115/34.5 kV Solar Power Plant & Substation

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Project Advisor- Dr. Venkataramana Ajjarapu

BLACK & VEATCH

Project Vision

Two Main Components: (All Conceptual)

- 60 MW Solar Farm - Fall 2023
- 115/34.5kV Substation - Spring 2024

SPP Interconnect - Located on the NM/TX border

Project Plan

FALL 2023 - SOLAR POWER PLANT DESIGN

PHASE

1. **RESEARCH (Week 1-3)**
   Collect data sheets for PV cells and solar farm components
2. **PLANNING (Week 4-6)**
   Finalize equipments and components for solar power plant
3. **DESIGNING (Week 7-9)**
   Create preliminary design sketch, and finalize actual design on AutoCAD
4. **CALCULATION (Week 10-12)**
   Perform voltage-drop calculation, economic analysis and do necessary amendments
5. **SIMULATION (Week 13-15)**
   Simulate solar circuit and analyze power flow

SPRING 2024 - SUBSTATION DESIGN

PHASE

1. **RESEARCH (Week 1-3)**
   Collect data sheets for substation equipments
2. **PLANNING (Week 4-6)**
   Finalize equipments for substation
3. **DESIGNING (Week 7-9)**
   Designing one-line diagram of the substation
4. **CALCULATION (Week 10-12)**
   Perform power flow calculation and economic analysis
5. **SIMULATION (Week 13-15)**
   Simulate solar farm and substation power flow

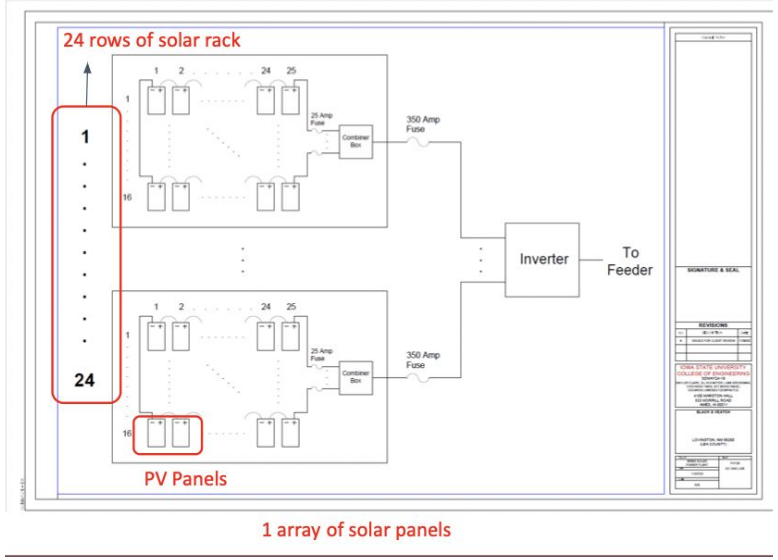
Requirements- Functional

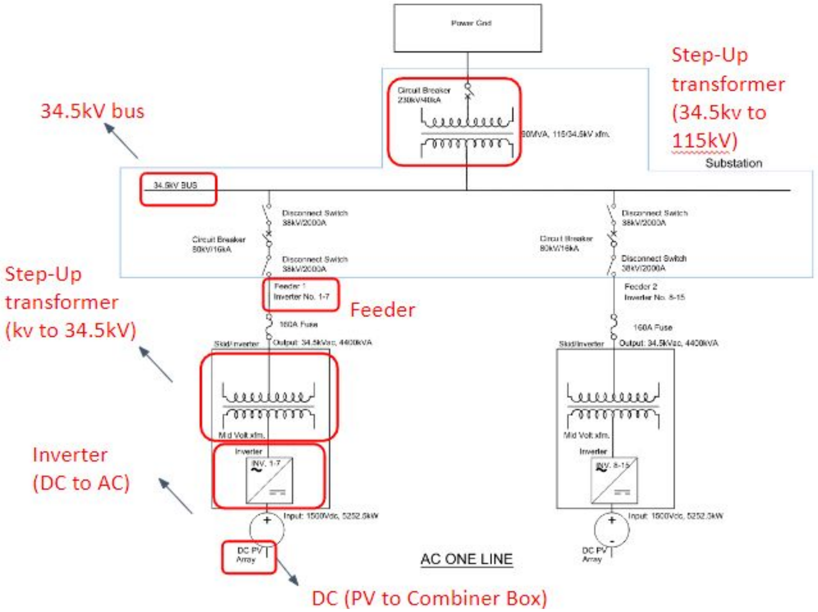
First Semester (Fall 2023)

- Research and select components
- Calculate equipment parameters, sizing, and layout
- Calculate voltage drops up to the substation
- Create solar layout drawings in AutoCAD

Second Semester (Spring 2024)

- Research and select substation equipment
- Calculate equipment parameters, sizing, and layout
- Create substation drawings in AutoCAD/BlueBeam
- Perform grounding analysis
- Simulate power flow of the overall system

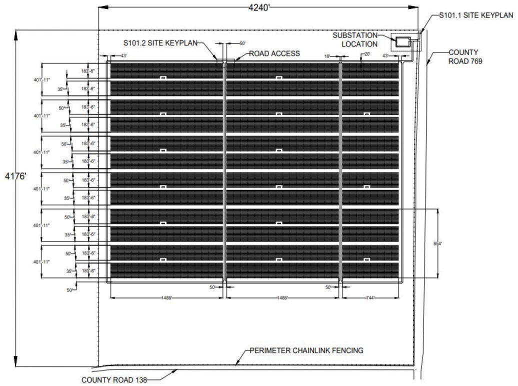




Requirements- Non-Functional

Environmental

- Flat and continuous land
- High annual sunshine and solar irradiance
- Safe substation power for nearby communities
- Efficient land use



Economic

- Our solar plant must be able to produce enough power per year to recover initial investment and operational costs over 10 years.

Present Value		
Year	Installation cost	Profit
10	$63,912,000.00	$147,392,524.13
O+M	Revenue	
$2,419,868.02	$149,812,392.14	

Project Impact

User

- The electricity generated from the solar power plant will benefit the people of New Mexico, especially in Lovington.

