115/34.5 kV Solar Power Plant & Substation Design Project

DESIGN DOCUMENT

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Executive Summary

Development Standards & Practices Used

We will use our knowledge in power systems and programs such as ETAP, Bluebeam, and AutoCAD to design a 115/34.5 kV substation and solar field. We will use IEEE, NEC, and some OSHA standards to ensure we construct a safe environment for everyone involved.

Summary of Requirements

List all requirements as bullet points in brief.

* Equipment sizing calculations (breakers, transformers, etc) – Excel files
* Solar layout drawings – Bluebeam/CAD/PDF editor
* Solar panel string sizing design – Excel files
* Electrical layout drawings (substation equipment) – Bluebeam/CAD/PDF editor
* Grounding analysis and ground-grid developed with IEEE-80 – Excel files
* Bus calculations for substation – Excel files
* Possibility of additional calculations (DC battery bank, lightning protection, etc.) – Excel files
* Creation of solar/substation design-optimizing tool – TBD
*Simulation of designed substation – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]
* Coordination Study / AC Arc Flash Study / Protection Element Analysis – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]
* Load Flow Scenario Wizard / Configuration Manager – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]

Applicable Courses from Iowa State University Curriculum

List all Iowa State University courses whose contents were applicable to your project.

EE322 Semiconductor Devices
EE303 Intro to Power Systems
EE455 Distribution Systems
EE456 Power Systems 1
EE457 Power Systems 2

New Skills/Knowledge acquired that was not taught in courses

List all new skills/knowledge that your team acquired that was not part of your Iowa State curriculum to complete this project.

AutoCAD – Computer-Aided-Design
ETAP – Electrical Transient Analysis Program
Solar and Substation Design

Table of Contents

List of figures/tables/symbols/definitions (This should be the similar to the project plan)

Definition

Term	Definition
ILR	Inverter load ratio, the ratio DC input capacity and the inverter AC output capacity, a higher DC input is required to overrun the inverter because the majority of operation the inverter is underrun.
Irradiance Correction Factor	A multiplier for the current output of a solar panel to compensate for current spikes due to high solar radiation.
Collector	The substation input from the solar array.
Xfmr or Xformer	Transformer abbreviation.
Feeder	Collector arrangement to 34.5 kV bus.
Array	A complete unit of solar panels and all associated components including inverters.
PV	Acronym for photovoltaic.
PV module/panel	Single solar module or panel unit. Module and panel are interchangeable terms.
STC	Standard temperature conditions, 1000 watts per meter squared irradiation & -25° C.
Inverter Skid	Base plate for inverter and step-up transformer in an array.
Jumper	Copper conductors connecting solar modules in series string.
String	A series combination of solar panel modules.

Rack	A solar string in parallel.
Combiner Box	Weatherproof enclosure for coupling DC conductors with serviceable disconnects, NEC690.16(B).
Azimuth	Angle between the north vector and the perpendicular projection of the star down onto the horizon.

1 Team

1.1 Team members

1.1.1 Baylor Clark

1.1.2 Eduardo Jimenez-Tzompaxtle

1.1.3 Eli Schaffer

1.1.4 Liam Gossman

1.1.5 Chicheng Tang

1.1.6 Siti Mohd Radzi

1.2 Required Skill Sets for Your Project

Technical Wise

CAD - Solar layout drawings
IEEE-80 - Grounding analysis and ground-grid calculations
Excel - Equipment sizing calculations, additional calculations (DC battery bank, lightning protection, etc), solar panel string sizing design. Grounding analysis and ground-grid calculations
ETAP/SKM/ASPEN- Solar Substation Simulation, Load flow scenario, Protection Element Analysis,
ETAP (Electric Transient Analysis Program) - Simulation software
Bluebeam - Electrical Layout drawings

1.3 Skill Sets covered by the Team

Everyone- Grounding and ground-grid circuit calculations/analysis

Baylor Clark: I have experience with project management and team communication through internships the past two summers. I also have experience working on projects with other group members from previous classes.

Elymus Schaffer: I bring my extrovert personality to help me invoke thought-provoking questions and discussions for our team. I have also worked for companies throughout semesters while keeping my grades up and communicating effectively with my employer. I know about creating a Bill of Materials and being able to help schedule who does what and when.

Eduardo Jimenez-Tzompaxtle: I have experience working with a group and communicating with people. I have taken some classes in transmission and power.
Chicheng Tang: I have experience collaborating with team members to complete the work. And I have taken a class about distribution and transmission systems.

Liam Gossman: I have experience with substation design and general operations through my internships at MidAmerican Energy. I also have experience with distribution systems design and effective communication skills necessary for collaboration between different design departments.

Siti Mohd Radzi: I have numerous experiences working in a team from various work environments, from working for technical projects, student organizations, volunteering programs, and fundraising; I believe I would be able to contribute to creating a healthy work environment within the team, by ensuring the expectation and performance of the team is consistent and good.

1.4 Project Management Style Adopted by the team

Majority vote in group decisions to keep everyone in the loop and ensure that nobody has more power than anyone else. People voice their opinions and concerns freely to avoid unfair or decision bias.

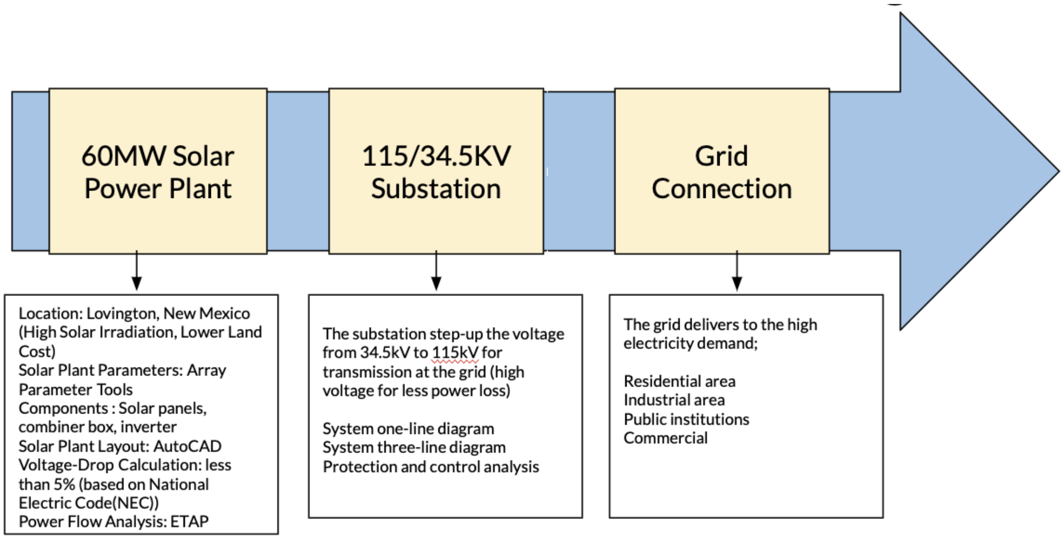
1.5 Initial Project Management Roles

- Baylor: Team Organizer
- Bell: Recorder and Testing
- Liam: Client Correspondent
- Chicheng: Research and Testing Leader
- Eduardo: Submission, Research and Testing Leader
- Eli: Team Lead

2 Introduction

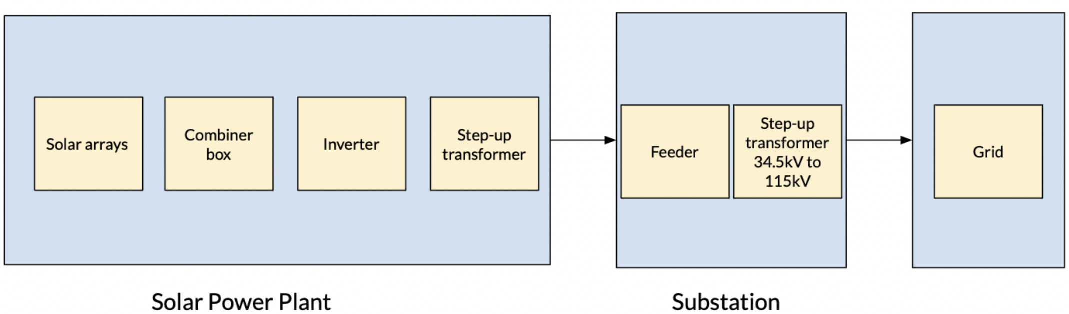
2.1 Problem Statement

Our project comprises a 60 MW solar power plant and a 115/34.5 kV substation design. For the Fall 2023 semester, we are focusing on designing the solar power plant, starting with the solar power plant. In this design part, considerations are taken into account: location, power rating of the components, solar layout design, voltage-drop analysis, and cost analysis. For the next Spring 2024 semester, we will continue designing the substation to increase the power from 34.5 kV to 115 kV before transmitting it to the grid. We will focus on designing one-line and three-line diagrams for power flow, protection, and fault analysis in this design area. The power will be transmitted to the grid and distributed to accommodate the high electricity demand from local demand, residential, industrial factories, commercials, and public needs.



