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

Team sdmay19-26

Nur Shuazlan, Tam Nguyen, Ahmed Sobi, Katayi Katanga, Yao Jiang Cheah, Chufu Zhou

Advisor: Dr. Ajjarapu
Client: Black & Veatch

http://sdmay19-26.sd.ece.iastate.edu/

Black & Veatch Information

- A global engineering, construction and consulting company which specializes in infrastructure development for power, oil and gas, water, telecommunications, government, mining, and banking and finance markets.
- The largest majority employee-owned company in the U.S, and is ranked by Forbes as one of the largest privately owned companies.
- A large amount of its revenues comes from power.

Project Plan

Problem Statement

- General Problem:
  - An increasing need for a growth in the use of renewable energy to reduce enhanced greenhouse effect
  - Prevent high power loss for long distance transmission
  - The Renewable Energy Standards (RES) allow companies to push more toward renewable energy
- Solution:
  - Design a 60 MW solar plant and a 115kV/34.5kV substation

Operating Environment

- Substation and plant must be able to withstand any extreme weather conditions they will be subjected to in Estancia, New Mexico, and must be able to do so for a long time.
    - The design is equipped with all of the necessary protection devices in order to withstand any abnormal voltages that are expected.

Possible Risks

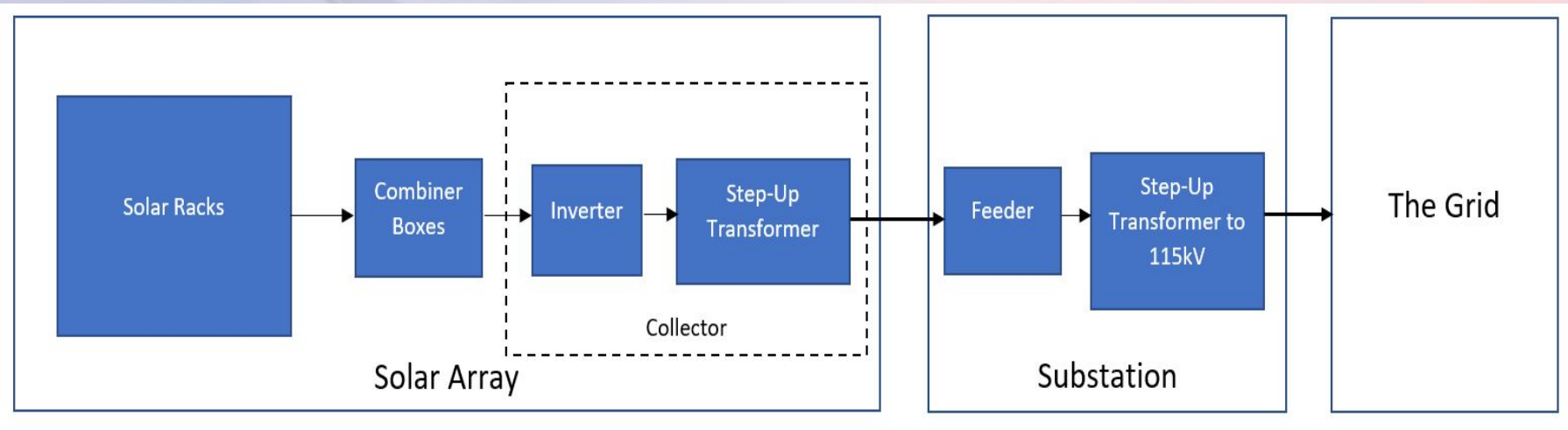
- Defect on components
- Electric shock
  - Electric shock upon substation installation
  - Our design does not include substation grounding

Market and Literature Survey of Similar Products

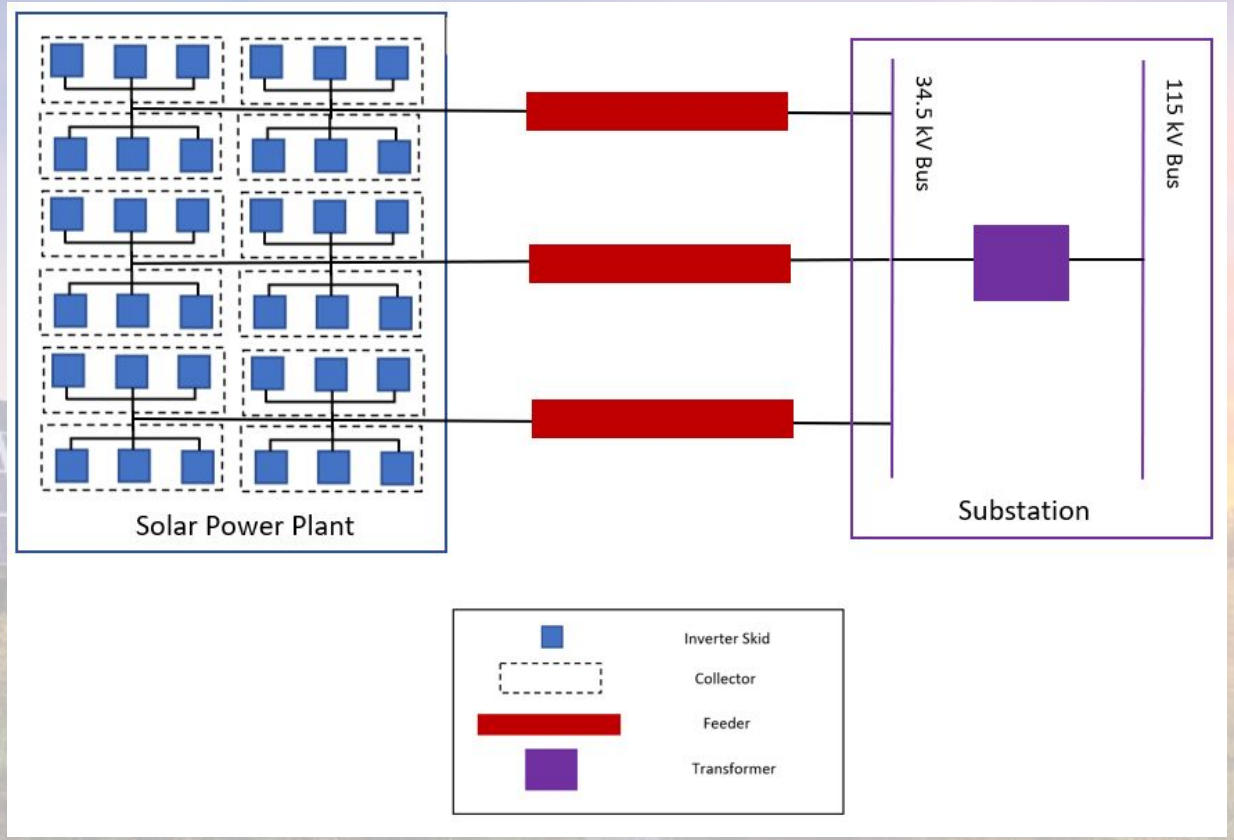
MISO North Star Solar Project 100 MW capacity:

- Location in Saint Paul, MN
- 100 MW of solar PV capacity(440,000 solar panels)
- Approximately 800 acres of agricultural land
- Single axis tracking technology to maximize production
- Grid connection at the Chisago County substation 115kV

System Block Diagram



Conceptual Sketch



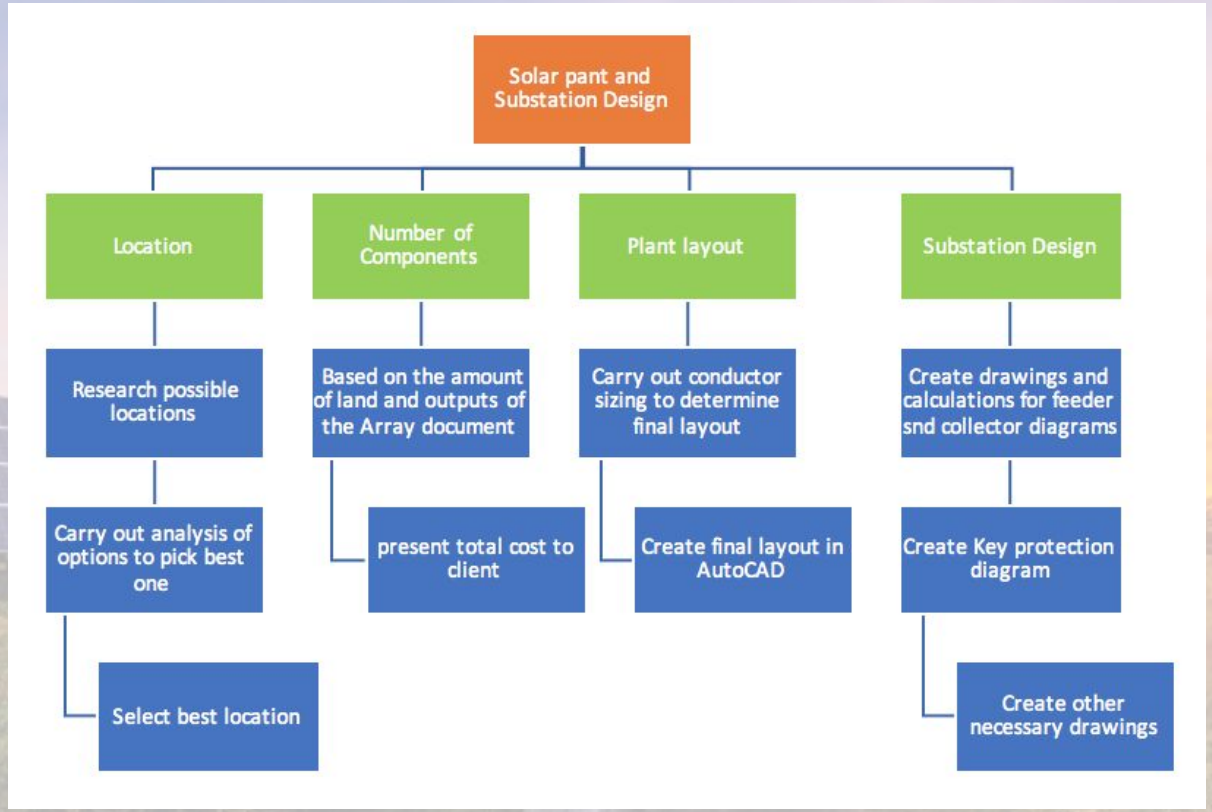
Requirements (Functional/Non-Functional)

- Location of solar plant and substation
- Meet specifications set by the client
  - DC Voltage: 1000 V
  - Inverter: Eaton 1666kW
  - Panel: Hanwha 325W
  - ILR: 1.30
  - Fixed rack system
- Solar power plant array design
- Voltage drop calculations
- Substation diagrams
  - Relays and controls
  - 3 phase drawings
  - Communications

Deliverables

- Man Hour Budget
- Solar plant design
  - Location
  - Number of components and total cost
  - Plant layout
  - Wiring and conductor sizing
- Substation Design
  - Feeder and collector diagrams
  - Key protection Diagram
  - AC drawings
  - Relay diagrams
  - Communication diagrams