For example,

- Residential consumers
- Commercial and Industrial Consumers
- Government facilities

User:

Cost savings: reduced electricity cost due to cheaper alternative.
Reliability: Reliable energy supply, reduced reliance on the main grid distribution.
Clean energy access: Reduce carbon footprint and promote sustainability.

Society:

Job opportunities: Construction, operation, and maintenance, benefiting local economies.
Infrastructure development: Enhance region's infrastructure, attract further investments and development.
Improved health: Mitigate air and water pollution, improve public health and quality of life.

Humanity:

Climate change mitigation: Renewable energy sources contribute to global efforts on reducing greenhouse gas emissions.

Conceptual Diagram

60 MW Solar Power Plant

115/34.5 kV Substation

Grid Connection

1. Location: Lovington, New Mexico
(High Solar Irradiation, Lower Land Cost)
1. Components : Solar panels, combiner box, inverter
2. Solar Plant Parameters: Array Parameter Tools
3. Solar Plant Layout: AutoCAD
4. Voltage-Drop Calculation: less than 5% (based on National Electric Code(NEC))
5. Cost Analysis

The substation step-up the voltage from 34.5 kV to 115 kV for transmission at the grid (high voltage for less power loss).

1. System one-line diagram
2. System three-line diagram
3. Protection and control analysis
4. Power Flow Analysis (ETAP)

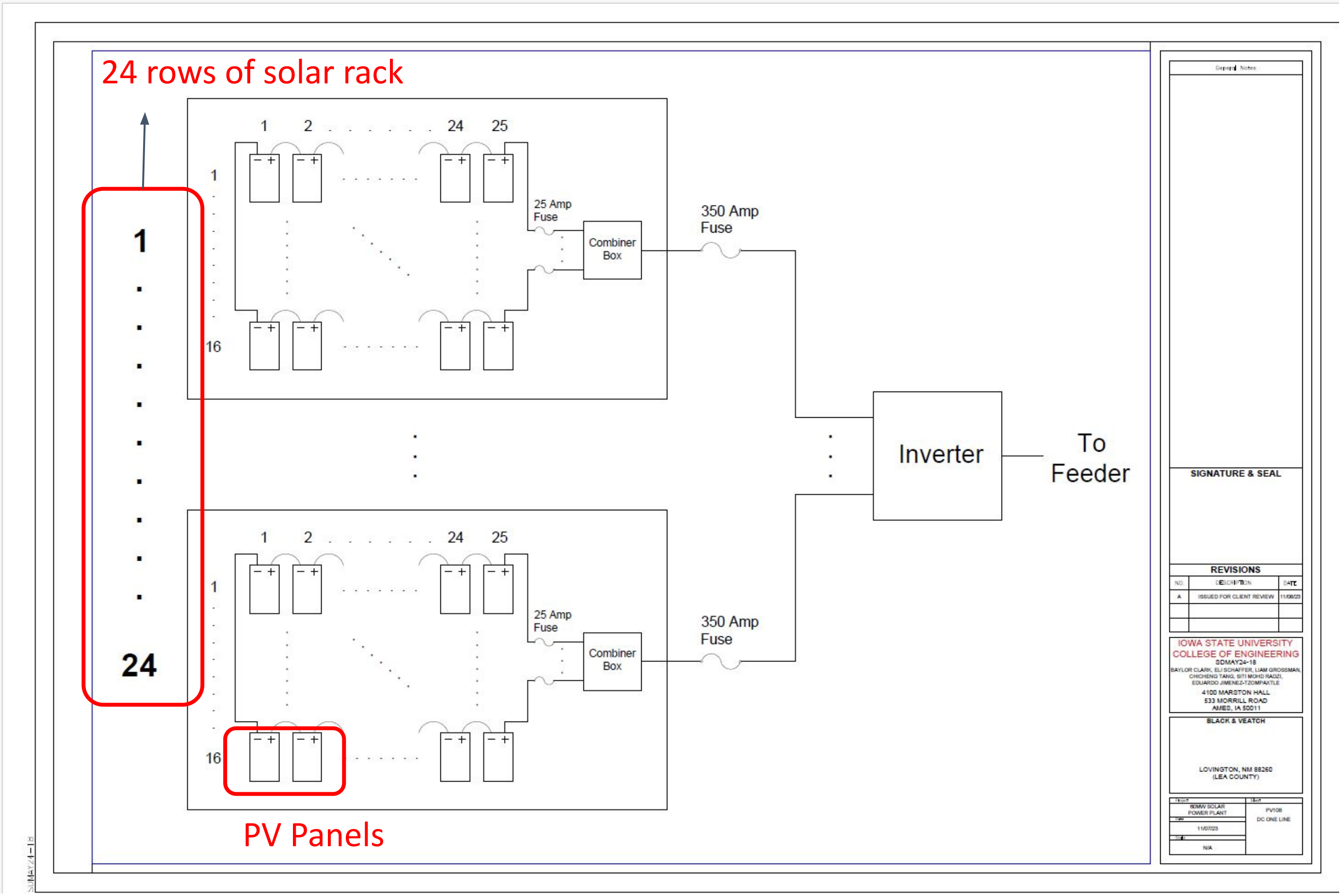
The grid delivers to the high electricity demand;

Residential area
Industrial area
Public institutions
Commercial

Design Standards & Practice - Solar Farm

Code	*Standards Description*
NEC690.8(B)	Overcurrent ratings shall not be less than 125% of the max current calculated
NEC690.8(A)	The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by correction multiplier, 125 percent.
NEC690.9	PV system dc circuit and inverter output conductors and equipment must be protected against overcurrent.
NEC 240.6	240.6(A) Fuses and Fixed-Trip Circuit Breakers: The standard ampere ratings for fuses and inverse time circuit breakers shall be considered 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes.
NEC 210.19	Voltage drop would be 2% from DC, and 1% from AC side
NEC Table 8 Conductor Properties & NEC AWG Chart	Provides information on conductor properties, including ampacity, insulation types, and other specifications. NEC AWG Chart provides information on the ampacity of conductors based on their size (gauge) and the type of insulation which is crucial for ensuring that the conductors used in electrical installations can safely carry the expected current without overheating.
Lovington & Lea County Ordinance	The fence, wall or barrier required by [this subsection] shall not be less than eight (8) feet in height with no openings, holes or gaps larger than four (4) inches measured in any direction. Gates and doors opening directly into the area enclosed by a fence, wall or barrier, as required by this section, shall be equipped with a lock to keep the doors or gates securely closed and locked at all times. Tower sites located within industrial yard areas with existing secure fencing of the entire yard may construct secure fencing six (6) feet in height.

