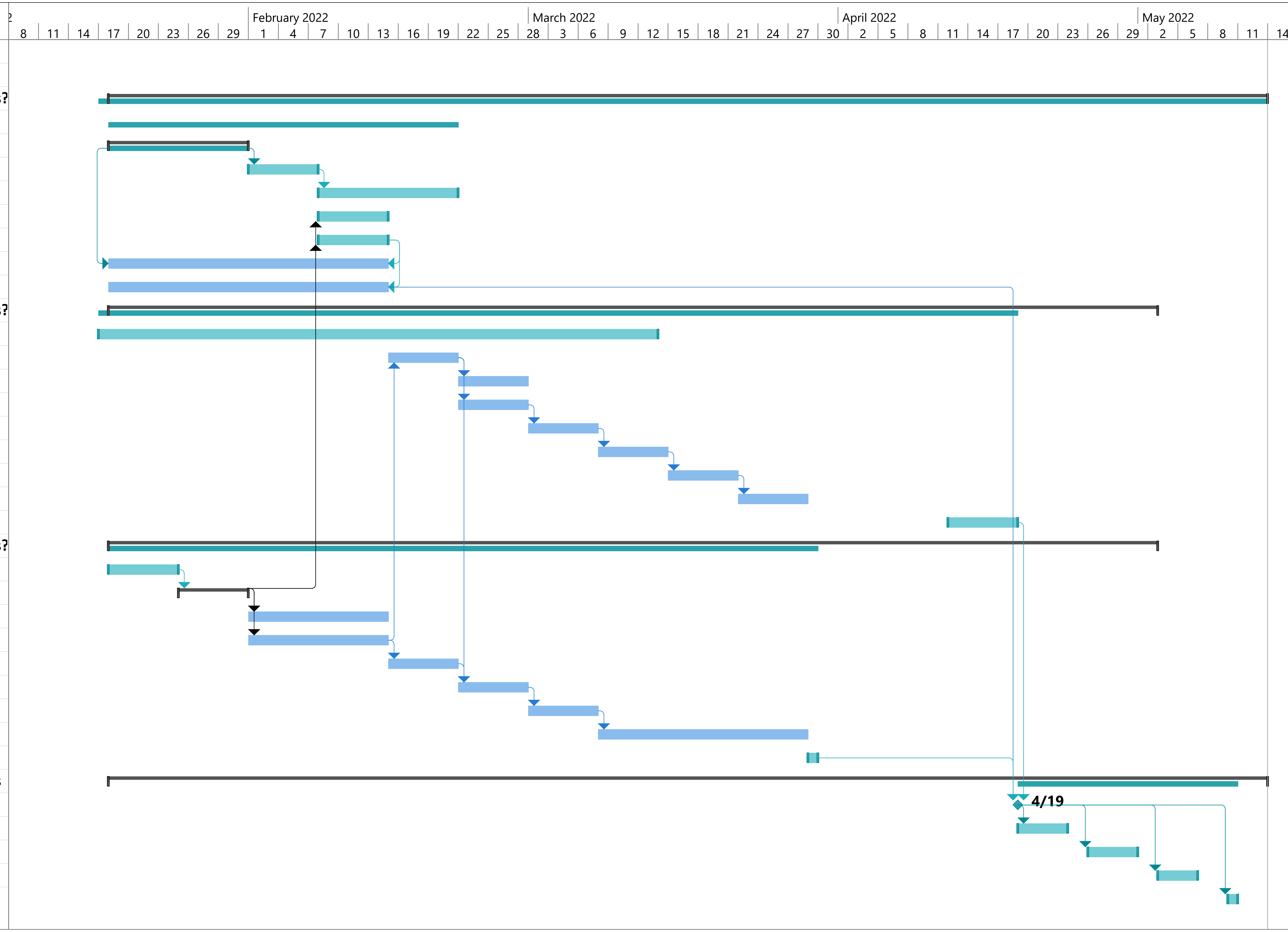
ID	Task Name	Work	Duration
1	**Solar Power Plant Design**	**175 hrs**	**78 days?**
2	**Solar Panel String Sizing Design**	**65 hrs**	**71 days?**
3	Initial Equipment Selection	4 hrs	4 days
4	Array parameter Tool	8 hrs	3 days
5	Select Solar Panels,Inverters, Cc	2 hrs	4 days
6	Cable list	4 hrs	4 days
7	Solar Cost Analysis	21 hrs	21 days
8	Conduit list	4 hrs	4 days
9	Bill of Material	6 hrs	54 days
10	Finish cable and conudit list	0 hrs	0 days
11	Draft Report	16 hrs	49.5 days
12	**Equipment Sizing Calculation**	**36 hrs**	**71 days**
13	Voltage Drop	12 hrs	21 days
14	Electrical Ratings	6 hrs	7 days
15	Trench Fill	6 hrs	7 days
16	Lightning Protection	6 hrs	7 days
17	Calculation Summary Report	6 hrs	7 days
18	**Solar Layout Drawings**	**49 hrs**	**71 days**
19	One lines	12 hrs	14 days
20	key plan	12 hrs	14 days
21	Finish Key Plan Drawing	0 hrs	0 days
22	Equipmnent Plan	12 hrs	16 days
23	Elevations	6 hrs	16 days
24	grounding plan	6 hrs	7 days
25	Drawing list	1 hr	54 days
26	Finish Drawing Date	0 hrs	1 day
27	**1st Semester Delvirable Review and Submittal**	**25 hrs**	**77 days?**
28	All First Drafts Complete	0 hrs	0 days
29	Review Report	8 hrs	5 days
30	Review Calcualtions	8 hrs	5 days
31	Review Drawing Packege	8 hrs	5 days
32	Merge Documenets	1 hr	2 days
33	**EE 491 Canvas Weeklys**	**94.5 hrs**	**63 days**
43	**Substation Design**	**194 hrs**	**116 days?**