[Figure 2.1.1: Solar Power Plant and Substation Design Process]

The solar power plant design consists of 4 components, which are the solar layout, combiner box, inverters, and step-up transformer. Meanwhile, the substation design consists of the feeder and the step-up transformer.



[Figure 2.1.2: Components of the design]

2.2 Requirements and constraints

In this project, we must design the solar power and substation plants using AutoCAD, ETAP, and Bluebeam. We also have requirements to calculate voltage drops, grounding currents, and design specifications. We are not required to have a replica of our designed substation and solar farm, but we must have all of the documentation that goes along with the design work. Here are a few deliverables we need to provide as well:

Functional

- Must be able to operate in environmental conditions
- Power rating at the solar farm of 60 MW
- Adhere to IEEE, NEC, ANSI standards
- Maintain reliability throughout the lifespan of the project
- Minimize voltage drop across solar plant
- Safely ground the entirety of the substation
- Establish overcurrent protection system
- Calculate overall DC and AC loads

This solar farm will operate outside in typically hot, sunny weather but also must be able to withstand temperatures below freezing. It must be resistant to common weather conditions of the area, such as thunderstorms or snow. The substation will operate in the same environment as the solar farm as it will only be 50 feet from the solar field.

Environmental

- Parcel of land must be flat and continuous (i.e. no hills, creeks, ravines)
- High amount of average sunshine per year
- High irradiance on the land
- Substation should be able to safely provide power to nearby communities
- Efficient use of land

Economic

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

2.3 Engineering standards

Solar Power Plant Design Standards

IEEE 1562:2007 Guide for Array and Battery Sizing in Stand-Alone Photovoltaic (PV) Systems

IEEE 2778-2020 Grounding System Design for Ground-Mount Photovoltaic (PV) Solar Power Plant

Substation Standards

NEC 2020- (National Electrical Code)

2.4 Intended users and uses

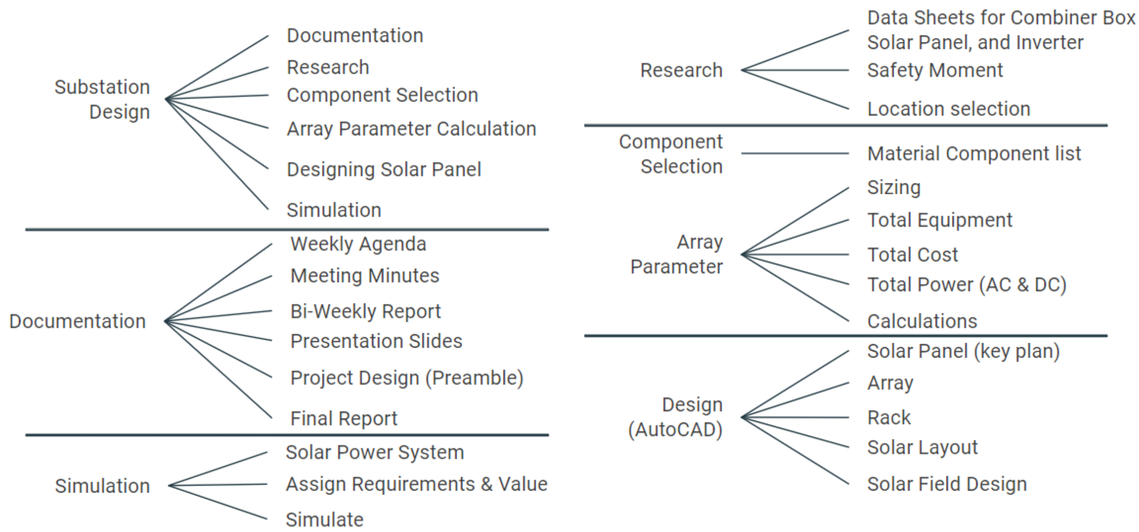
Two groups could potentially benefit from the results of our project. The first interest group is our sponsor company, Black & Veatch. After completion of the project, they can take our design and compare it to other senior design groups and traditional designs done at the company. The other group that could benefit from our project if it were to be implemented in the real world would be the public using the energy produced by our solar power plant. This would help out the local community and power grid by adding another 60 MW of power to be consumed.

Black & Veatch is a group interested in designing and implementing solar power plants and substations. Renewable energy advocacy groups would also be interested in designing and creating a solar power plant. Black & Veatch could take the design of our project and implement our design if the situation makes sense and applies to a specific location.

3 Project Plan

3.1 Task Decomposition

In this design project, there are two main tasks: designing a 60 MW solar farm in Fall 2023 and designing the 115/34.5 kV substation in Spring 2024. A few sub-tasks are worked on, such as research, component selection, simulation, designing, calculation, and documentation. The first sub-task is initial research. In the Fall of 2023, we worked on researching the strategic location for solar energy production by taking several factors into account, for example, solar irradiation, land cost, ROI, local policies, and many more. We also researched suitable components of the solar farm: Solar panels, combiner box, inverter skids, connectors, and fencing materials, by comparing different best components from the datasheet consisting of the information of the specification, power ratings, efficiency, and cost. Then, we continued designing the solar array by using array parameter tools using the specification values of the solar panels while considering standards to produce a DC power of 78.79 MW to finalize AC power of 60 MW, as per project requirement. Next, we draw the design in AutoCAD, from solar layout, solar mount, string connection diagram, and DC and AC one-line diagram. Next, we simulated the effectiveness of the design by calculating the voltage drop and doing simulations on ETAP. In Spring 2024, we will be working on the same tasks, in this case, to design a 115/34.5 kV substation. Throughout the process, we consistently worked on the documentation, from meeting minutes, agendas, design documents, website, and legal documents.



[Figure 3.1: Task Decomposition]

3.2 Project Management/Tracking Procedures

The group has adopted the waterfall management style for the organization and progression of the project. However, the group uses an agile methodology for communication and leadership between group members. The waterfall method emphasizes completing certain tasks before moving the project forward. Agile stresses the importance of leadership and freedom for group members.

A typical waterfall management style has five phases: requirements, design, implementation, verification, and maintenance. The style is a linear progression from one phase to the next. In particular, the next phase should not begin until the previous phase is completed. The typical waterfall style suggests not returning to previous phases once completed, but the group will most likely have some crossover between phases to revise and ensure everything is completed properly.

Our Gantt chart for tracking tasks and the design process loosely follows this waterfall design style. The Gantt chart the group has created details the different phases of design and what is involved in each phase. Furthermore, a timeline outlines when different phases should be completed, and deadlines are coming up in the future.