Project Plan: Workflow Diagram



Resource Requirements

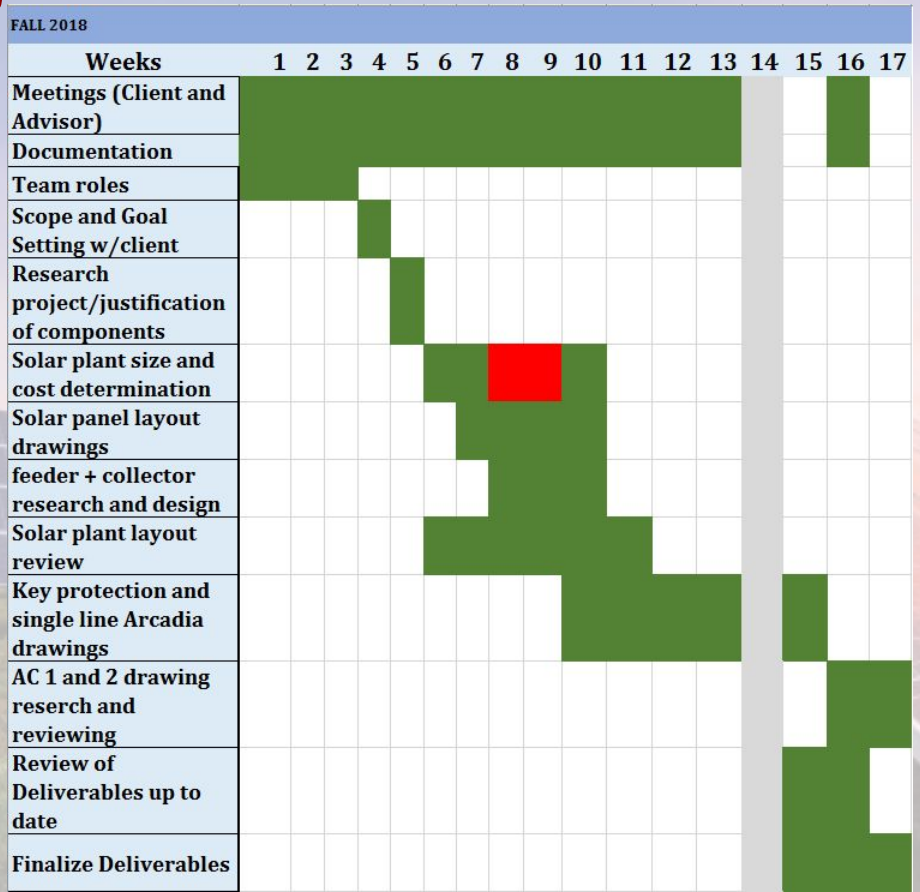
Solar Power Plant

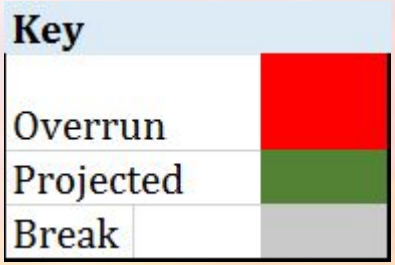
- Equipment
  - 238,032 solar panels
  - 792 combiner boxes
  - 36 inverters
  - Conductors/Cables
- 244 acres of land
  - We found a 560-acre land for sale for $195,000

Substation

- Equipment
  - 12 collectors
  - 3 feeders
  - Surge arrestors
  - Transformers
  - Conductors/cable

Project Schedule For Fall 2018





System Design

System Requirement

- Compliance with the following NEC codes:

NEC Code	Description	How to Check	Design Steps
Article 300.50 and Table 300.50	Discusses acceptable depth to bury conductors	Using this information during to plan wiring	Design a plant layout that applies this information
Article 310.10	Discusses the uses of conductors under different conditions	Ensure that we select the right conductors for our conditions	Choose wires that satisfy our conditions and implement them into the design
Article 310.15 and table 310.15	Defines ampacities for different conductors	Using this information in the voltage drop calculations	Applying values from calculations into conductor sizing
Section 310.120	Explains necessary markings for different conductors	Using this information to choose the right type of conductors	Choose wires with the right markings

Functional Decomposition

Part	Input	Function	Output
Solar Modules	Sunlight	Convert sunlight into DC power	DC power
Combiner Boxes	Current from strings	Combine the currents before sending it to inverter	Combined currents
Inverters	DC Voltage from array	Convert DC voltage to AC voltage	AC Voltage
Transformer	Voltage from inverter	Step up voltage	Voltage proportional to input voltage that goes to feeder
Relays	Current in line	Measure the current in a line	Current in line
Current Transformer	Currents from a line	Measure alternating current	Current proportional to input current
Surge Arrest	Voltage in line	Protect equipment from overvoltage transients	Voltage in the line

System Analysis

- Array parameter tool
  - Determine number of components and verify the voltage and power of the system
- Voltage Drop Calculations
  - Carried out conductor sizing by analyzing the currents in the plant at different points.
- Correspondence with seasoned engineers (Client)

Detailed Design

Overview of Designs

Drawing List		
Drawing Number/Name	**Description**	**State**
sd-26-1-1 single array	Wiring diagram of a single array	Completed
sd-26-1-1 power plant	Wiring diagram of the entire solar plant	Completed
sd-26-1-2 collector	Collector diagram	Completed
sd-26-1-2 feeder	Feeder diagram	Completed
sd-26-2-2 key prot	Substation key protection diagram	Completed
sd-26-2-2 ac1	Three-line diagram	In Progress
sd-26-2-2 ac2	Three-line diagram	In Progress
sd-26-2-2 it rel	Installation relay diagram	Not Started
sd-26-2-2 pri rel	Primary relay diagram	Not Started
sd-26-2-2 ethernet port	Ethernet port diagram	Not Started
sd-26-2-2 bu relay	Back-up protection diagram	Not Started