Overview of Solar Power Plant - 60MW



1 array of solar panels

In a 60 MW solar farm, the solar panels connected in series for a string, to the total voltage of the string. Then, they are connected parallel into racks connected to the combiner box. The combiner box combines the power to the inverter, inverted into AC current. The inverter includes skids, would step-up the voltage to 34.5kV, before carried to the feeder to the substation.

PV Panels

- 550 W
- 50.2 Voc
- 13.89 Isc

Combiner Boxes

- Supports 1500 VDC
- 16 Inputs
- 1 Output

Inverters

- 1500 VDC Inputs
- Converts DC to AC
- Transformer steps up voltage

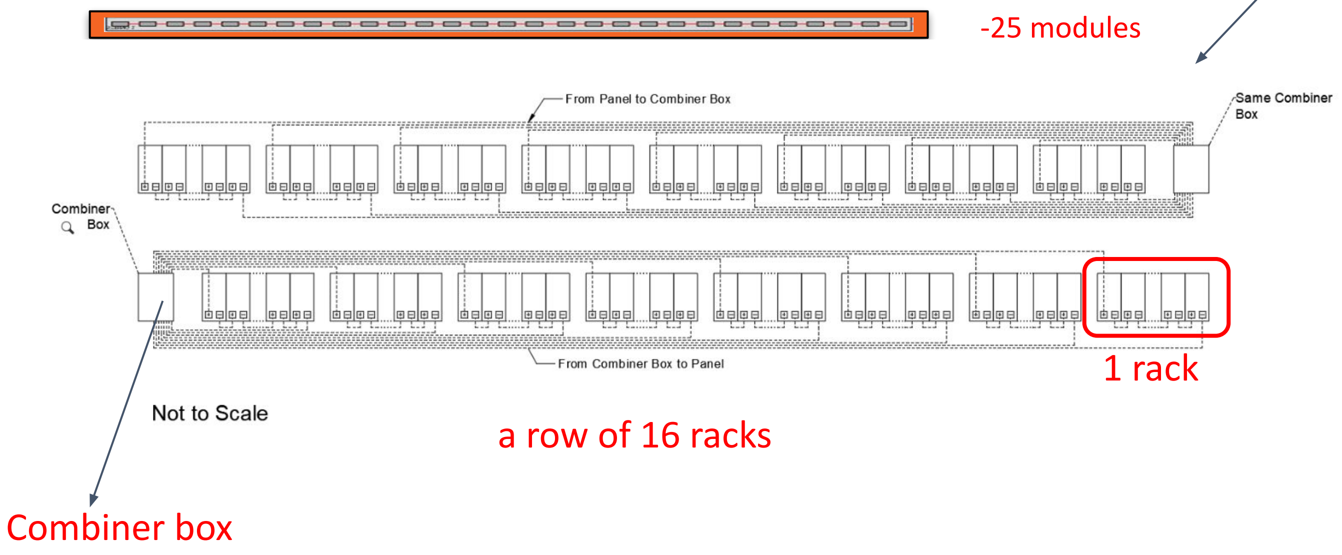
Array Parameter Tools

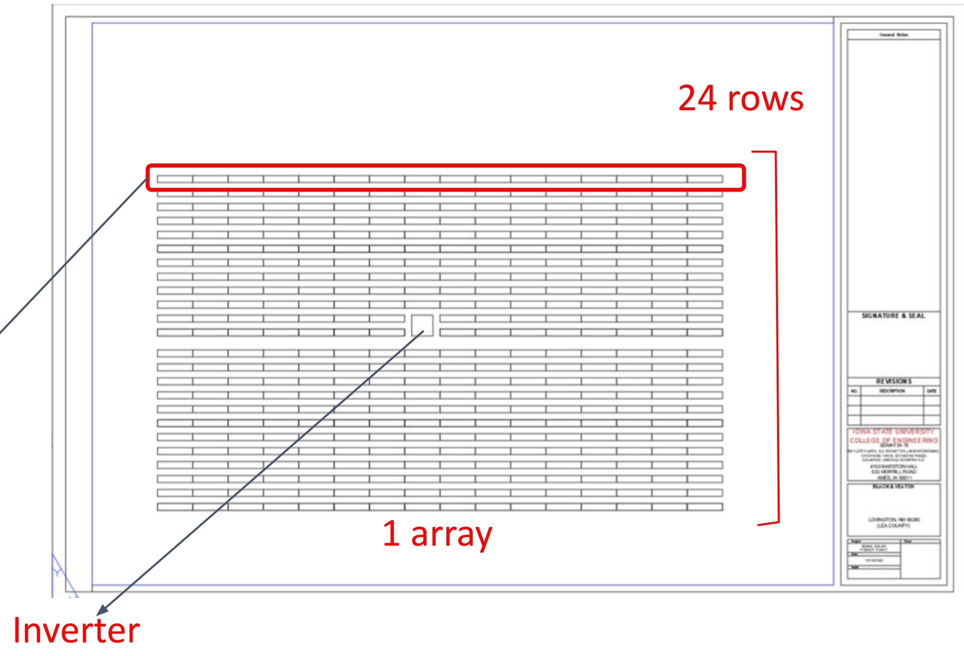
		String Size				Electrical Rack Size				CB capacity				Array Design			Array Size		
					Designer Choice		portrait or Landscape												
	Location Dependent	Min Temp	-40	C	Datasheet	Module width	3.72	ft	Datasheet (STC)	mod/string Isc	13.89	A	Designer Choice	Racks per row	16	Designer Choice	tilt	35	
					Datasheet	module height	7.474	ft	NEC secti	multiplier	1.25								
	Datasheet (STC)	Voc	50.2	V						nom Isc	17.3625		Designer Choice	rows per Array	24		table height proj	6.122342	ft
	Datasheet (STC)	Ref temp	25	C	Designer Choice	Rack width	25	modules	Irr.	multiplier	1.25								
					Designer Choice	Rack height	1	modules		max Isc	21.70312	A	Designer Choice	Racks removed	2	Designer Choice	row space	10	ft
	Datasheet	Temp Coeff of Voc	-0.0029	/C		Modules per rack													
		Temp delta	-65			Rack width	93	ft	Choice:	allowed current	350	A		Total Racks/Array	382		pitch	16.12234	ft
		temp correction	1.19			Rack height	7.474	ft	200,	is this disconnect A?							Space for Inverter Maintenance	35	ft
		V0c corrected	59.6627						400A	strings per CB	16.12670			Total modules	9550		Array height	386.9362	ft
									etc.	Round down:	16								
Confirm possible with Panel type chosen		string voltage	1500	V						racks per CB	16		Datasheet (STC)	module capacity	550	W	Array width	1488	ft
		String size	25.14133														Ground Coverage Ratio	0.463580	
	Designer Choice: 600, 1000, 1500, 2000V	string size	25											dc capacity	5252.5	kW			
		Actual String Voltage	1491.6																
													Designer Choice	inverter capacity	4000	kW			
															4	MVA			
													: Industry standard 1.3	ILR	1.313125				
		Input Information =																	