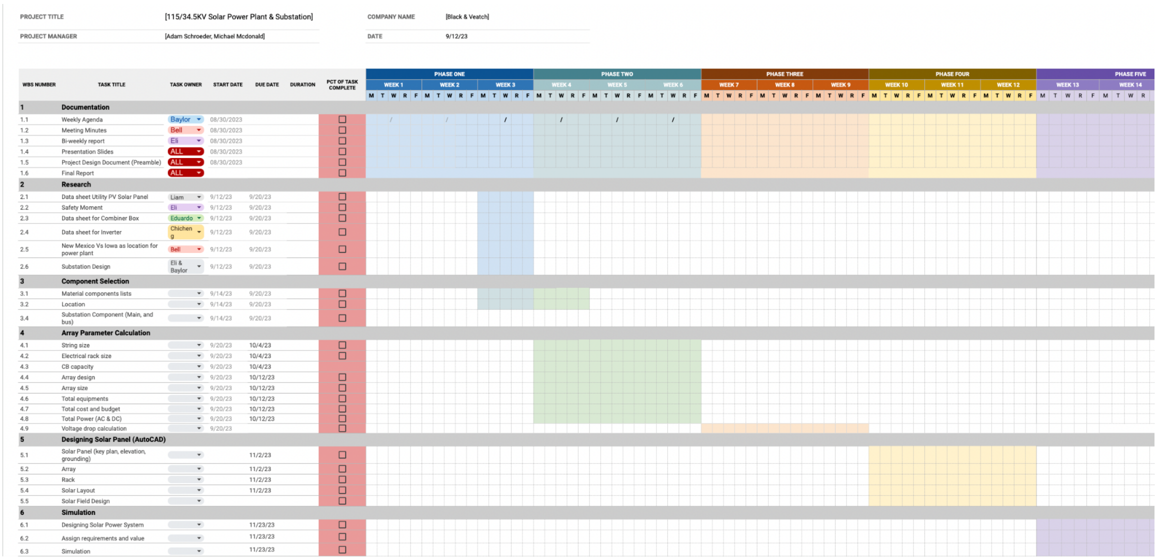
Additionally, the group will use GitHub to help keep track of design phases and assign tasks to each team member. The agile methodology involves frequent check-ins with group members and early detection of obstacles. This method of group collaboration allows for the most fluent progression through the phases of our senior design project.

3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

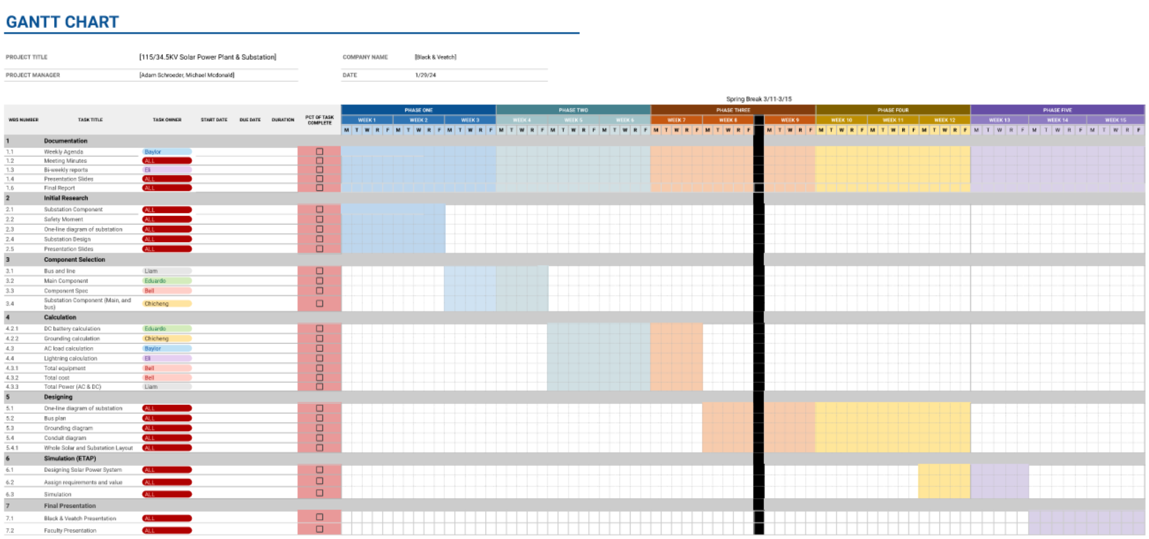
- Research Equipment
  - Collect 3 datasheets for PV panels, combiner boxes, and solar inverters
  - Research necessary components and present our understanding of them
- Select Components
  - Finalize component selection
  - Find appropriate location for construction
- Array Parameters
  - Use array calculation tool to select solar farm sizing (number of panels, combiner boxes, inverters, etc)
  - Component numbers and arrangement should result in an AC output of 60 MW and a DC to AC ratio of approximately 1.3
  - Component costs will be calculated to provide overall array cost
  - Voltage drop calculations will be done to provide realistic power loss statistics
- Design Solar Array (AutoCAD)
  - Solar array will be designed in AutoCAD based on array calculation tools
  - A professional title block will be created for array drawings
- Solar Farm Simulation
  - The solar farm will be set up within a simulation software (ETAP)
  - The power flow of the solar farm will be simulated
  - Array parameters will be checked and adjusted to ensure all necessary deliverables are met

3.4 Project Timeline/Schedule

A realistic, well-planned schedule is an essential component of every well-planned project. Most scheduling errors occur due to improperly identifying the necessary activities (tasks and/or subtasks) or incorrectly estimating the effort required to complete the activity. A detailed schedule is needed for the plan: Start with a Gantt chart showing the tasks (that you developed in 2.2) and associated subtasks versus the proposed project calendar. The Gantt chart shall be referenced and summarized in the text. Annotate the Gantt chart with when each project deliverable will be delivered. Project schedule/Gantt chart can be adapted to an Agile or Waterfall development model. A sprint schedule with specific technical milestones/requirements/targets will work for Agile. Also see Figures 8.4.2 - 8.4.5 for more information about our project timeline.

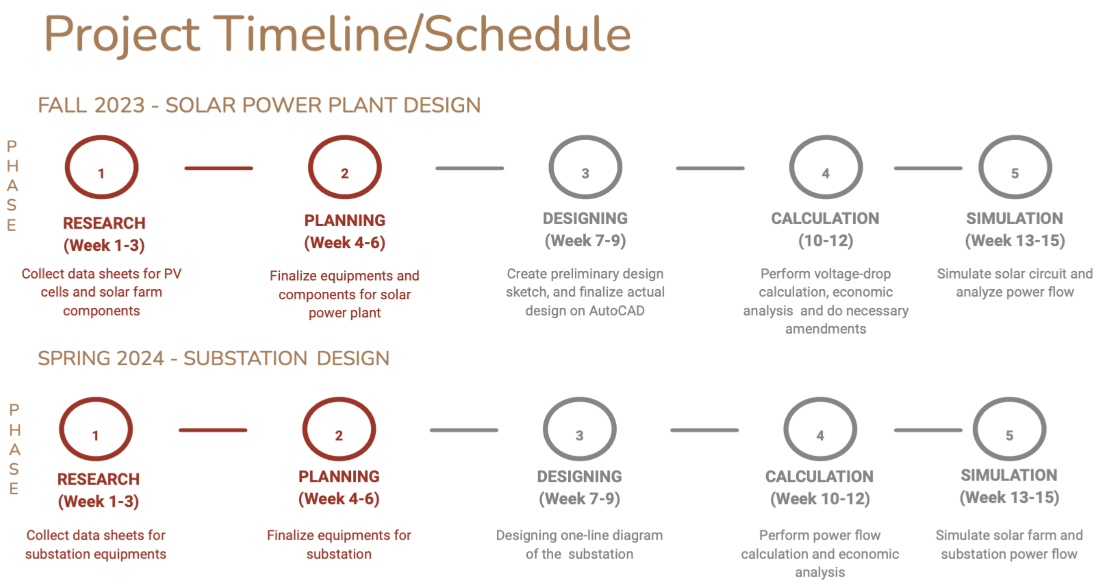


[Figure 3.4.1: Gantt Chart for Solar Power Plant Design for Fall 2023]



[Figure 3.4.2: Gantt Chart for Substation Design for Spring 2024]

Figure below shows the summary of the Gantt chart above, displaying the design phases and each time frame allocated throughout the semester.