Location Decision

0 Peacock Rd

Estancia, NM 87016

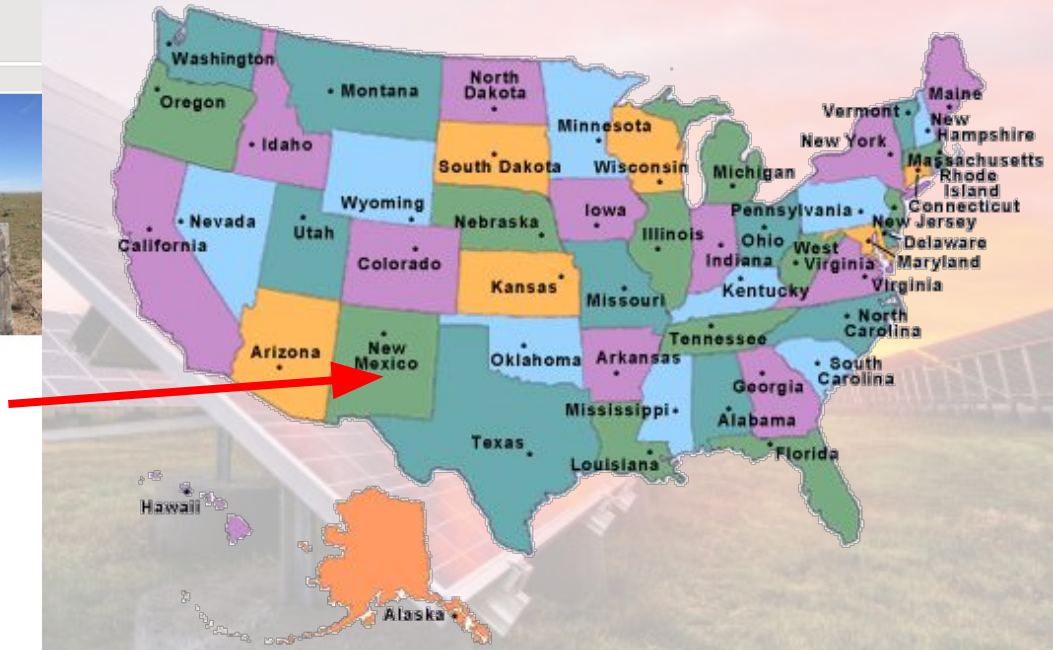
LOT/LAND

$195,000

Price cut: -$15,000 (8/4)

560 acres

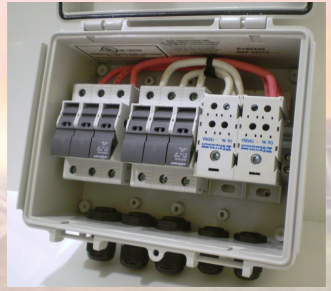
Central New Mexico grazing land located in the Estancia Basin near Estancia. Approximately 60 miles South of Santa Fe, 45 Miles Southeast of Albuquerque. Fully fenced with panoramic views of the Manzano Mountains. The Survey was completed on 10/9/2017.