Liam Gossman

System Design - Solar Layout

Based on Array Tool calculations





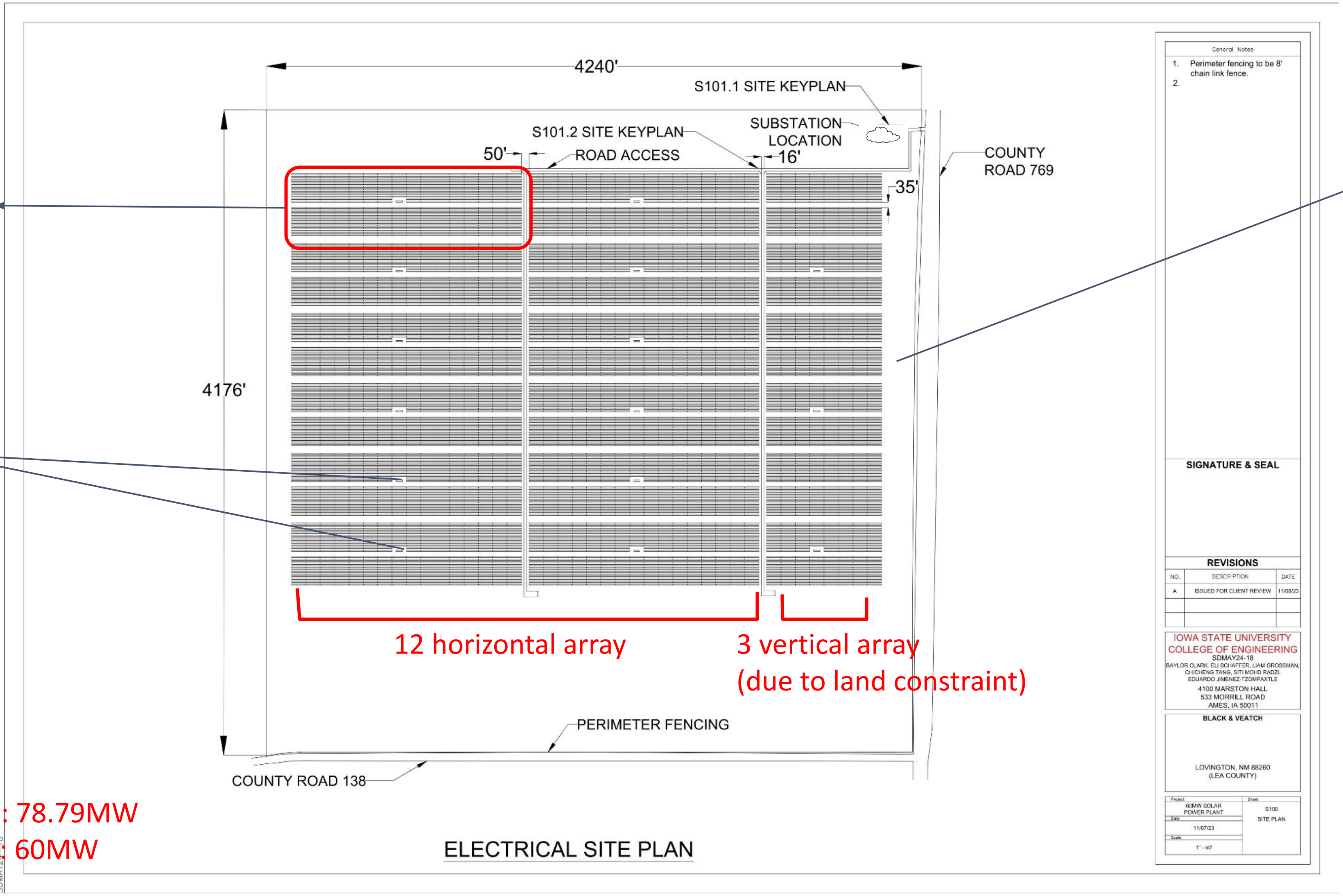
1 array layout:

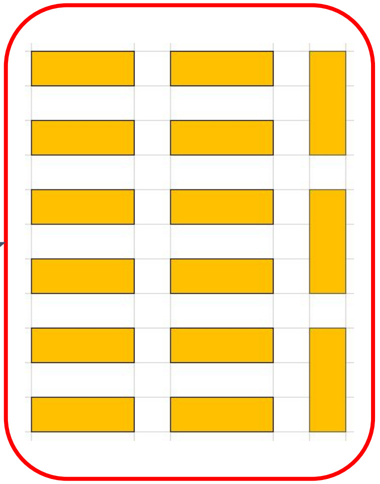
a. One string of 25 series module per rack
b. 16 racks in 1 row (16-input combiner box)
c. 24 rows of racks (24 combiner box)
d. 1 AC inverter