[Figure 3.4.3: Project Timeline]

3.5 Risks and Risk Management/Mitigation

There are a lot of different risks that we have in our project. Some include technical, land and site, construction, financial, and policy risks. All of these risks can add up and cause a lot of potential mistakes that can happen in our project or the future. For our technical risks, we have technology selection and system design. This risk would be when we design something and don't fully understand the ratings or what amperage the wire can carry. If this were to happen, we would overload the wire and cause a fire or explosion. Another possible risk would be construction risks. This risk is out of project scope, but one that we need to consider in our design work. An example would be if a maintenance team worked in the arrays and then clipped a solar panel with a piece of equipment. We can mitigate this risk by giving more space in between the arrays. We found a larger piece of land than we need, so it shouldn't be an issue if we give extra space in the arrays.

We also have some hypothetical risks because we won't be constructing this array. We have identified some land, site, and financial and policy risks. Some land risks include acquisition risks, meaning someone else could buy the land out from under us, or we could lose in a bidding war with other companies. We also have a financial risk where we would have the risk of not being able to buy the property. We could also have trouble repaying a loan that we get when we purchase the land.

3.6 Personnel Effort Requirements

Task	People	Expected Person-Hours
Solar Power System Simulation	Eli	10
Requirements and Values	Baylor	5
Simulation	ALL	20
Data Sheets for Equipment	ALL	10
Safety Moment	ALL	3
Location Selection	Bell	6
Material Component List	Liam	3
Sizing	Chicheng	4
Total Equipment	Eduardo	6
Total Cost	Eli	10
Total Power (AC & DC)	Liam	6
Calculations	Bell/Chicheng	7
Solar Panel Plan	Eduardo	5
Array	Baylor	8
Rack	Eli/Baylor	3
Solar Layout	Liam/Chicheng	5
Solar Field Design	Bell/Eduardo	15

[Figure 3.6.1: Personnel Requirements]

3.7 Other Resource Requirements

Software (ETAP, AutoCAD, BlueBeam, Excel)

4 Design

4.1 Design Content

Our project requires us to design several key features of the solar farm and substation. We must choose each array's solar panels, combiner boxes, and inverters for the solar farm. We must set up each array so that the solar farm's desired power output is met while not overloading or underloading each piece of equipment. For the substation, we must choose a bus layout to construct and the specific connections and equipment used. We must also analyze the substation for fault protection and design the protection methods to maintain safe operations.

4.2 Design Complexity

Our project contains multiple connected subsystems that each utilize distinct engineering principles. For the solar farm, each piece of equipment needs to be selected to meet the parameters of the overall farm but also selected to be compatible with each other. This means that voltage, current, and temperature ratings need to fit with the ratings of the other equipment while also being sufficient to fit the needs of the farm and the location it is built. These factors are related to the principles of efficiency and iteration, as many different component combinations must be iterated to find the most efficient setup.

Another design aspect of our project is the physical layout of the farm. The farm must be set up in a layout that fits the physical plot of land chosen for the farm, having all necessary access points and enough space for maintenance. This process is related to the principle of simplicity, as the arrangement of the arrays should not be needlessly complicated to avoid unnecessary expenses or inefficient land use.

The design of the substation is another component of our project that requires complex design. The layout of the substation and the protective equipment must be carefully analyzed to ensure faults are avoided, and reliable operation is maintained. This piece of the project is related to the principles of reliability and quality, as the substation must be designed to create the minimal expected number of outages and require the least amount of maintenance.

4.3 Modern Engineering Tools

Here are a few tools we expect to use during our project. There is some description of tasks to go along with it:

AutoCAD: Sheet/view editing software, Layout, Solar/substation design-optimizing tool

Bluebeam Revu: Sheet viewing software, markups from Industry professionals

ETAP: Coordination Study, AC Arc Flash Study, and Protection Element Analysis, Simulation of Designed Substation

Microsoft Excel: Equipment sizing calculations, voltage drop calculations, String sizing calculations, Grounding analysis, Bus calculations, DC Battery Bank calculations,

4.4 Design Context

4.4.1 Impact of the project

In any engineering design endeavor, a pivotal factor to bear in mind is the profound understanding of the design's contextual framework. This comprehension is vital for accurately pinpointing the target audience and purpose of the design. As engineers, we must encompass a holistic perspective, meticulously assessing the economic, environmental, and global ramifications that the design might invoke.

While crafting solutions tailored to address specific challenges is undoubtedly essential, its effectiveness reaches a critical juncture when considering the potential harm it may inflict upon the environment or adversely affect particular communities. A design, however innovative, falls short of its true potential if it inadvertently contributes to environmental degradation or disproportionately impacts a specific group of individuals. Thus, our design pursuits must align harmoniously with sustainability principles and social equity, ensuring that they serve their intended purpose and foster positive contributions to our world.

Solar energy holds a significant and multifaceted position concerning the general public, its global ramifications, environmental effects, and economic implications. Solar energy and solar energy production affect any community that is affected.

1. Public Health:

   Regarding public health and welfare, solar energy directly and indirectly affects the broader community. The direct impact is most evident in the physical placement of commercial solar facilities. Conventional solar plants necessitate extensive tracts of open land, a characteristic that may sometimes pose disruptions or inconveniences for nearby residents. Indirectly, commercial solar energy reduces the need for fossil fuels in electricity production. As a result, this reduction in air pollution plays a pivotal role in mitigating the prevalence of respiratory illnesses, particularly in communities near coal and natural gas facilities. With improved air quality from decreased pollution levels, a subsequent reduction in healthcare costs associated with respiratory diseases and other health conditions linked to air pollution becomes a tangible benefit.

2. Global Impact:

   As the world shifts towards using renewable energy to counter climate change and other environmental impacts, governments and the general public have become much more receptive to the building and use of renewable alternatives. Solar and wind energy are on the leading edge of renewable energy worldwide. Commercial solar energy reduces greenhouse gasses being released into the atmosphere. Little to no emissions are produced through solar energy. The surge in solar energy production also fosters international cooperation. The exchange of ideas and knowledge among nations regarding renewable energy contributes to mutual understanding and strengthens diplomatic ties for the future.

3. Environmental Impact:

Commercial solar energy usage has some notable direct environmental drawbacks, primarily regarding the initial resource requirements for manufacturing solar panels and related equipment. However, it's crucial to emphasize the substantial, positive indirect benefits it offers in clean energy production. While producing solar panels necessitates utilizing natural resources, solar power plants, once constructed, do not entail ongoing resource consumption.

One direct environmental concern is the potential disruption of local biodiversity in the areas where solar fields are situated. Researchers are beginning to test the possibility of growing plants or crops under and around solar fields. Furthermore, certain interest groups are also bringing animals to graze on the grass that grows in and around solar fields. While solar power plants require large amounts of land, movements are being made to better use the land while the solar field is there.

4. Economical Impact:

The transition to solar energy significantly increases the demand for jobs in various sectors. The construction phase of solar power plants and installations calls for a skilled workforce, including engineers, electricians, and laborers. Additionally, the operation and maintenance of these facilities require technicians, maintenance workers, and monitoring staff. The adoption of renewable energy sources, like solar power, leads to a decrease in energy costs for both individuals and businesses. Solar panels and power plants generate electricity from a free and abundant energy source – the sun. Governments often incentivize the adoption of solar energy by providing tax exemptions, rebates, and other financial incentives. These measures make it more financially attractive for businesses to invest in solar power. The growth of the solar energy industry contributes significantly to economic stimulation. Investments in solar infrastructure, manufacturing, and research and development lead to a surge in economic activity. This growth impacts the solar sector and ripples through the entire supply chain, from raw material production to the transportation and installation of solar components.

Considering the design's overarching context is important to ensure your design continually mitigates any negative impacts on the categories discussed above. Furthermore, it motivates the group to consider each design option and ensure nothing negatively impacts a certain interest group. The group will work to remind ourselves of the importance of context through our design process.