Project: Project Schedule Fall 20
Date: Wed 11/10/21

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

ID	Task Name	Work	Duration
1	**Solar Power Plant Design**	**175 hrs**	**78 days?**
33	**EE 491 Canvas Weeklys**	**94.5 hrs**	**63 days**
43	**Substation Design**	**200 hrs**	**116 days?**
44	**Substation Planning**	**60 hrs**	
45	**Equipment selection**	**16 hrs**	**14 days?**
54	Bus Design	8 hrs	7 days
55	Control House Design	8 hrs	14 days
56	Conduit List	4 hrs	7 days
57	Cable List	4 hrs	7 days
58	Bill of Materials	4 hrs	28 days
59	Draft Report	16 hrs	28 days
60	**Calculations**	**62 hrs**	**105 days?**
61	Bus Calc (Tentative)	12 hrs	56 days
62	Grounding Calc	6 hrs	7 days
63	AC Calc	6 hrs	7 days
64	DC Calc	6 hrs	7 days
65	Voltage Drop	6 hrs	7 days
66	Lightning Protection	6 hrs	7 days
67	Trenchfill	6 hrs	7 days
68	Cable Tray Fill	6 hrs	7 days
69	Draft Calculation Report	8 hrs	7 days
70	**Drawings**	**52 hrs**	**105 days?**
71	Bus Plan	0 hrs	7 days
72	**Key Plan**	**14 hrs**	**7 days**
75	One Lines	6 hrs	14 days
76	Three Lines	6 hrs	14 days
77	Elevations	6 hrs	7 days
78	Grounding Plan	6 hrs	7 days
79	Lighting Plan	6 hrs	7 days
80	Controls Drawing	6 hrs	21 days
81	Drawing List	2 hrs	1 day
82	**Review and Submittal**	**26 hrs**	**116 days**
83	All First Drafts Complete	0 hrs	0 days
84	Review Report	8 hrs	5 days
85	Review Calcualtions	8 hrs	5 days
86	Review Drawing Packege	8 hrs	4 days
87	Merge Documenets and Submit	2 hrs	1 day



Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			

Project: Project Schedule Fall 20
Date: Wed 11/10/21

8.4.3 Drawings

Drawing List

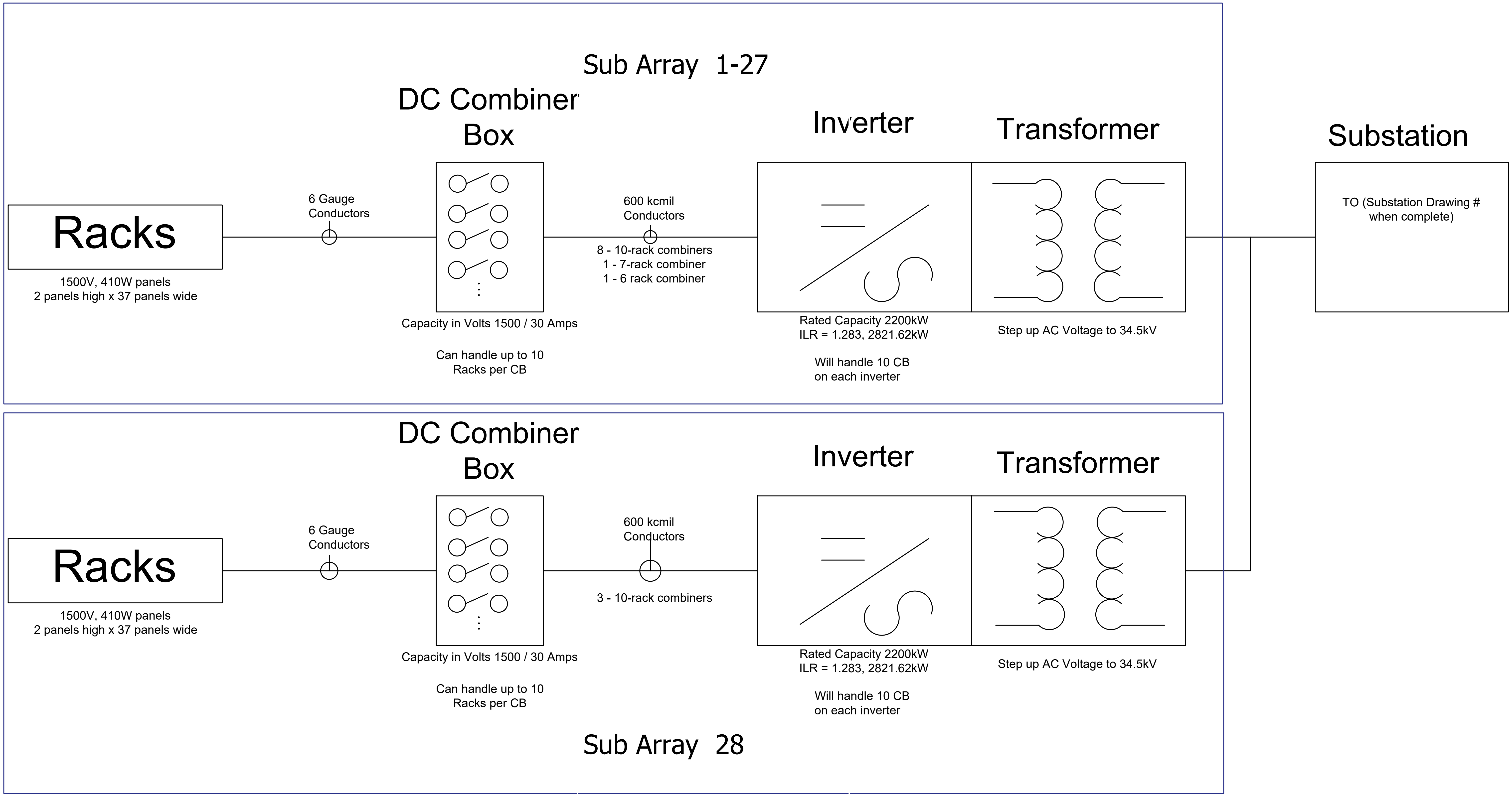
```
One Line 1

Key Plan 2

EqP Normal 3
Grounding Plan 4
EqP Flipped 5
Grounding Plan 6
EqP 28th 7
Grounding Plan 8

Elevations 9

Drawing list
```