Conceptual Final Design Diagram

1 horizontal array

Inverter



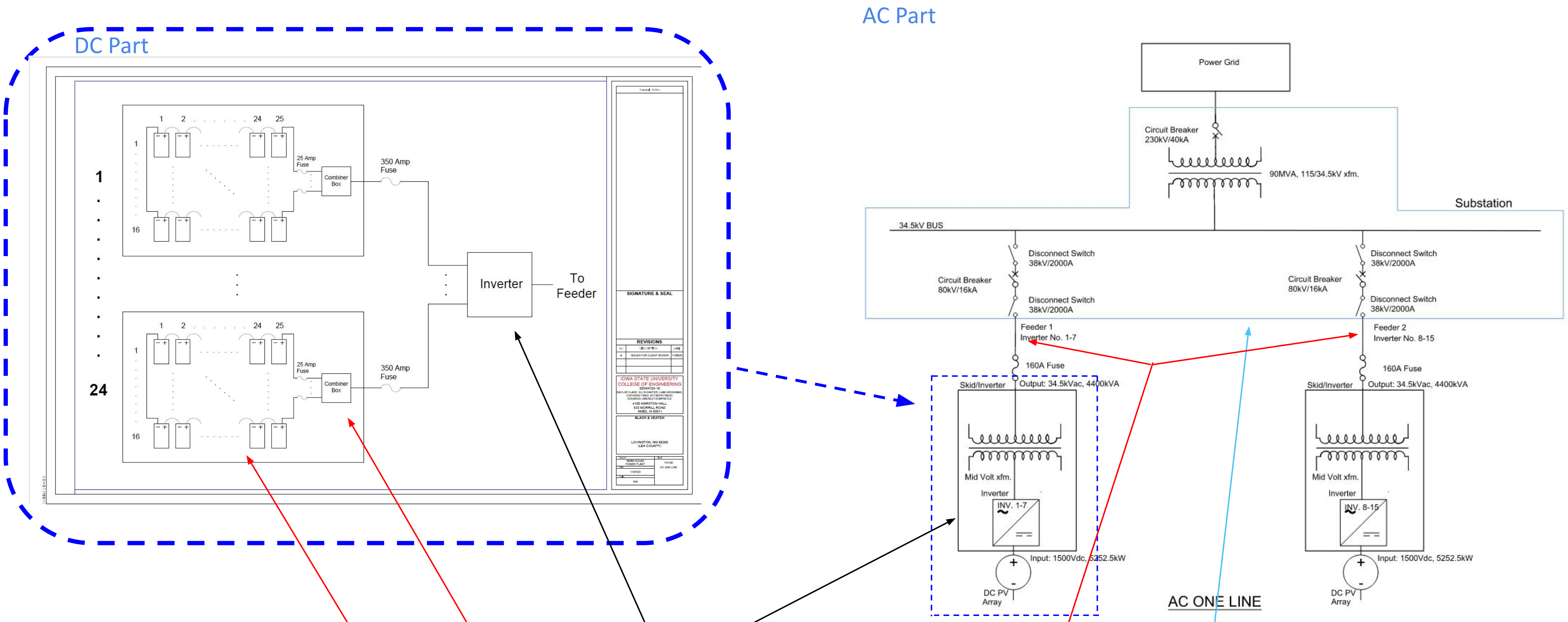


Preview

Estimated DC Power Output: 78.79MW
Estimated AC Power Output: 60MW

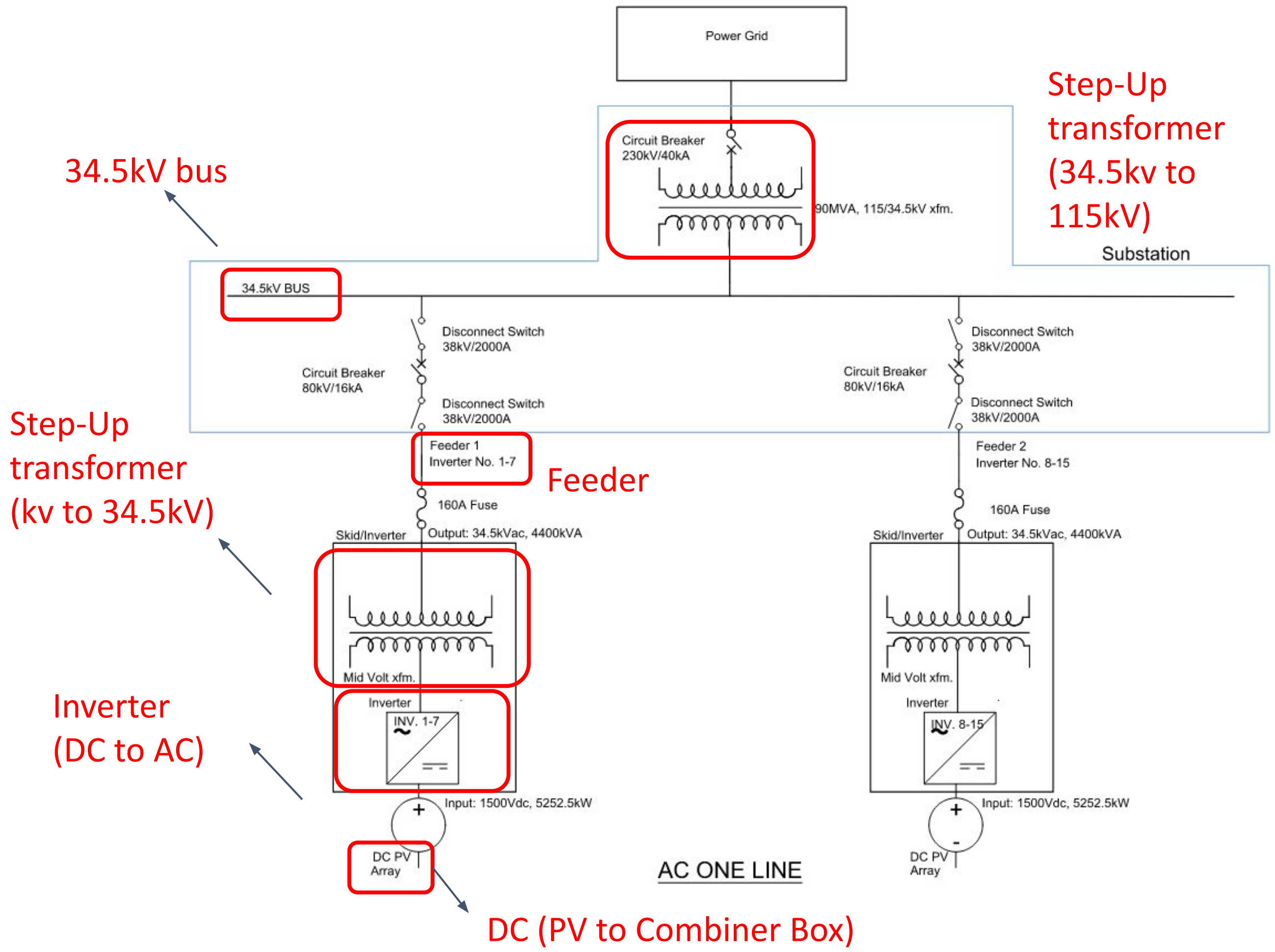
15 array
15 inverter
406 acres land

Overall Conceptual/Visual Sketch



Solar panel -> Combiner Box -> Inverter skids (34.5kV) ->Feeder (34.5kV) -> Substation (115kV) -> Grid
(DC convert to AC)