4.4.2 Development Standards & Practices

In the dynamic realm of energy infrastructure, developing and adhering to industry standards plays a pivotal role in ensuring the safety, reliability, and efficiency of power generation and distribution systems. The 115/34.5 kV Solar Power Plant & Substation Design Project is a testament to the commitment to excellence, incorporating best practices from renowned organizations such as the National Electrical Code (NEC) and the Institute of Electrical and Electronics Engineers (IEEE).The design shall meticulously incorporate NEC provisions related to electrical installations, grounding, overcurrent protection, and equipment integrity. Compliance with NEC standards enhances safety and facilitates seamless integration with the broader electrical infrastructure. The IEEE, a globally recognized authority in advancing technology, provides a comprehensive framework for designing and operating electrical and electronic systems. For this project, IEEE standards, particularly those about substation design, equipment specifications, and power system reliability, serve as guiding principles. Adhering to IEEE standards ensures the project's alignment with global best practices, fostering interoperability, resilience, and optimal performance.

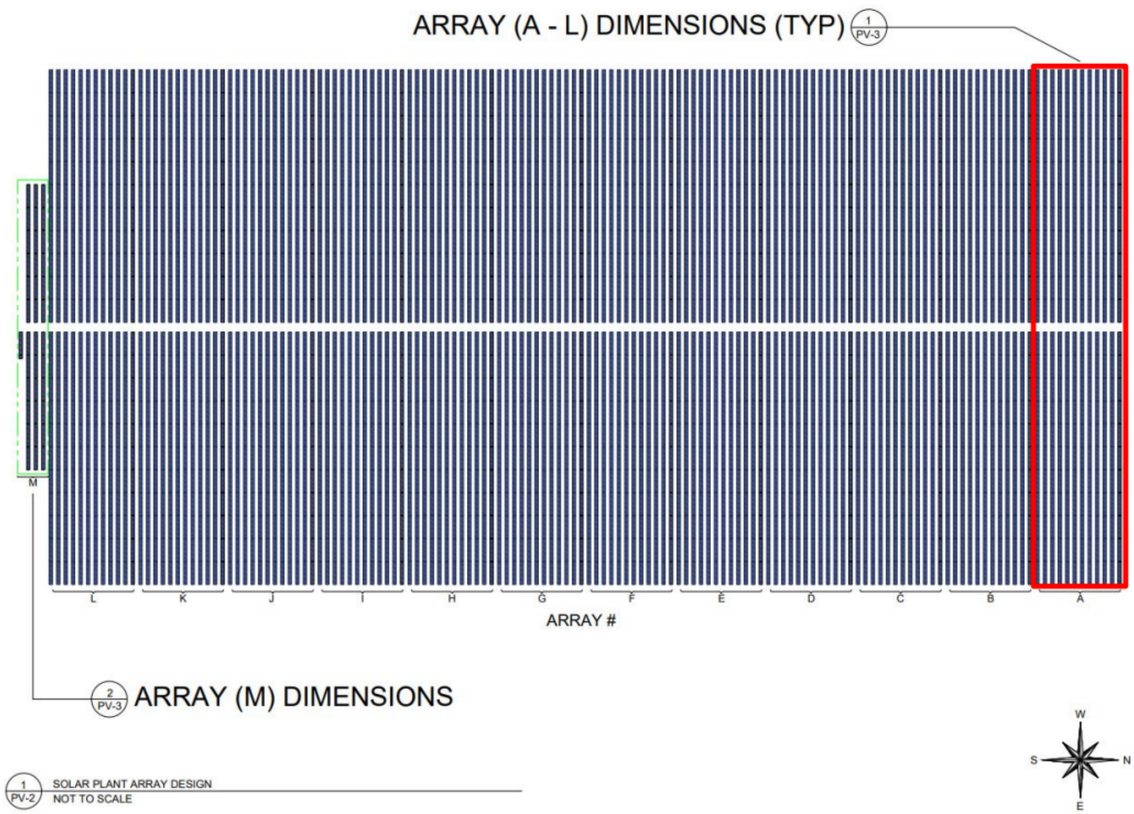
Practice Code	Standards Description
NEC690.8(B)	Overcurrent ratings shall not be less than 125% of the max current calculated
NEC690.8(A)	The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by correction multiplier, 125 percent.
NEC690.9	PV system DC circuit and inverter output conductors and equipment must be protected against overcurrent.
NEC240.6	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 the DC side and 1% from the 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. As required by this section, gates and doors opening directly into the area enclosed by a fence, wall, or barrier 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 tall.
IEEE 80-2013	IEEE guide for safety in AC substation grounding,

[Figure 4.4.2.1: Development Standards & Practice]

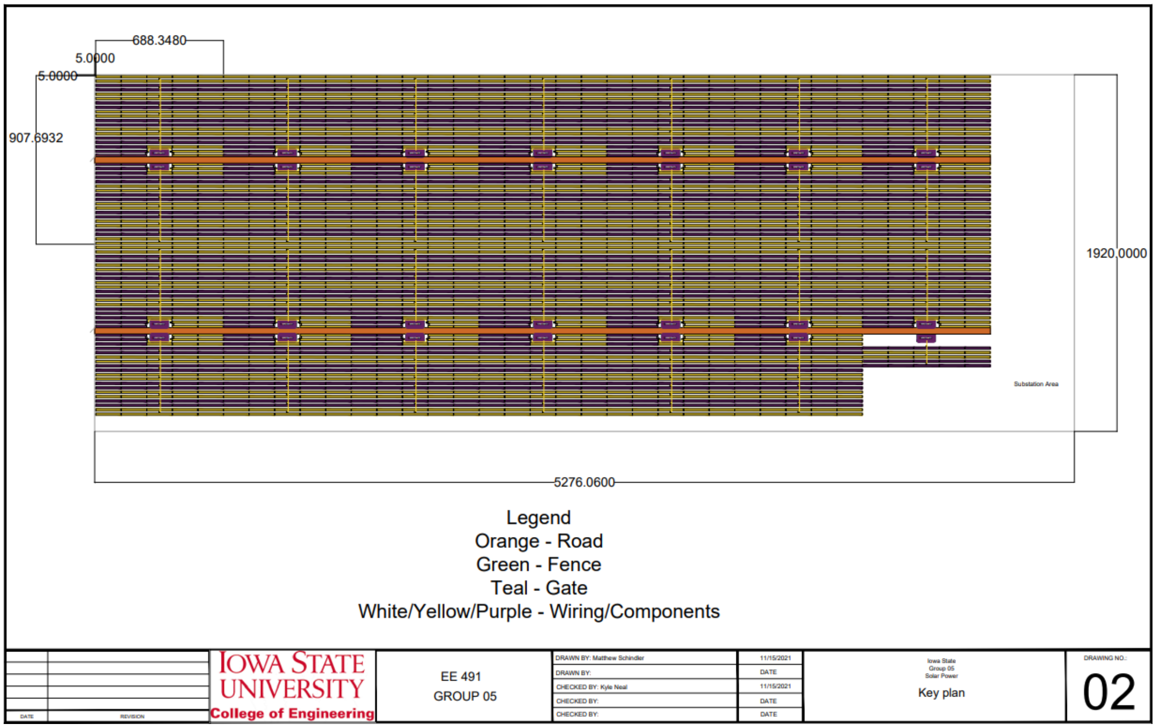
4.5 Prior Work/Solutions

Black & Veatch has sponsored this specific senior design project for several years. Furthermore, Black & Veatch has gone through the design process with their engineers. The group has several previous solutions to use only if needed. The group has made a point to use these previous solutions only when needed. Our selection of equipment and location of design makes it difficult to rely on any other previous projects. Beyond the scope of Iowa State University and Black & Veatch, commercial solar power plants are a continually growing renewable resource alternative. These projects outside the scope of our requirements are hard to use as a reference because any given product can differ greatly depending on several variables.