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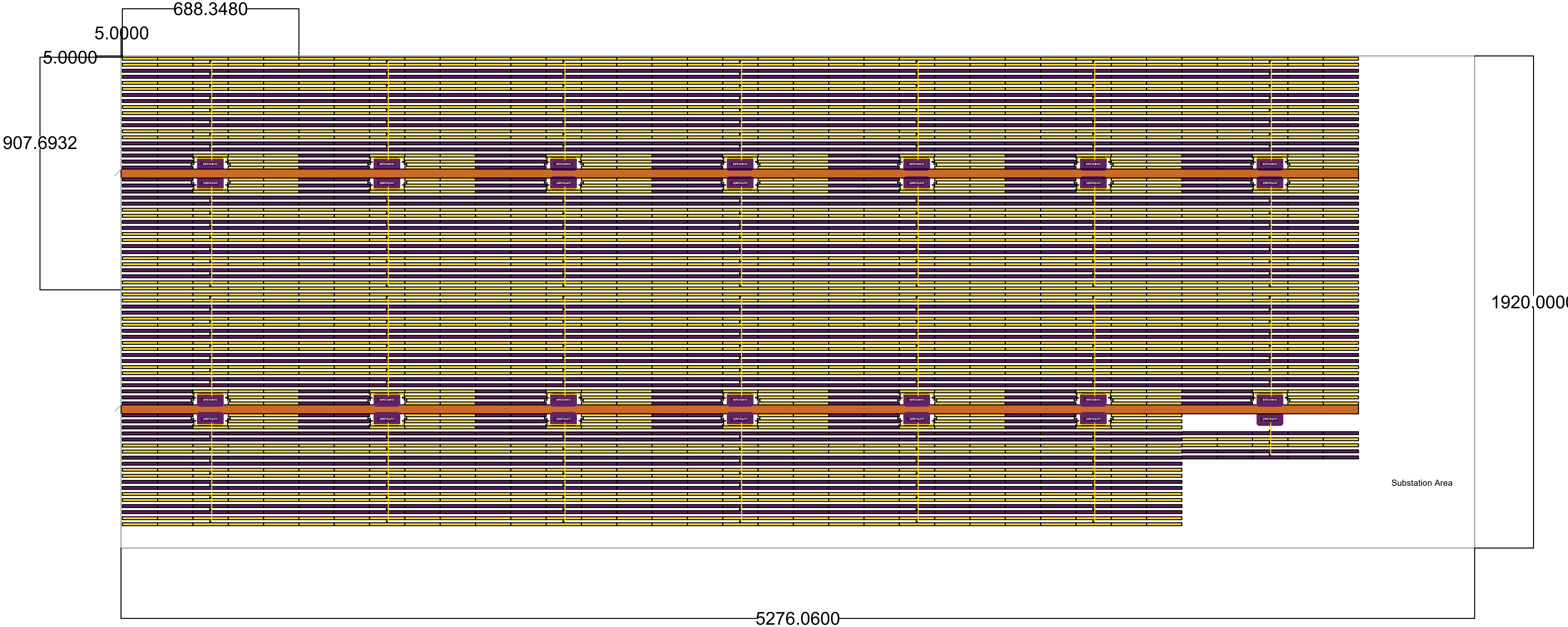
				CHECKED BY: Kyle Neal	11/10/2021		
				CHECKED BY:	DATE		
				CHECKED BY:	DATE		