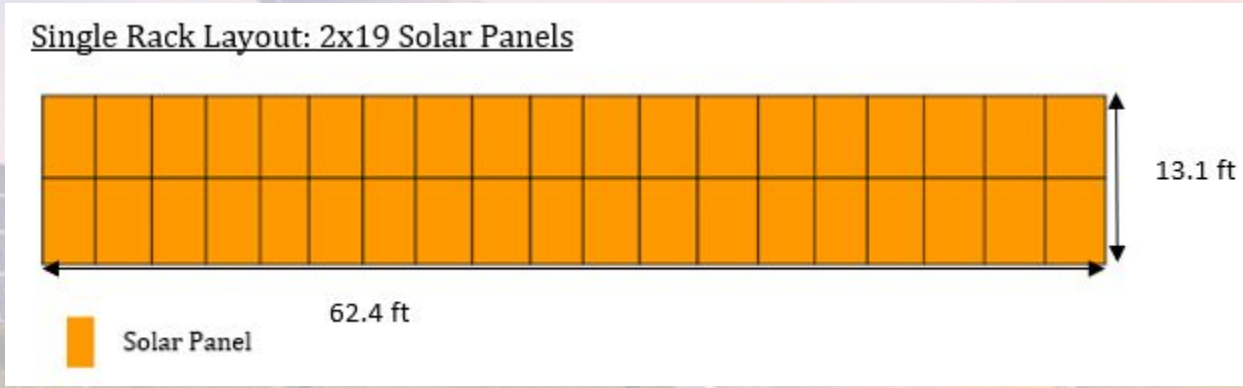
Solar Power Plant

- Solar modules
- Combiner boxes
- Inverters

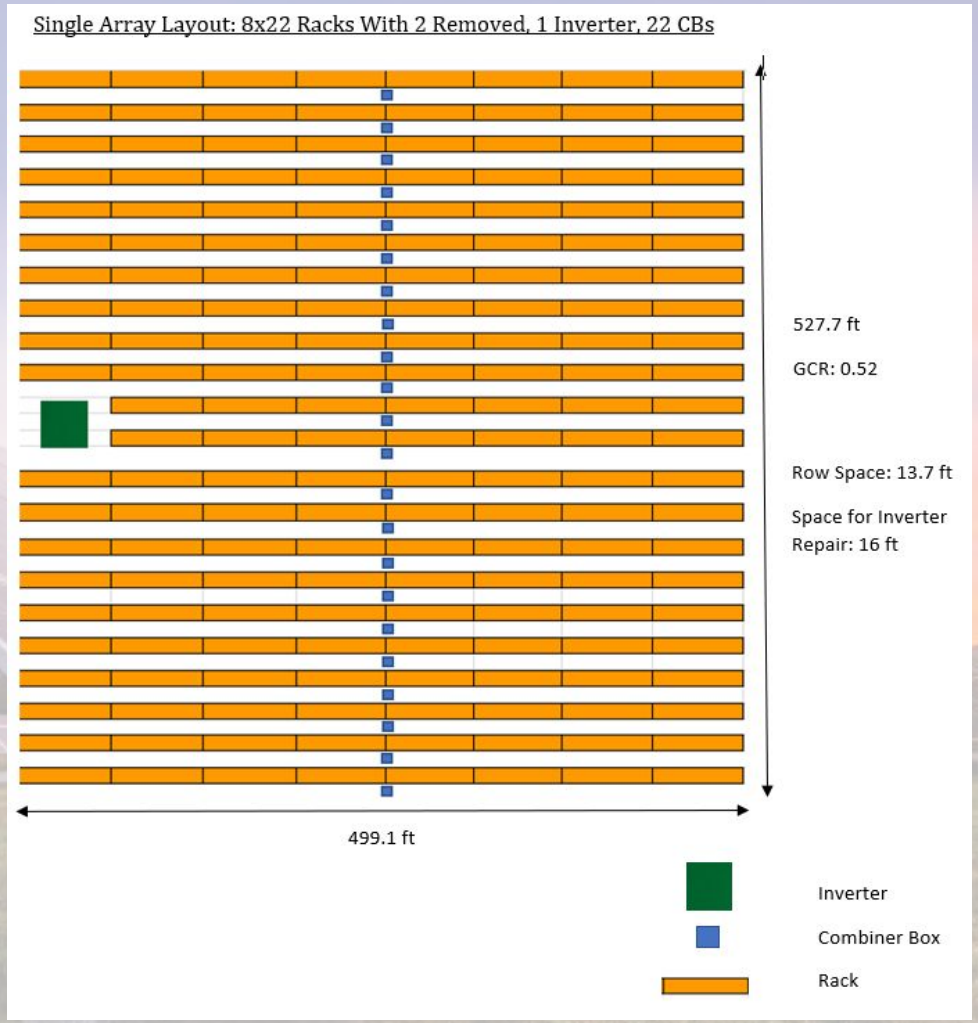
The solar plant generates, collects energy, and sends it to the substation.