Overview of Substation- 115/34.5kV



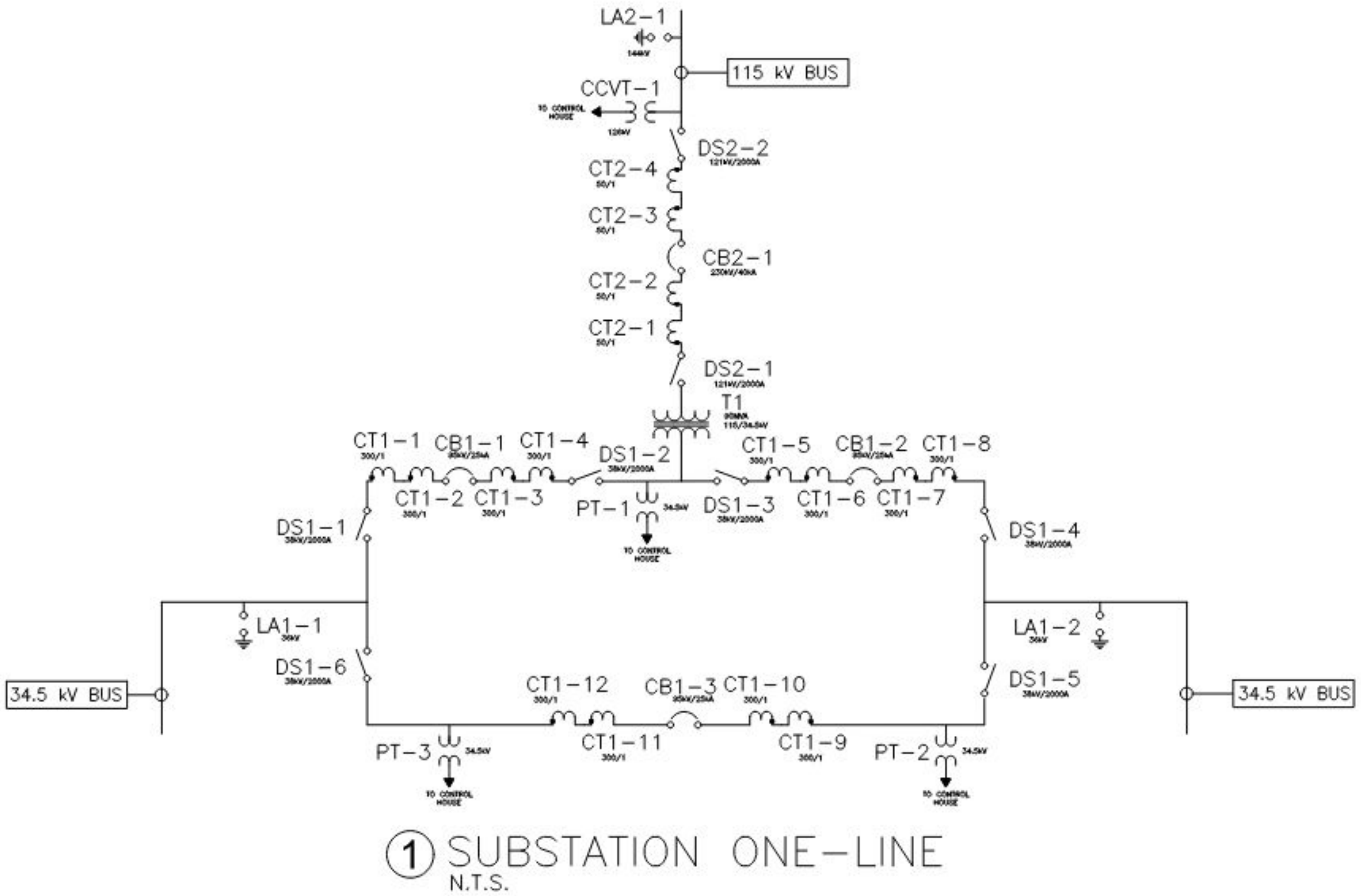
The electricity travels through transmission lines to a substation, where another step-up transformer boosts the voltage further to 115 kV. This elevated voltage is suitable for seamless integration into the broader electrical grid. The electricity is fed into the grid, facilitating its distribution to various consumers, including homes and businesses.

The circuit diagram to the left shows 115/34.5kV system substation.