Legend

Orange - Road

Green - Fence

Teal - Gate

White/Yellow/Purple - Wiring/Components

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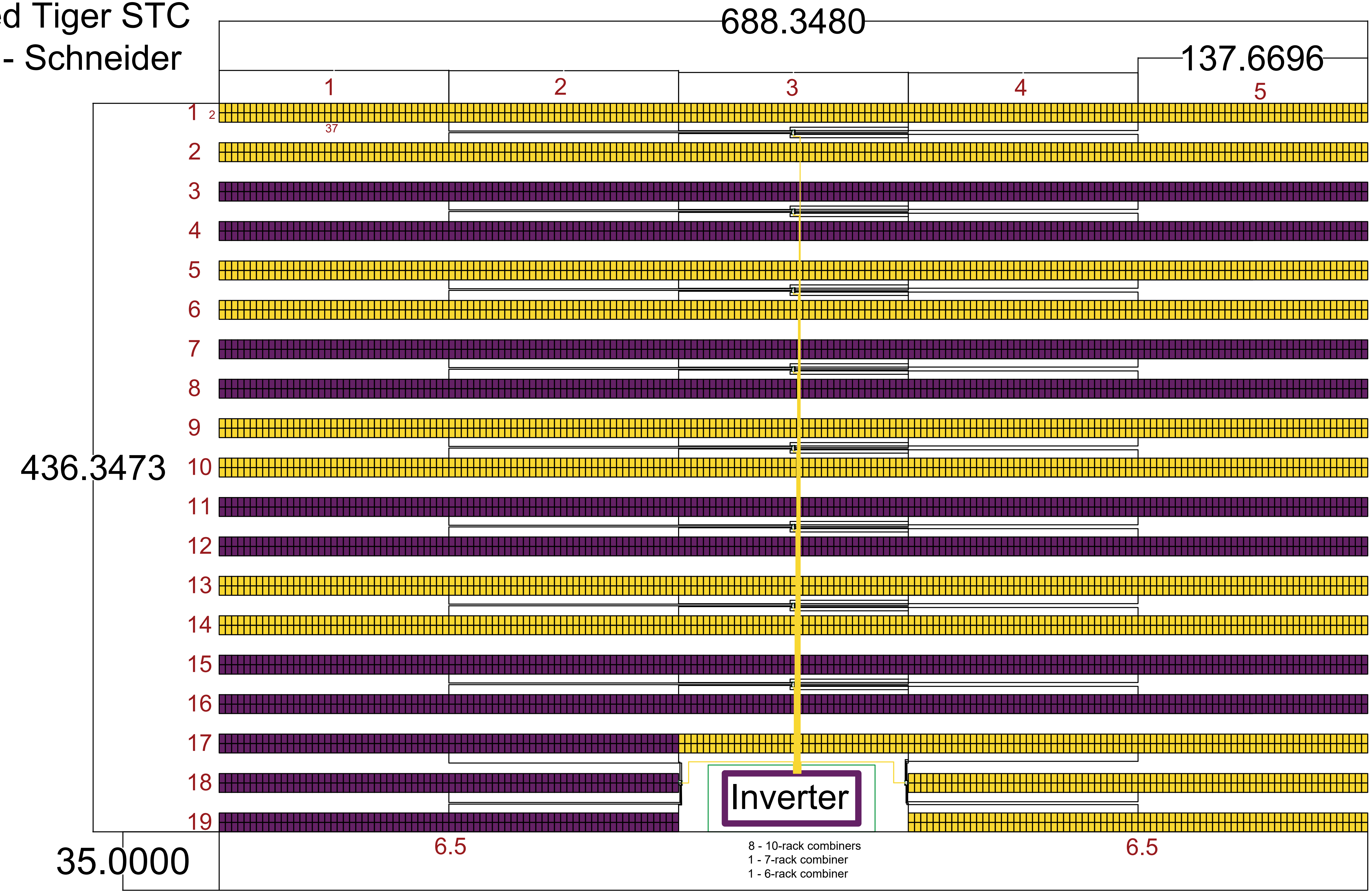
				DRAWN BY:	DATE
				CHECKED BY: Kyle Neal	11/15/2021
				CHECKED BY:	DATE
				CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

Key plan

DRAWING NO.: 02

Rotated Tiger STC 410W - Schneider



8 - 10-rack combiners
1 - 7-rack combiner
1 - 6-rack combiner

DATE	REVISION

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College of Engineering

EE 491
GROUP 05

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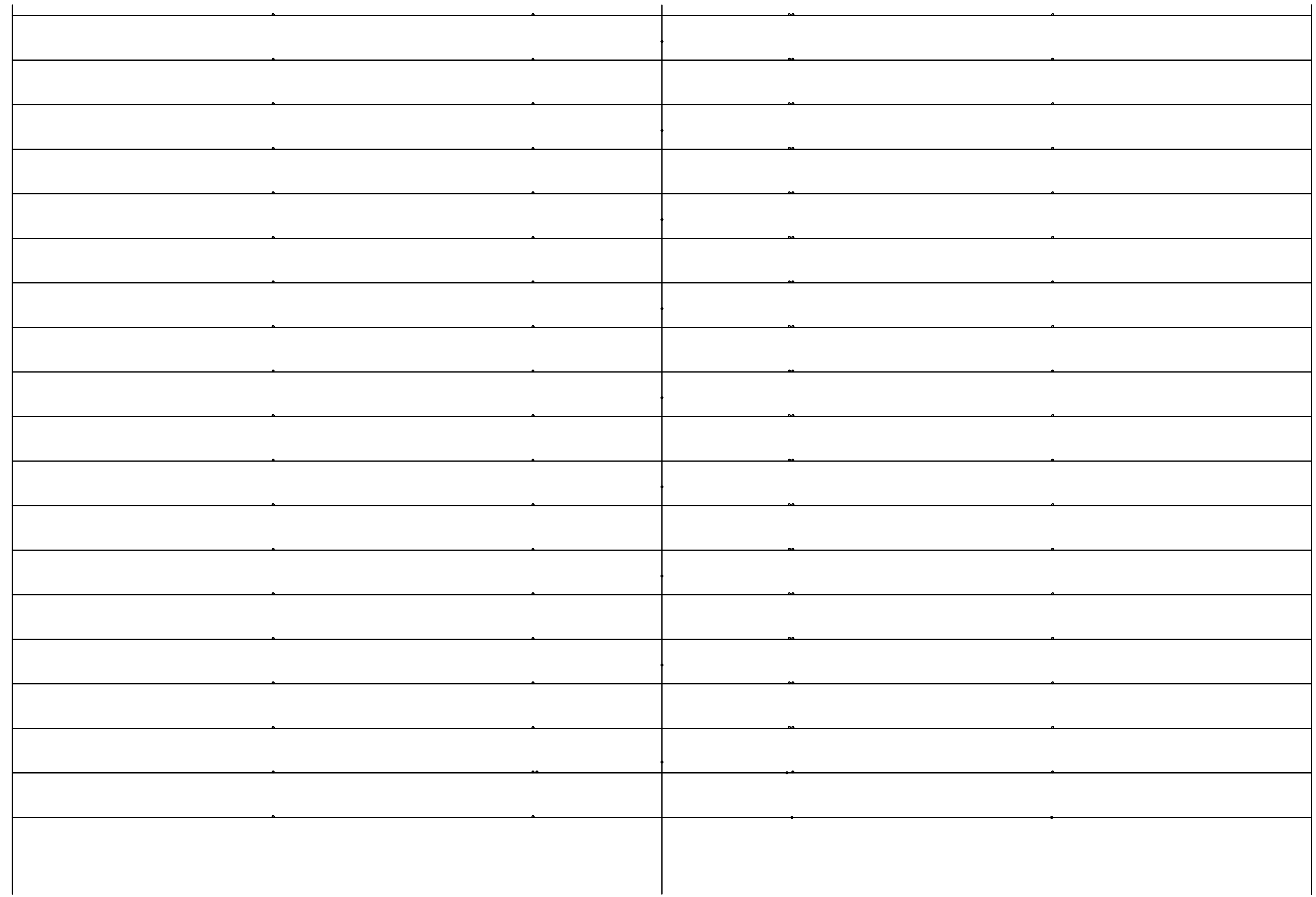
CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