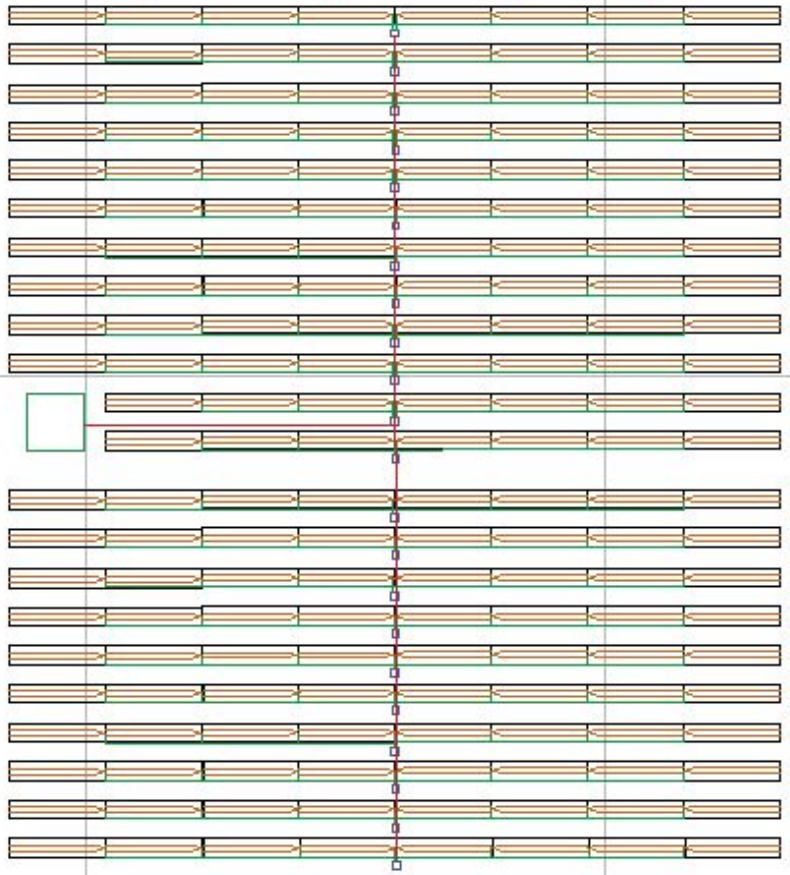
Single Rack Layout



Single Array Layout

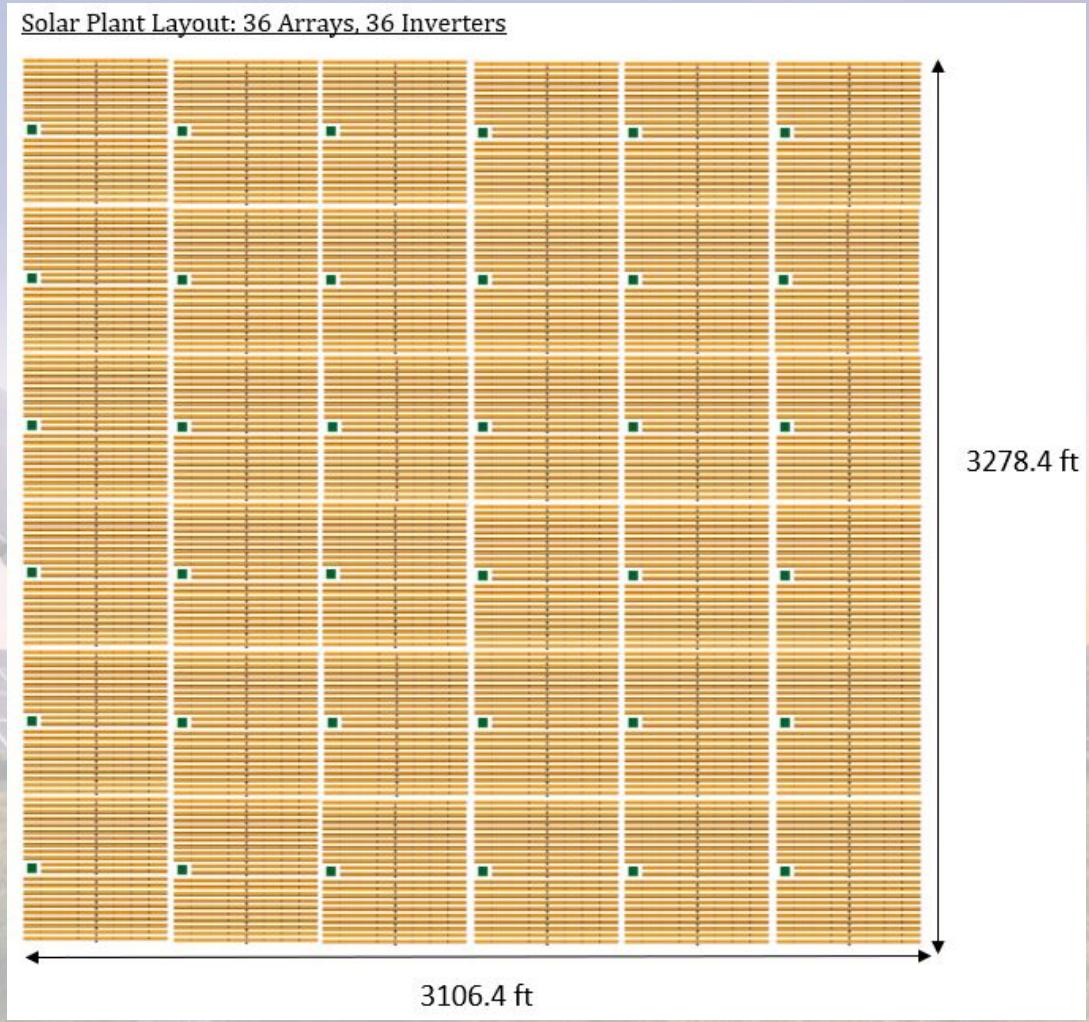


Single Array Wiring Diagram



Legend	
	Combiner Box
	Solar Rack
	Inverter
	Jumper Cable
	Rack Harness
	Feeder Cable

Solar Plant Layout



Solar Power Plant Wiring Diagram

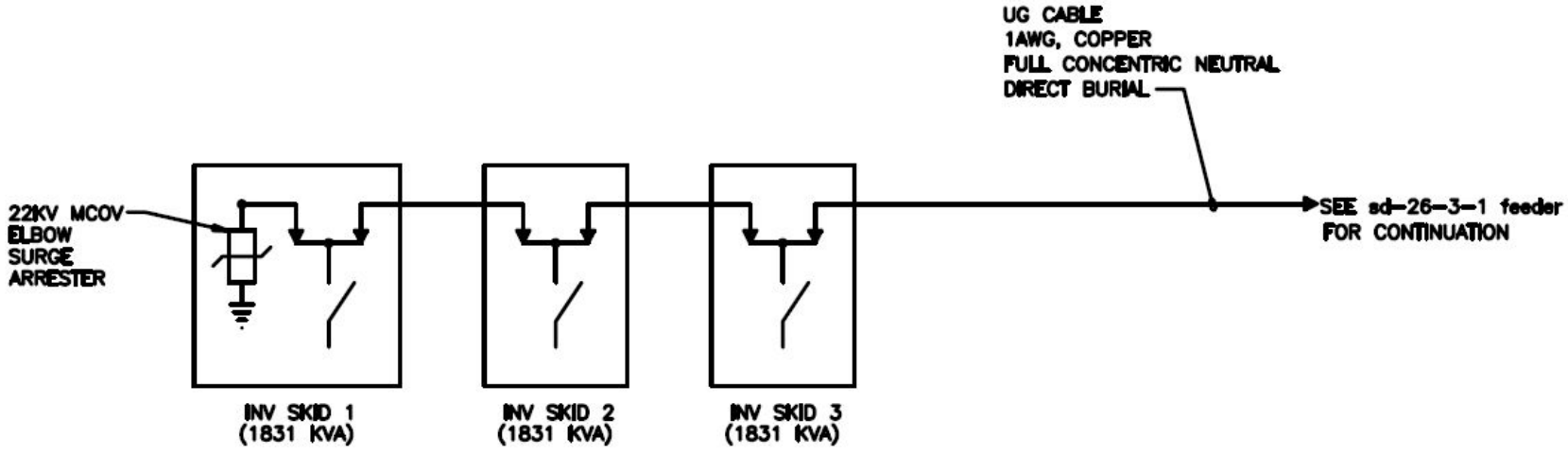
Legend

- Combiner Box
- Solar Rack
- Inverter
- Jumper Cable
- Rack Harness
- Feeder Cable