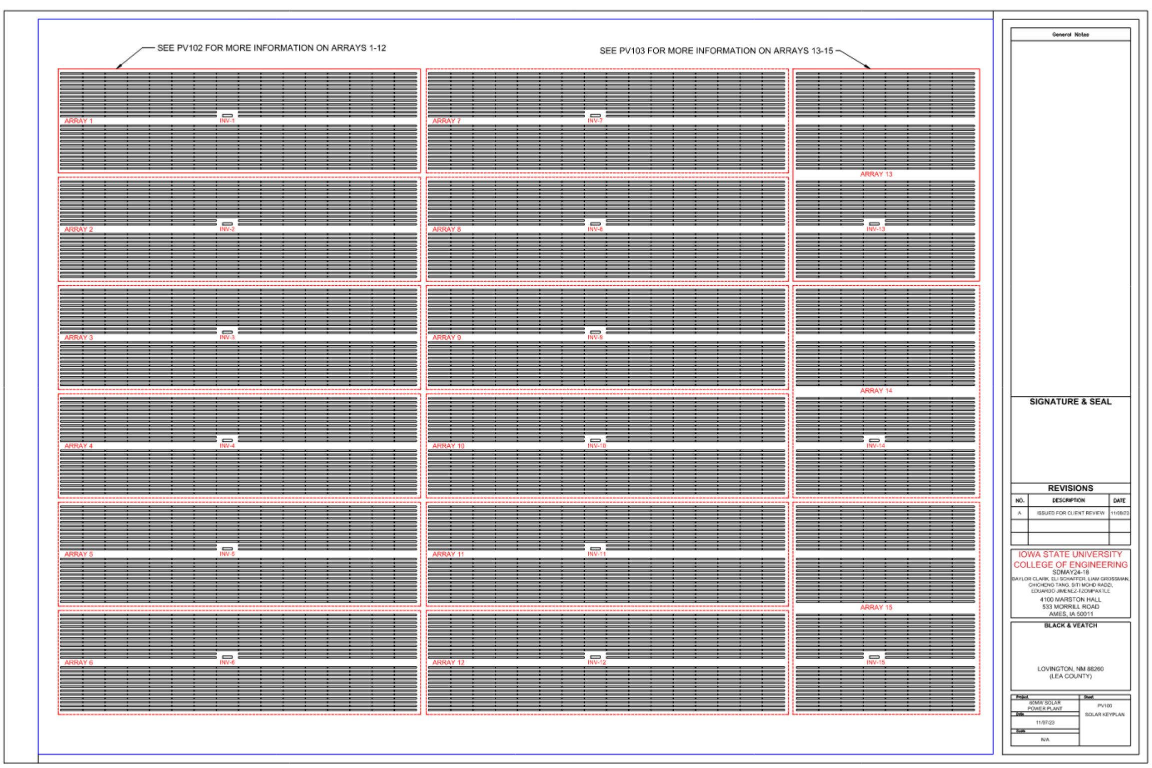
Some previous work done for this company and senior design projects can be viewed with these links, and we can compare some of their design choices with ours. Here are the links for the sdmay20-14 project, the sdmay21-37 project, the sdmay22-05 project, and the sdmay23-27 project. We can see that the project done in 2023, shown in Figure 4.5.1, has 13 different arrays with two different array sizes. We also have 2 different array sizes due to size restrictions in our plot of land. Figure 4.5.2 shows the work done by the 2022 senior design team. They used 22 inverters for their design, while we only used 15 inverters with them all balanced, which can be seen in Figure 4.5.3.



[Figure 4.5.1: sdmay23-27 Overall Array Layout]



[Figure 4.5.2: sdmay22-05 Overall Array Layout]



[Figure 4.5.3: sdmay24-18 Overall Array Layout]

Topic	Pros	Cons
Solar Panel	550 W 41.1 V which gives us a nice string voltage of 1500 V	Limits 1 strings/rack
Combiner Box	1500 V rated and a price per combiner box	Only 16 inputs
Skid Inverter	4 MW so we only need 15 inverters for the project	Dual Output

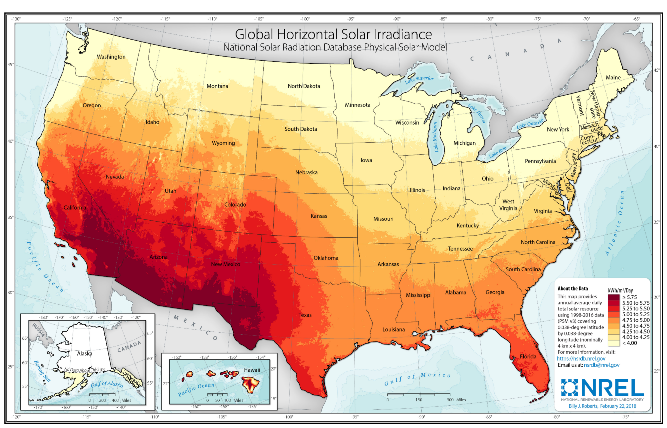
[Figure 4.5.4: Pros and Cons For Our Design Choices]

We can see some topics as well as some pros and cons for those topics in figure 4.5.3. Some background we needed for this project was the knowledge of solar panels and their work. We also needed to understand how voltages and currents combine so we could rate the right equipment for the right purposes. There are many other solar farms and substation combos, but we can't use those designs because they belong to a company, and don't have access to them. Our project differs from most solar farms because we use one rack to one combiner box. We also will use a 4 MW skid inverter, which is uncommon in farms because of the size we need to achieve. There are many different options for designing a solar farm, so each design is unique.

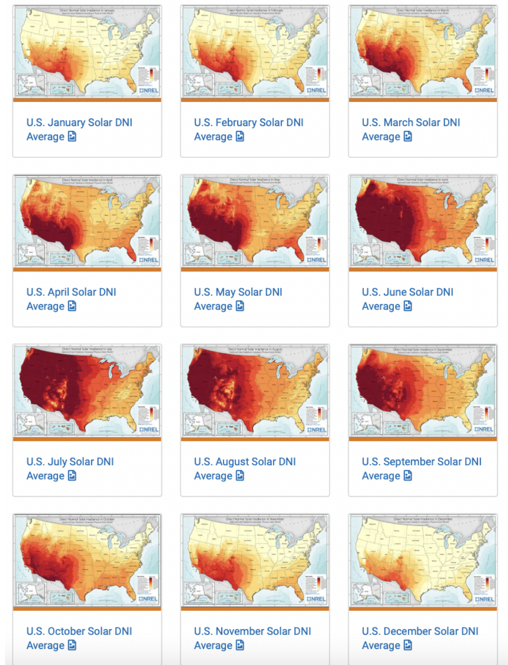
4.6 Design Decisions

4.6.1 Location

Our project will be in Lovington, New Mexico since it is a perfect candidate for producing power with a high level of sunlight and low amount of clouds throughout the year. New Mexico generally has a superior solar resource with higher solar irradiance and more sunny days throughout the year. This results in higher energy production and potentially better ROI.Solar resources of 5.00 - above 5.75 kWh/m2 per day are among the highest in Arizona, California, and Texas.



[Figure 4.6.1.1: Solar irradiance across U.S]



[Figure 4.6.1.2: Solar irradiance throughout the year]

Realistic average daily solar insolation by month ($kWh/m^2/day$)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2.835	3.592	4.645	5.587	5.932	6.321	5.954	5.503	4.460	3.792	2.885	2.410

[Figure 4.6.1.3: Solar insolation of Lovington, New Mexico

There are several solar energy projects around Lovington, New Mexico, which shows that the area/location is a strategic location, whereas the solar radiation, access to water supply, labor and maintenance resources, and grid connection are reliable. Land costs can vary significantly in New Mexico, but land may be more affordable in many areas than in regions with high agricultural demand. Land in southern New Mexico, particularly in rural areas, is often more affordable than other regions with high population density. Lower land costs can significantly reduce the overall project expenses, making it economically attractive for solar developers. One of the cheapest in the US, approximately $1931 per acre. 60 MW solar farm would need approximately 230 acres (estimate 1 kWh per sq ft) + 20 acres (for substation) = 250 acres. Estimated Cost = $2000 X 250 acres = $500,000.

This is our chosen location for the solar farm and substation in Lovington, New Mexico. It is a ranch with flat land with a size of 406 acres costing $609,000. It is also on the border of New Mexico and Texas, which makes the laws and other regulations more difficult to follow.

406 Acres in Lovington, NM - $609,000

Acreage - Lovington, NM

406 Acres Of Ranch Land On State Line Rd. Easy Access To Plains Hwy. Small Farm House At Sw Corner Of Property. Native Terrain And Mostly Flat. Possibilities Are Great!!