Equipment Plan - Standard Array

DRAWING NO.:
03



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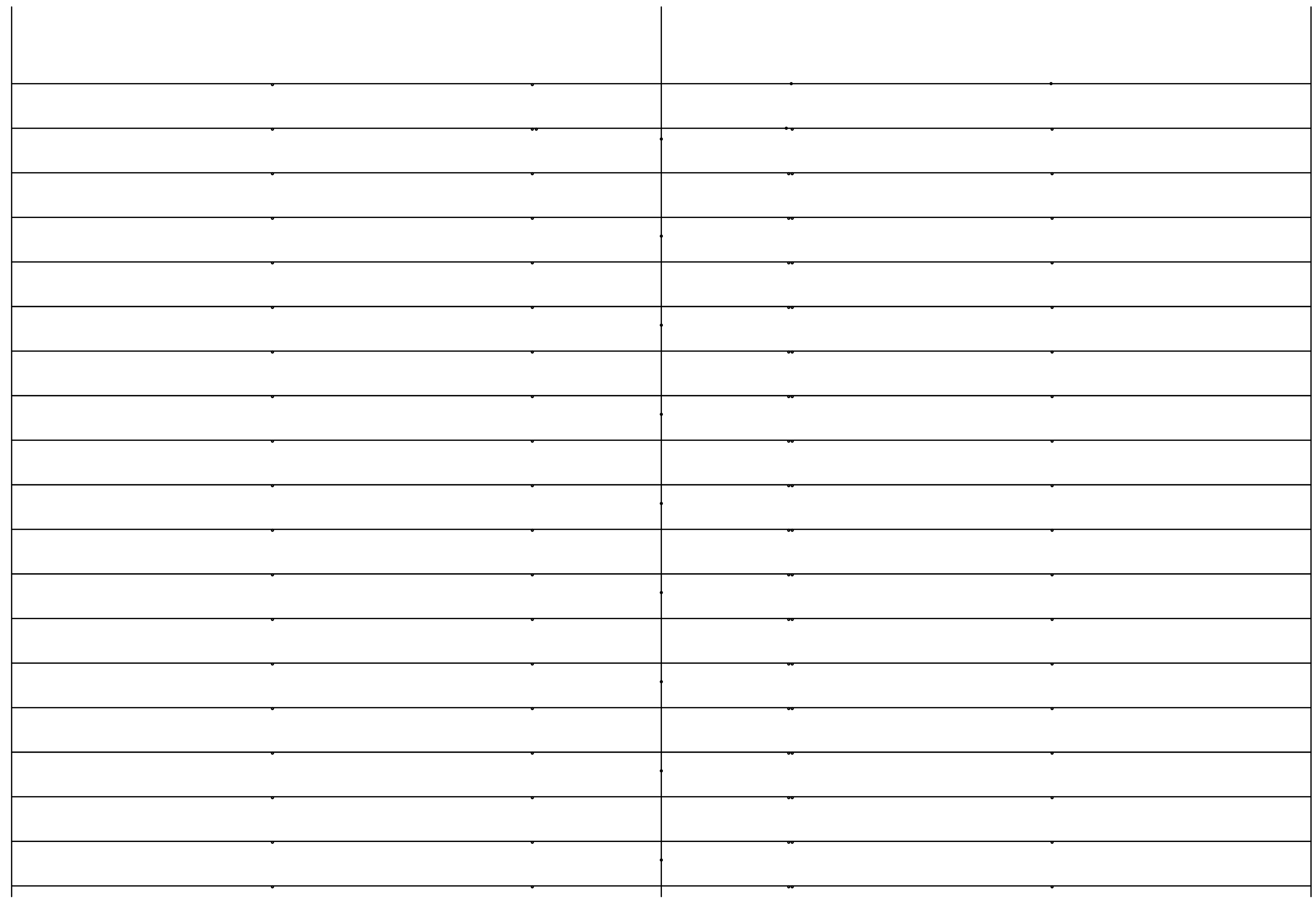
CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

Sub-Array Grounding Plan

DRAWING NO.:

04



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EE 491
GROUP 05

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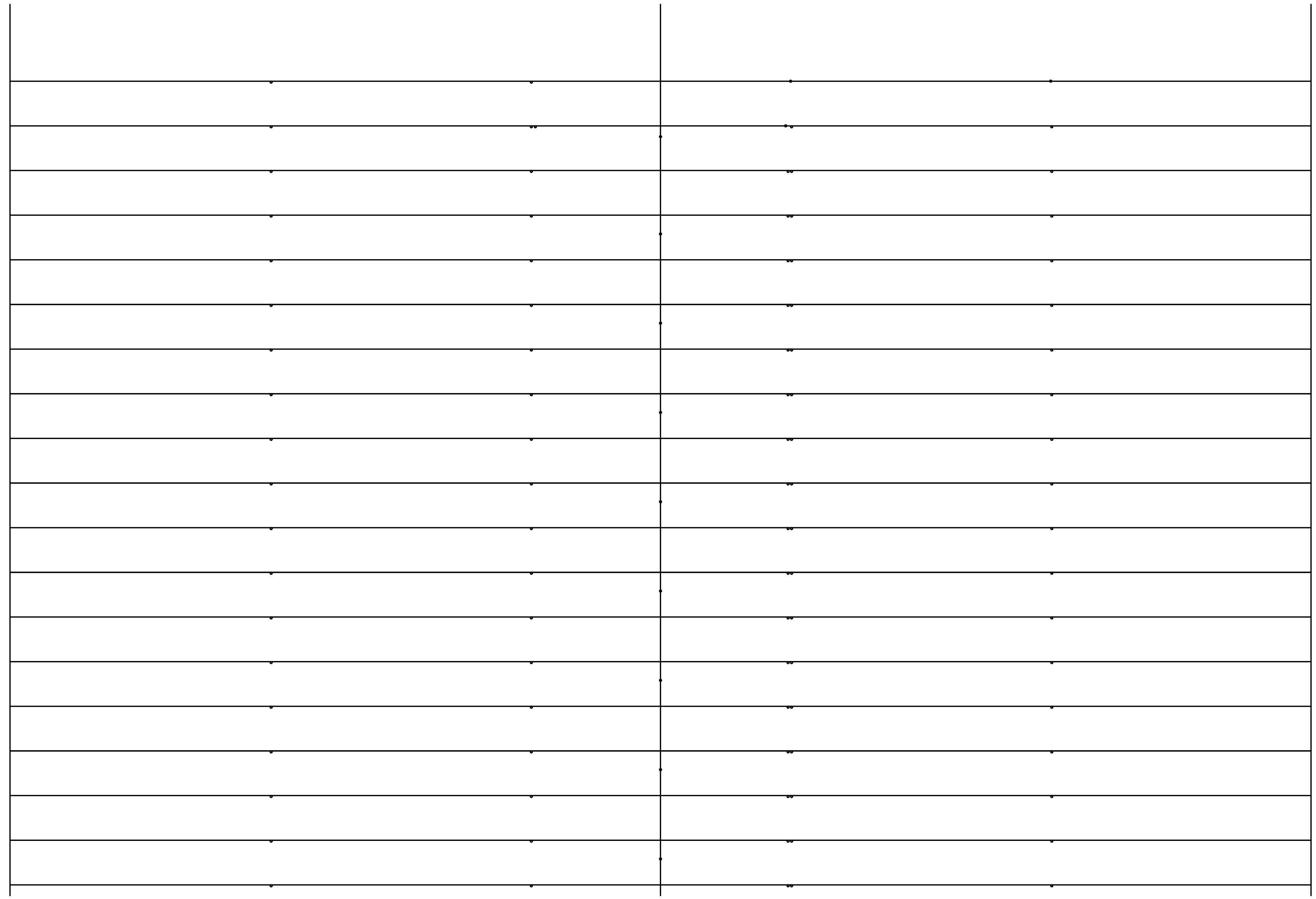
CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

Flipped Sub-Array Grounding Plan

DRAWING NO.:
05



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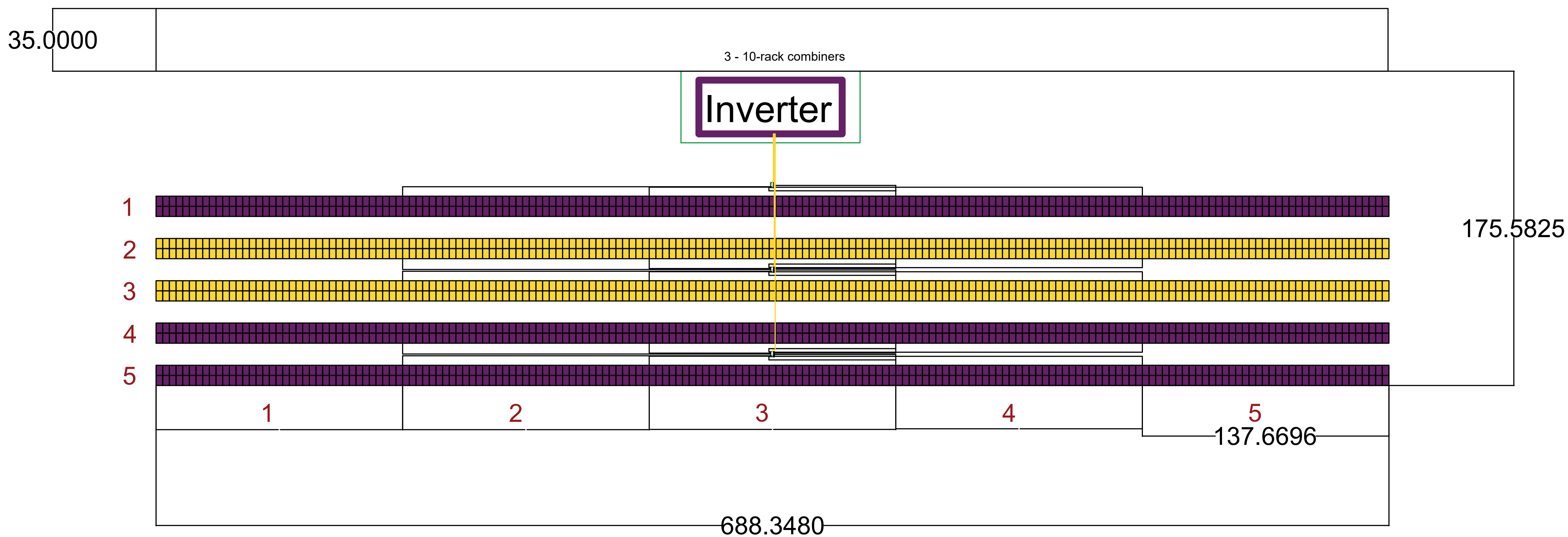
CHECKED BY:	DATE
CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