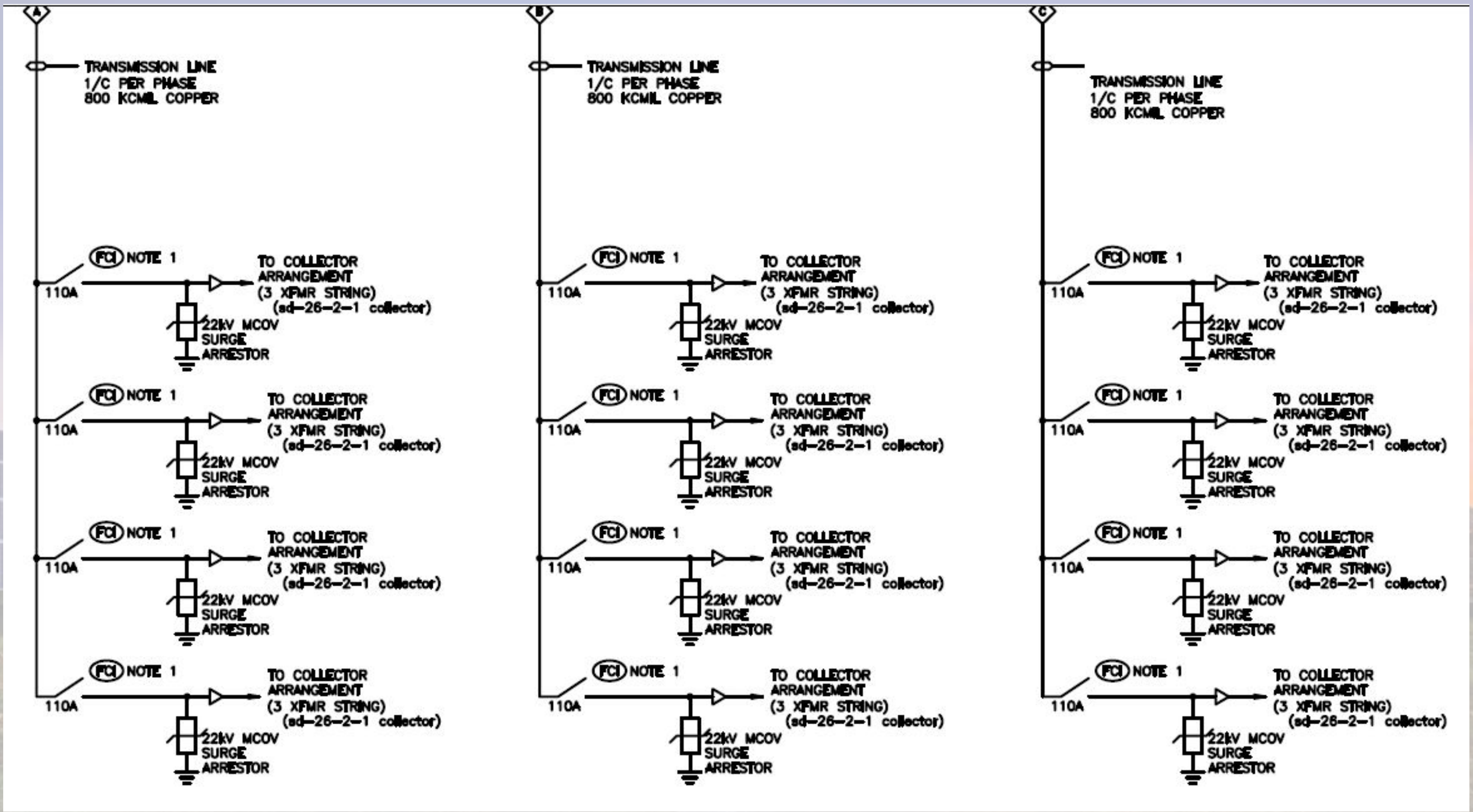
Substation

- The one-line diagram
- The key protection diagram
- The three-line diagram
- Protection and controls schematics

The substation steps up the voltage to reduce power loss during transmission and transfers the power to the main grid.



COLLECTOR ARRANGEMENT
3 XFMR (TYP)


A
TRANSMISSION LINE
1/C PER PHASE
800 KCMIL COPPER
FCI NOTE 1
110A
TO COLLECTOR
ARRANGEMENT
(3 XFMR STRING)
(sd-26-2-1 collector)
22kV MCOV
SURGE
ARRESTOR
FCI NOTE 1
110A
TO COLLECTOR
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ARRESTOR
B
TRANSMISSION LINE
1/C PER PHASE
800 KCMIL COPPER
FCI NOTE 1
110A
TO COLLECTOR
ARRANGEMENT
(3 XFMR STRING)
(sd-26-2-1 collector)
22kV MCOV
SURGE
ARRESTOR
FCI NOTE 1
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1/C PER PHASE
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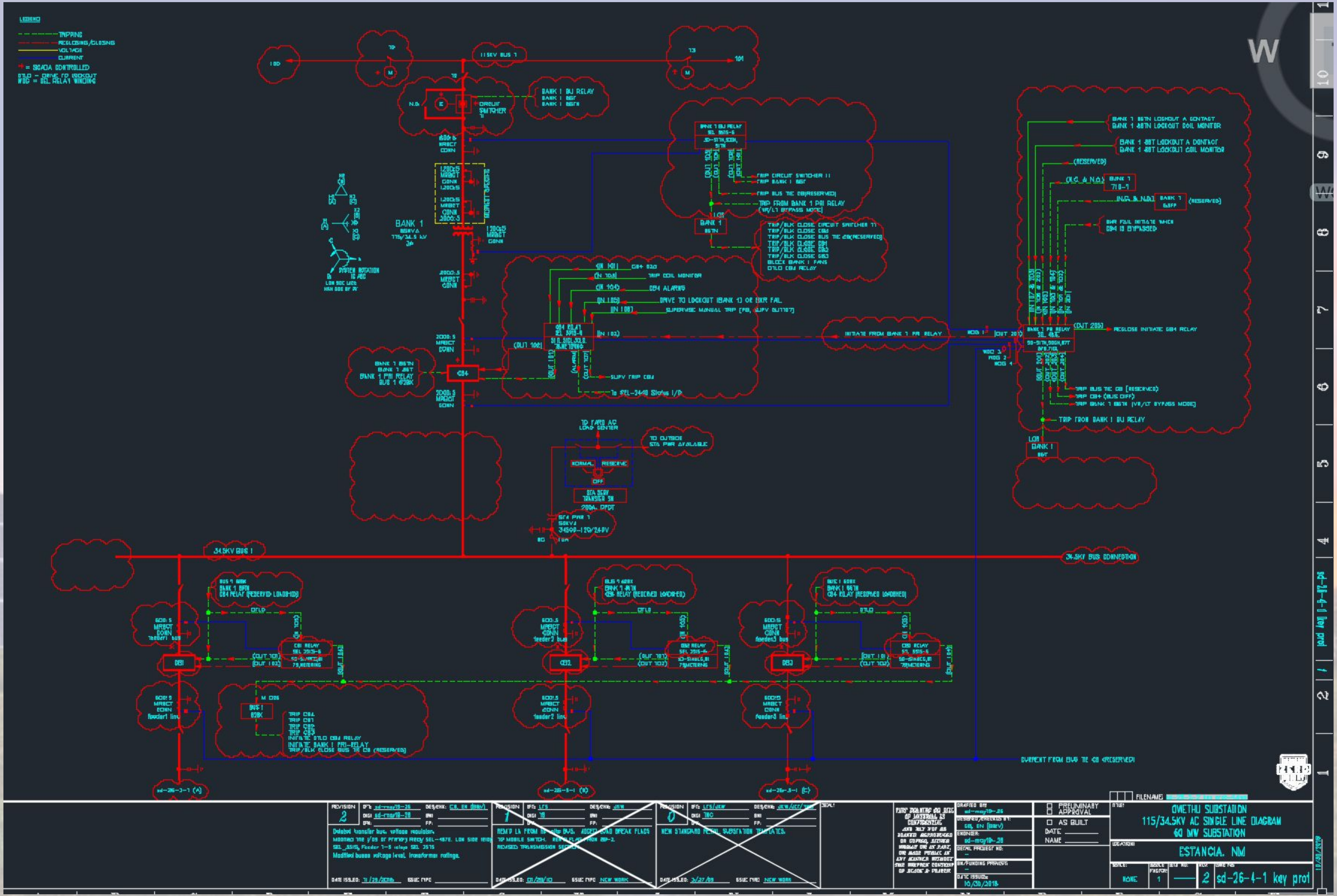