[Figure 4.6.1.4: Site location]

4.6.2 Solar Farm

The group has decided on some components and designs for the solar farm. The combiner box the group chose has the capacity of 1,500 V, 16 inputs, 1 output, and will cost about $1812. The skid has an inverter and a transformer in one system. The skid has a capacity of 1500 volts and can output 4600 kVA in AC. The solar panel changed from the original selection, but we decided to pick a panel with a capacity of 550 watts and an efficiency of 21.48%. The voltage for the panel is 41.1 volts with a short circuit current of 13.65 each. The cables connecting to the combiner box will be #10 AWG sizing. 400 MCM cable was also chosen for higher currents connecting the combiner box to the inverter.

The group also chose to have an input of 78 MW in DC to 60 MW AC since there will be a loss of power when converting from DC to AC. The connection of each component will be arranged in the order of a solar panel, combiner box, inverter, transformer, and to the grid/substation. The solar farm will consist of 15 array modules stacked in 2 columns with 6 rows for one set and 1 column with 3 rows for a different set due to constraints on the land the group has selected.

4.6.2 Array Parameter Tool

		String Size				Electrical Rack Size				CB capacity		
					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
					Datasheet	module height	7.474	ft	NEC secti	multiplier	1.25	
	Datasheet (STC)	Voc	50.2	V						nom Isc	17.3625	
	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
	Datasheet	Temp Coeff of Voc	-0.0029	/C		Modules per rack						
		Temp delta	-65			Rack width	93	ft	Choice:	allowed current	350	A
		temp correction	1.19			Rack height	7.474	ft	200,	is this disconnect A?		
		V0c corrected	59.6627						400A	strings per CB	16.12670	
									etc.	Round down:	16	
Confirm possible with Panel type chosen		string voltage	1500	V						racks per CB	16	
		String size	25.14133									
		string size	25									
	Designer Choice: 600, 1000, 1500, 2000V	Actual String Voltage	1491.6									

[Figure 4.6.2.1: Array Parameter Tools]

	Array Design			Array Size		
Designer Choice	Racks per row	16	Designer Choice	tilt	35	
Designer Choice	rows per Array	24		table height proj	6.122342	ft
Designer Choice	Racks removed	2	Designer Choice	row space	10	ft
	Total Racks/Array	382		pitch	16.12234	ft
				Space for Inverter Maintenance	35	ft
	Total modules	9550		Array height	386.9362	ft
Datasheet (STC)	module capacity	550	W	Array width	1488	ft
				Ground Coverage Ratio	0.463580	
	dc capacity	5252.5	kW			
Designer Choice	inverter capacity	4000	kW			
		4	MVA			
:	ILR	1.313125				
Industry standard 1.3						

[Figure 4.6.2.2: Array Parameter Tools]

4.6.3 Cost

The cost analysis for the 115/34.5 kV Solar Power Plant & Substation Design Project involves systematically evaluating financial aspects throughout its lifecycle. Beginning with a preliminary assessment that considers feasibility studies and regulatory compliance, the analysis extends to design and engineering costs, procurement and installation of equipment, construction expenses, and grid connection costs. Ongoing operational and maintenance costs, financing considerations, contingency planning, and adherence to regulatory requirements are integral components. The analysis culminates in a comprehensive life cycle assessment, accounting for the total cost of ownership and return on investment. Transparent documentation and regular reporting ensure effective communication and informed decision-making, contributing to the project's success by aligning with budgetary constraints and performance expectations.

Economic Cost Analysis

Solar Field Rating (MW) (FIxed Axis)	Hours of sunshine/year	Average Monthly Electricity Cost (cents/kwh)
60MW	6.6/day = 2400/year	14.71

Assumed Efficiency	
Inverter	0.8
Indirect sunlight	0.7

Hours of sunshin	ws.com/blog/peak-sun-hours-explained
Average monthly	gy.com/resources/electricity-bills-by-state/
ninverter	
nindirectsun	
PPA	North American Solar and Wind PPA Prices Increased 6.6 ...LevelTen Energyhttps://www.leveltenenergy.com › post
O&M	
Payback period	MQFnoECC4QAQ&url=https%3A%2F%2Fwww.energysage.com%2Fsolar-panels%2Fnm%2F&usg=AOvVaw36O5dbAHZvRAaloVuX0hfL&opi
CF	l.com%2Fmarketintelligence%2Fen%2Fnews-insights%2Fresearch%2Fusual-sun-states-shine-bright-at-top-of-us-solar-capacity-factor-leader
Price	0.16/kwh
Tracking Cost	cker-cost%2F%23%3A~%3Atext%3DHigh%252Dperformance%2520single%252Daxis%2520GPS%2C%253A%2520%25240.08%2520%25

Solar Field Rating (MW) (Axis Tracking)	PPA	Axis Tracking Efficiency	
74.85MW	$49/MWh	0.2475	
		Annual	7,762,532.66

Fixed Tilt (No axis tracking) 5.8 kw

Installation cost ($)	O+M/year	Infaltion rate (%)	Annual Revenue	Space Cost (Acre/MW)
63,912,000	348,000	3.7	15,277,467	4-5

Cash flow

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
63,912,000	14,929,467	14,941,884	14,953,857	14,965,404	14,976,538	14,987,275	14,997,629	15,007,614	15,017,242	15,035,481

Present Value

Year	Installation cost	O+M	Revenue	Profit
10	63,912,000	2419868.02	149,812,392	147,392,524

1-axis tracking) 6.96 kw

Installation cost ($/MW)	O+M/year	Infaltion rate (%)	Annual Revenue	Space Cost (Acre/MW)
71,712,000	417,600	3.7	22,622,400	4-7

Cash flow

Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
71,712,000	22,204,800	22,189,349	22,173,326	22,156,710	22,139,480	22,121,612	22,103,082	22,083,868	22,063,942	22,043,279

Present Value

Year	Installation cost	O+M	Revenue	Profit
10	71,712,000	2903841.623	221,279,447	218,375,606

[Figure 4.6.3.1: Solar Farm Cost Analysis]

4.7 Proposed Design

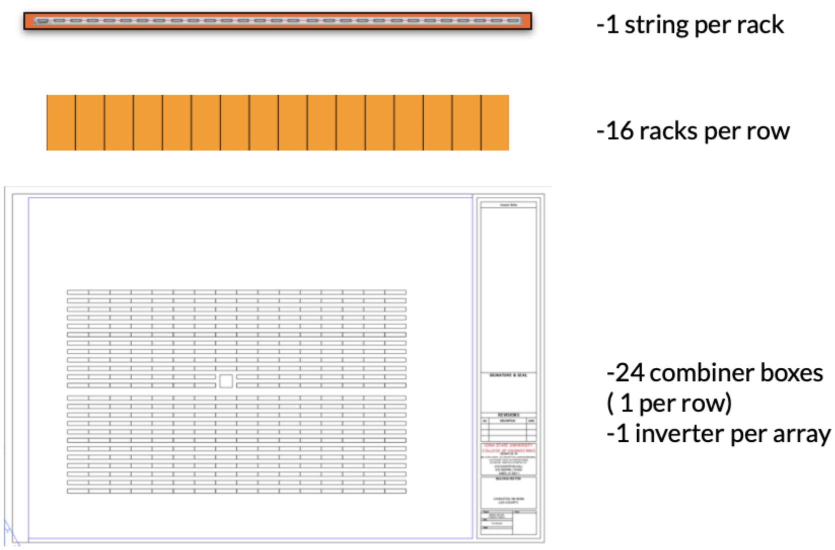
4.7.1 Design 0 (Initial Design)

4.7.1.1 Solar Farm

Initially, we researched strategic locations such as solar sites to compare locations in Iowa and New Mexico. We have decided to locate the solar power plant and substation at Lovington, New Mexico, due to high irradiation throughout the year and lower land cost, which would be cost-effective and profitable. Next, we went through the process of surveying the suitable components, solar panels, combiner boxes, and inverters by taking note of the power rating, efficiency, and compatibility with the condition and weather of the proposed location. Then, we continued estimating the DC power output using the information from the components data sheet and analyzed them to fit our design criteria. DC power output was around 79 MW to produce a net AC power output of approximately 60 MW, using the Array Parameter Tools provided by Black and Veatch. Our current design component is shown below.