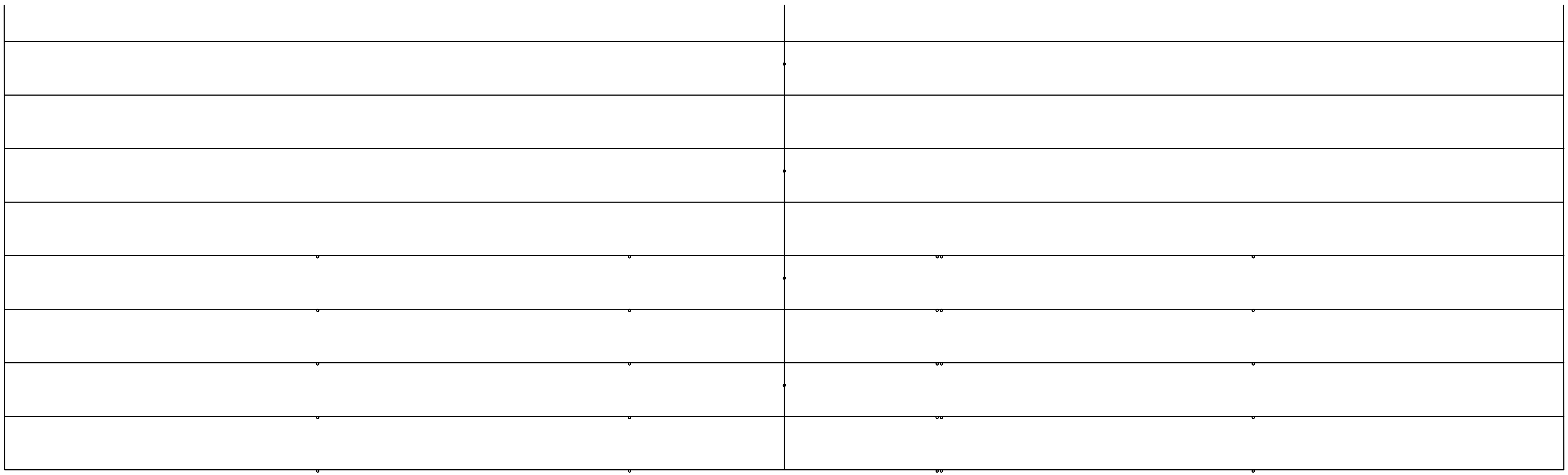
Flipped Sub-Array Grounding Plan

DRAWING NO.:
06

Rotated Tiger STC
410W - Schneider



		IOWA STATE UNIVERSITY College of Engineering	EE 491 GROUP 05	DRAWN BY: Kyle Neal	12/5/2021	Iowa State Group 05 Solar Power	DRAWING NO.:
				DRAWN BY:	DATE	Equipment Plan 28th Array	07
				CHECKED BY: Matthew Schindler	12/5/2021		
				CHECKED BY:	DATE		
DATE	REVISION			CHECKED BY:	DATE		



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DRAWN BY:	DATE
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CHECKED BY:	DATE
CHECKED BY:	DATE