OWETHU SUBSTATION
115/34.5KV AC SINGLE LINE DIAGRAM
60 MW SUBSTATION
ESTANCIA, NM
NONE
1
2
sd-26-4-1 key prot
10/30/2019
34.5KV BUS 1
115KV BUS 1
BANK 1
34.5KV BUS CONNECTION
PRELIMINARY APPROVAL
AS BUILT
FILENAME:

Testing Evaluation Plan

Array parameter tool:

- Spreadsheet given by the client to determine the specification of the project.
- Determine the number of (solar panels, combiner boxes, inverters)
- We also use it to determine the ILR, the size of the plant, and the cost of the project.

Compliance with NEC codes:

- Checking design against the codes specified
- Calculating the conductor sizes and the voltage drop according the code.

Correspondence with Client :

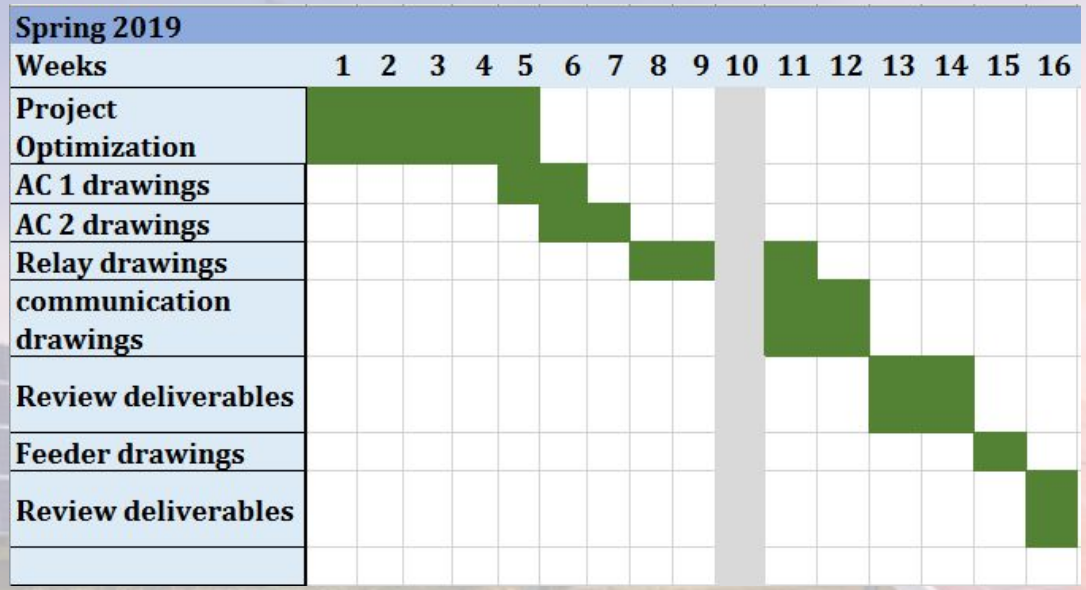
- Due to the nature of the project we used the client as a verification tool to monitor our progress and accomplishment.

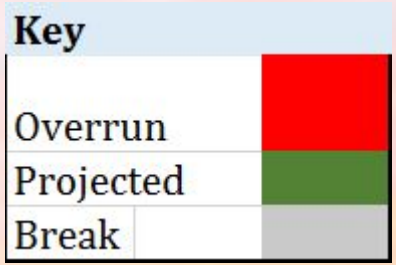
Conclusion

Current project status with respect to milestones

- Completed all the deliverables for this semester:
  - Substation one-line drawing and solar plant array layout/drawing
  - Engineering man-hour budget, project plan, design document, and team website. http://sdmay19-26.sd.ece.iastate.edu/

Plans For Next Semester





Thank You For Listening!

Any Questions?