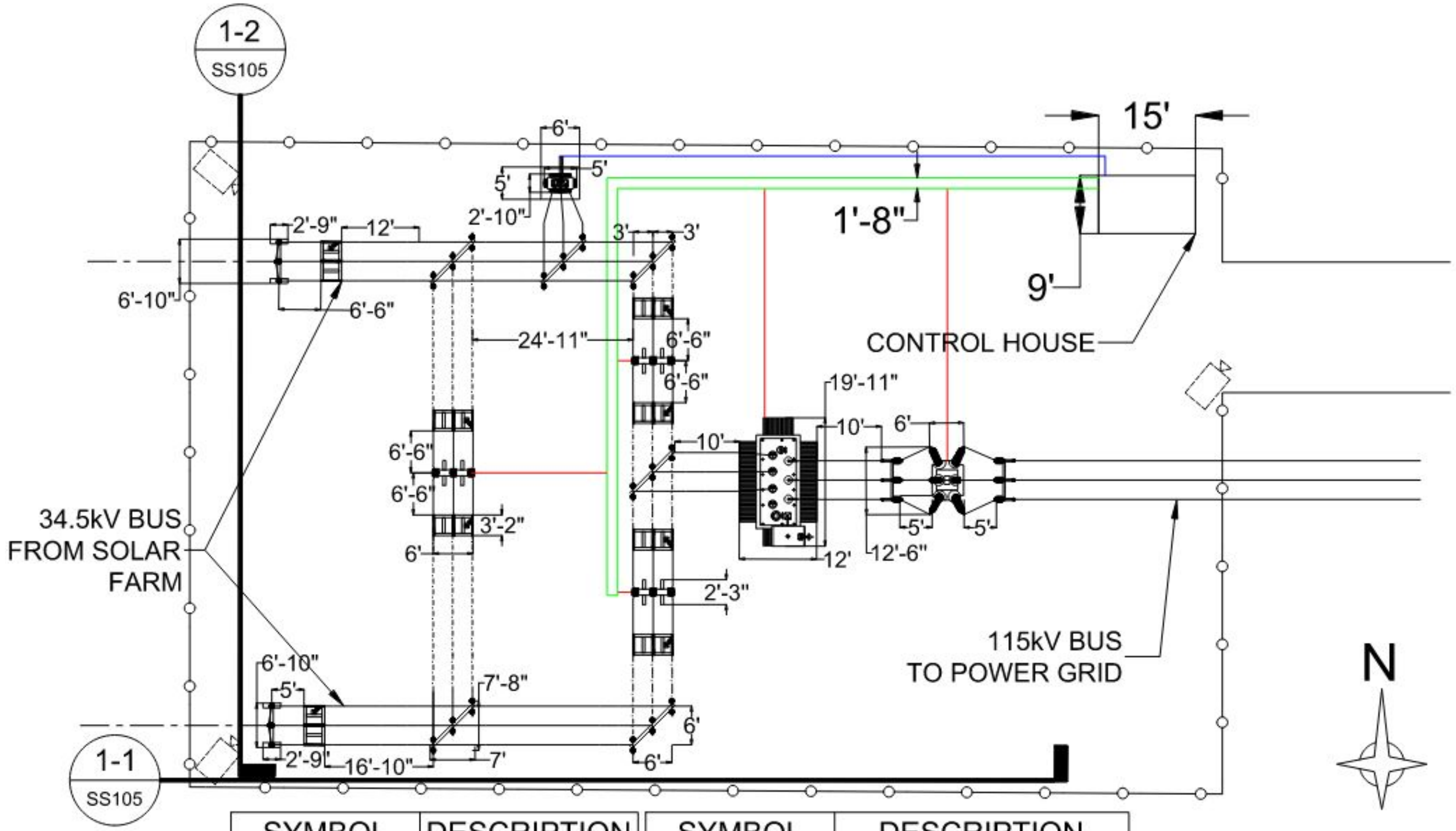
Design Standards & Practice - Substation

Code	***Standards Description***
IEEE 80-2013	IEEE Guide for Safety in AC substation grounding
IEEE 998-2012	IEEE Guide for Direct Lightning Stroke Shielding of Substations
IEEE 485 -2020	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
IEEE 605- 2008	IEEE Guide for Bus Design in Air Insulated Substations.
IEEE 1184-2006	IEEE Guide for Batteries for Uninterruptible Power Supply Systems

Conceptual Final Substation Design



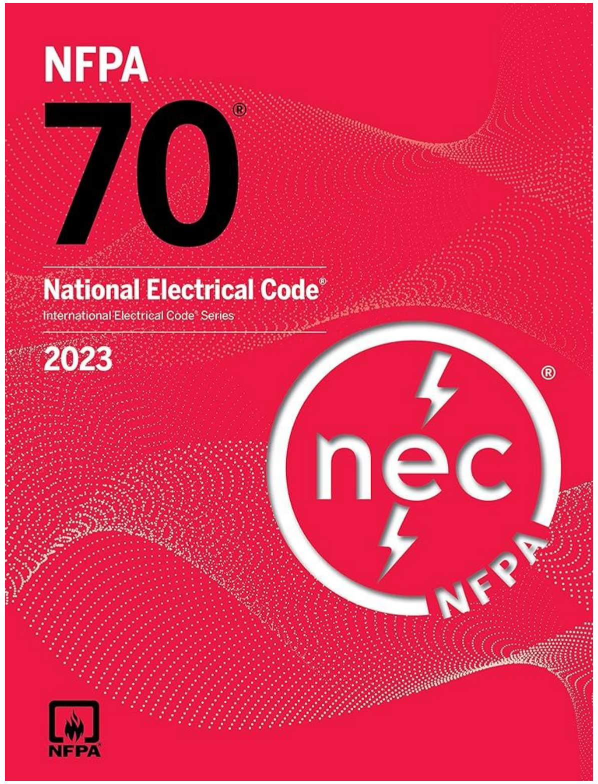
System Design - Substation Layout



SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
(red line)	CONDUIT	(dash-dot line)	UNDERGROUND
(blue line)	CH FEEDER	(dashed line)	RIGID BUS
(green box)	TRENCH	(solid line)	STRAIN BUS