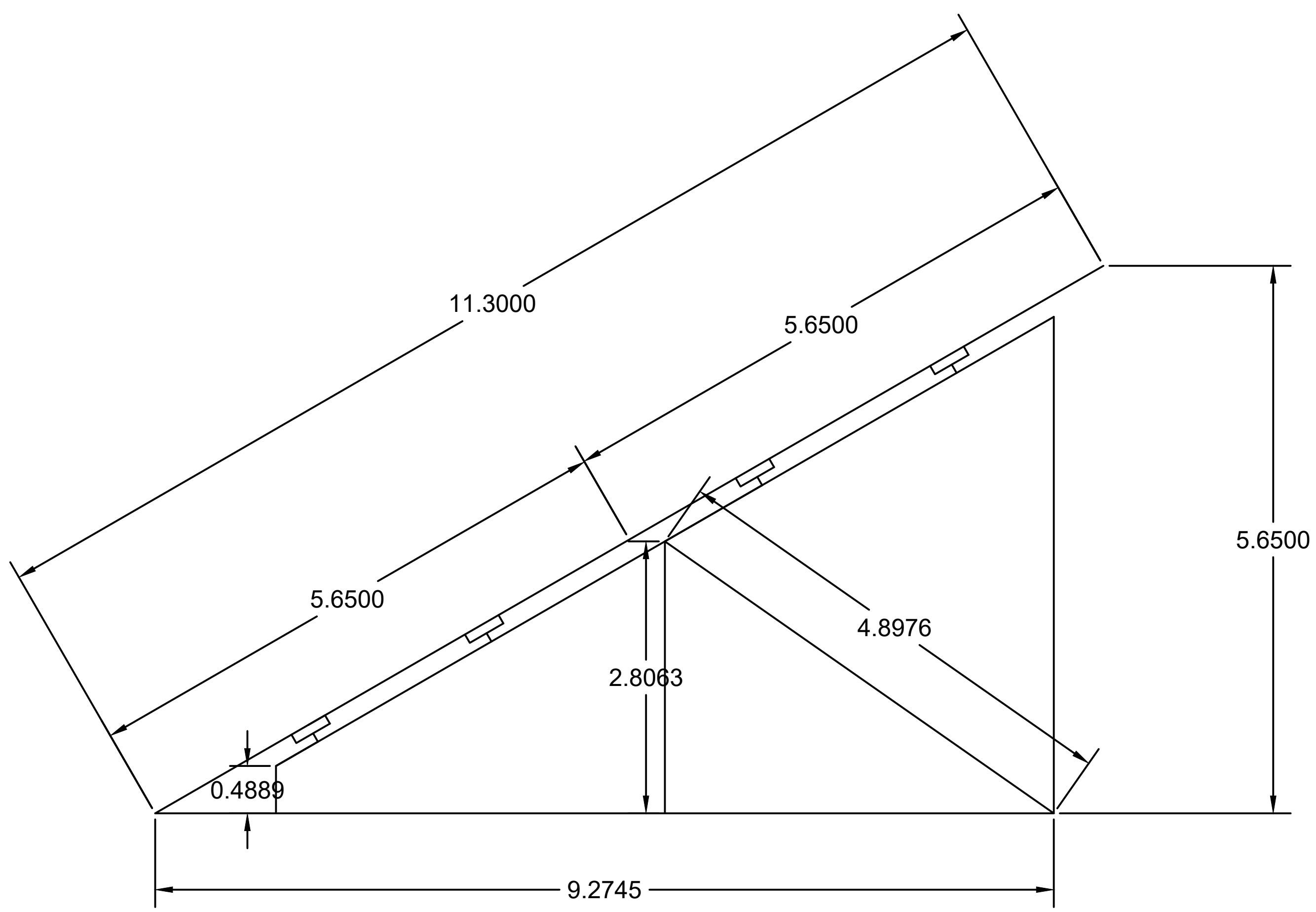
Iowa State
Group 05
Solar Power

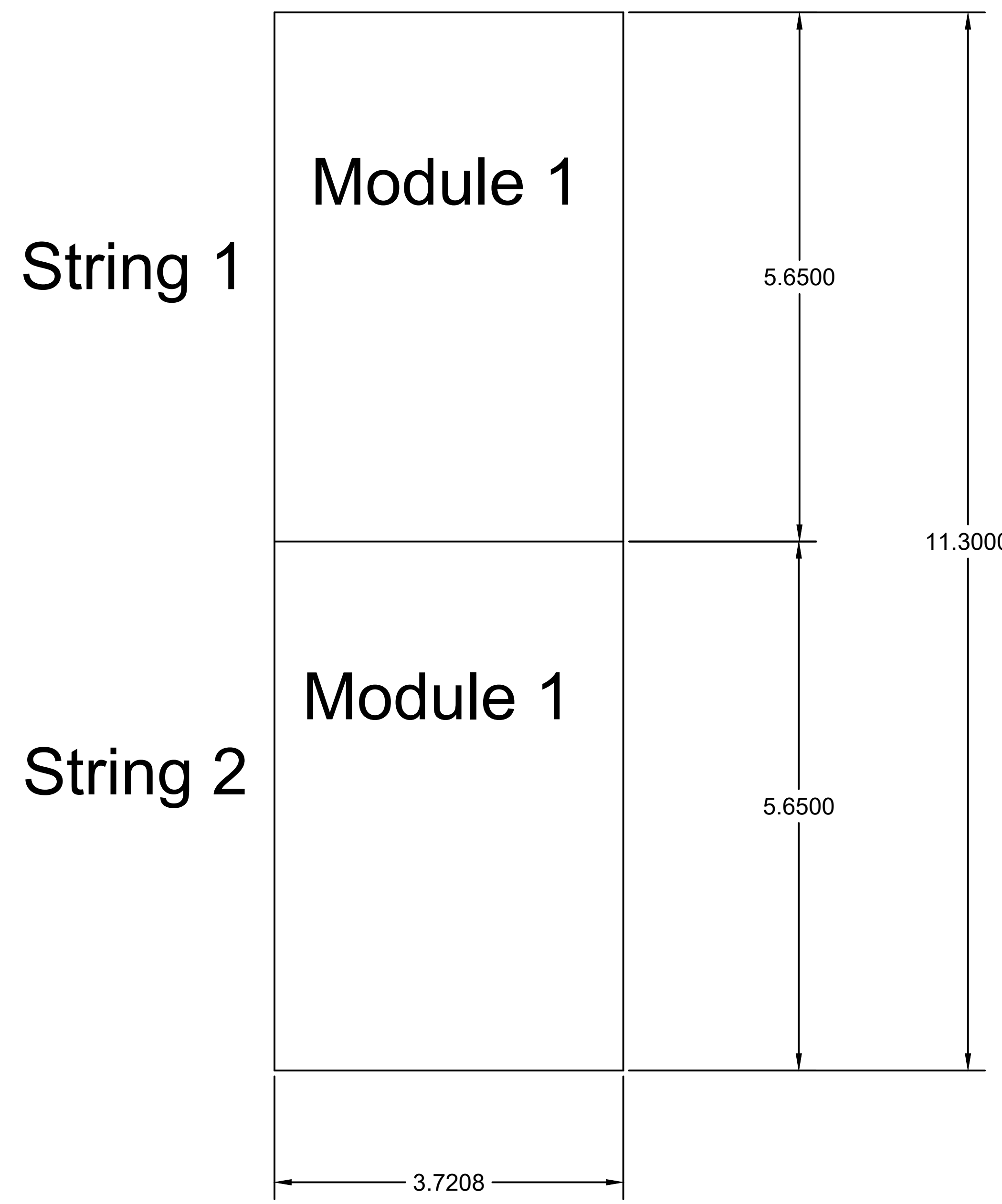
28th Sub-Array Grounding Plan

DRAWING NO.:
08

Head on view of 1/37th Solar Rack

Side view of the Solar Rack





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				CHECKED BY:	DATE
				CHECKED BY:	DATE

Iowa State
Group 05
Solar Power

Elevation Plan

DRAWING NO.: 09