Challenges & Risks

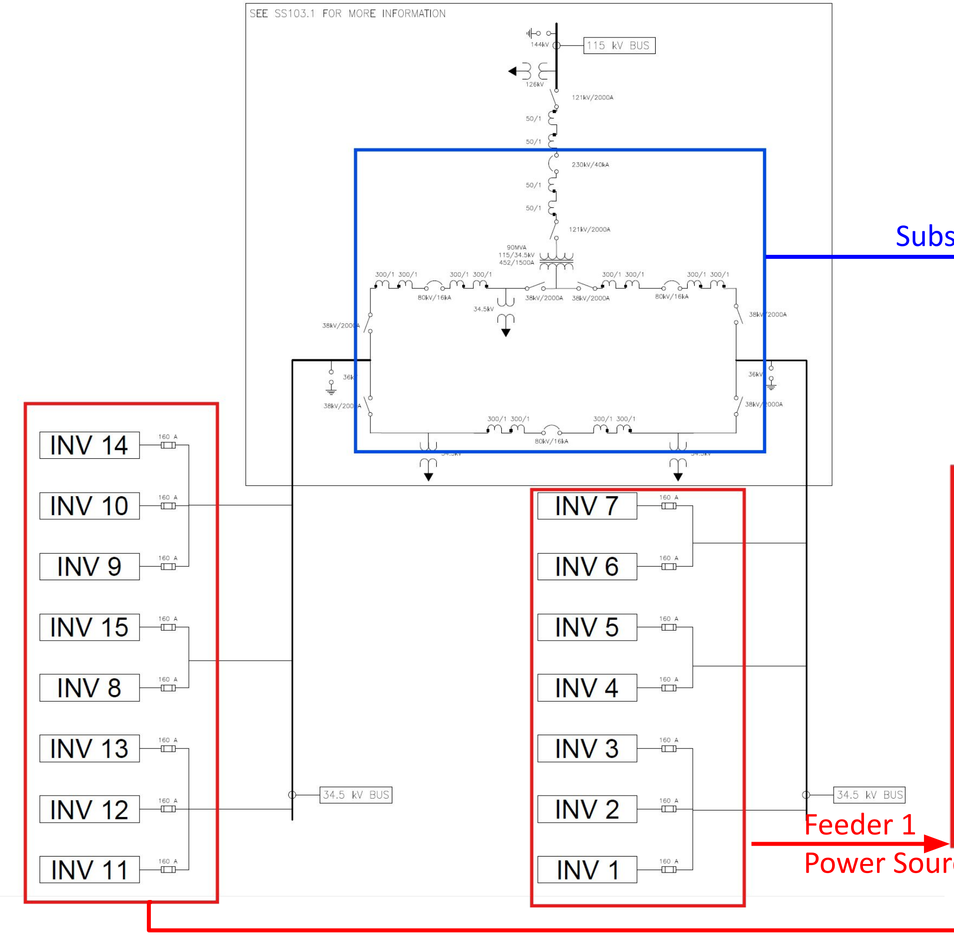
- Follow electrical codes/standards
  - IEEE/NEC and B&V requirements
- Accurate electrical calculations for design safety
  - Safety/Grounding
  - Battery Backup
  - Conductor spacing and sizing
- Project financial risks
  - Project should be financially viable
  - Need to keep cost in mind
- The team must also practice time management and good communication



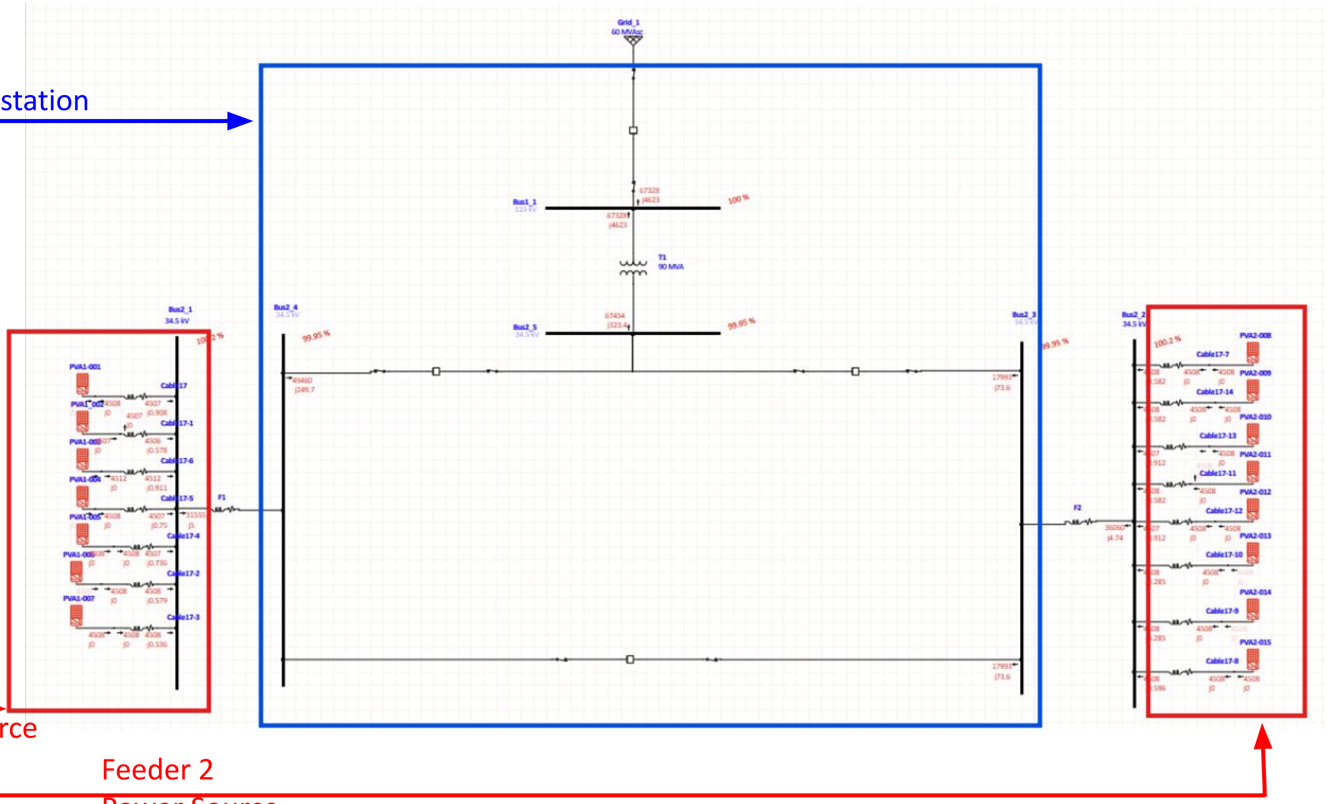
Testing: Modeling

- **Power Flow Result**
  - Each PV array can produce 4.5 MW Power 12.5% more.
  - Total Power produce is 67.3 MW.

AutoCAD Design



ETAP Simulation Model



Conclusions

Group Member Contributions

Bell: Calculations (Both Substation and Solar Farm), Cost Analysis, Site Location Research

Eduardo: AutoCAD drawings, Combiner Box Research, Bus Verification

Chicheng: ETAP Design,

Eli: AutoCAD Drawings, Poster, Website Design

Liam: Calculations, Client and Faculty communication, Component Selection

Baylor: Bi-weekly reports, ETAP

All Members: Weekly Meetings, Leadership Roles

Q&A Session