		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	Designer Choice: 200, 400A etc.	allowed current	350	A		Total Racks/Array	382		pitch	16.12234	ft
		temp correction	1.19			Rack height	7.474	ft		is this disconnect A?							Space for Inverter Maintenance	35	ft
		V0c corrected	59.6627							strings per CB	16.12670			Total modules	9550		Array height	386.9362	ft
										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 =																	

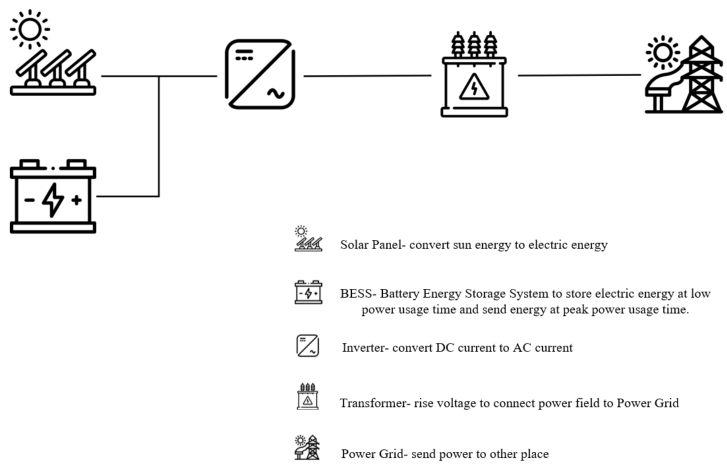
[Figure 4.7.1.1.1: Array Parameter Tool]



[Figure 4.7.1.1.2: Solar Rack Layout Design]

We have determined the location, the components, and the basic structure of the solar farm. Currently, we are using AutoCAD to design the structure of the solar power plant, for example, how to place all the solar panels, how to place the combiner box, how to connect the combiner box to the inverter, and finally to the substation.

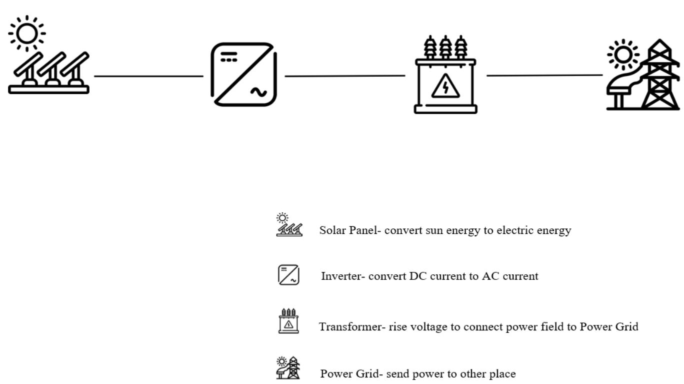
4.7.1.2 Substation



[Figure 4.7.1.2.1: Solar Rack Layout Design]

Solar power plants use solar panels to absorb sunlight. These panels are made of semiconductor materials (such as silicon) and can convert sunlight into direct current (DC) electricity. Since the power grid uses alternating current (AC), solar power plants need inverters to convert the DC power to AC power. Finally, the voltage is regulated to the desired level for the grid by using a transformer. Once the voltage is regulated properly, it can be fed into the grid. In the initial design, we used BESS (Battery Energy Storage System), which stores power from solar energy and releases it when it is unavailable, e.g., at night.

4.7.2 Design 1 (Design Iteration)



[Figure 4.7.2.1: Solar Rack Layout Design]

In the current design, we have eliminated the BESS system because our power plant is directly connected to the grid, so other regulation mechanisms may not require a large energy storage system. Secondly, the cost of a large energy storage system may be relatively high. According to the "*U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021*," if we use a two-hour system, we need 120 MWh of batteries for our Solar farm, which would cost $857 per kWh, or about $100 million in total for batteries. Third, the production and disposal of batteries at this stage may cause environmental problems. For these reasons, we have decided to abandon the use of BESS.

4.8 Technology Considerations

Solar panel technology is advancing, leading to a wide array of equipment with varying specifications. While higher-wattage solar panels offer increased energy production in a smaller space, they come at a higher cost and necessitate equipment capable of managing the greater load. Copper cables, though more efficient than aluminum, prove notably pricier when the gauge needed for transmitting utility-scale power is considered. Sun tracking technology enhances solar panel efficiency and power generation but entails heightened maintenance requirements and increased installation expenses. The typical trade-off in equipment selection revolves around the balance between power/efficiency and cost.

Following thorough research, economic assessment, and consultations with mentors, our conclusion was that implementing axis-tracking technology was unnecessary. The advantages of generating more power were outweighed by the additional installation and maintenance costs, especially given the already substantial power production from the sheer number of solar panels. Regarding the specific tilt angle for our panels, various sources indicated that an angle between 30 and 40 degrees is optimal for a region like New Mexico. Since we did not adjust the panel angle throughout the year, opting for the angle that yields the best year-round results makes more sense. Considering the lower sunlight output during winter, optimizing the tilt angle to maximize power during this season becomes paramount. Consequently, a carefully chosen angle of 35 degrees compensates for the reduced sunlight levels in the New Mexico winter. This meticulous design approach represents the sole means to minimize the impact of these trade-offs.

4.9 Design Analysis

The initial idea of having batteries for the solar array changed due to the cost of producing 2 hours of power. Mostly, everything has been kept the same for the general ideas on designing the solar farm. We see that there is room for expandability of solar power in the future if more power is needed.

5 Testing

5.1 Unit Testing

For unit testing, the group will use software to confirm all the design calculations will be correct. The voltage drop, current, power, and safety systems, like circuit breakers, will be tested for each component. The group will use the ETAP software to confirm the calculations. Voltage and current will be measured for the solar panels, combiner box, and cables, while the skid will be measured for voltage and power output.

For the voltage drop calculations, we needed to use the equation shown in Figure 5.1.1, where L is the length of the wire, R is the wire resistance per foot, and I is the current running through the wire. We used two different wires in our project; one was a #10 AWG wire, and the other was 600 MCM. The resistance of the #10 AWG is 0.9989 ohms/1000,' and the resistance of the 600 MCM is 0.0309 ohms/1000'

$$VD = \frac{2 \times L \times R \times I}{1{,}000}$$

$$VD\% = \frac{VD}{\text{SOURCE VOLTAGE}} \times 100$$

[Figure 5.1.1: Voltage Drop Equation and Voltage Drop Percentage]

Figure 5.2.1 and 5.2.2 below shows us the voltage drop at the DC section of the power plant by calculating the voltage drop of the string to the combiner box and the wire connection from the combiner box to the inverter. The calculation is made by using the voltage drop formula, considering the specification value of the components, such as the wire length, the resistance per ft, and maximum short circuit current, referring to the datasheet and NEC Table 8 Conductor properties, to adhere with the NEC standards of voltage drop less than 2% DC, and less than 1% for AC part. The result shows that horizontal and vertical voltage drops met the standards with 0.51% & 0.63% voltage drops, respectively.

Voltage-Drop Calculation = <3%

Resources	NEC Table 8 Conductor Properties
	NEC AWG Chart

16 racks Combiner box (Horizontal Array)

DCB	Strings per rack	ISC for string	String length	String wire size	String conductor resistance	String resistance	Voltage drop of string(AWG #12)	Voltage drop of string
DCB#-##	per rack	Amp	feet	AWG	ohm/kft	ohm	Volts	%
DCB1-01	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-02	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-03	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-04	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-05	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-06	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-07	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-08	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-09	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-10	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-11	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-12	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-13	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-14	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-15	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-16	1	13.89	93	10	1.24	0.11532	3.204	0.214

AWG=600

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	16	222.24	161	600	0.0241	0.004	1.725	0.11	8.13	1500	0.54
DCB2	16	222.24	151	600	0.0241	0.004	1.618	0.11	8.02	1500	0.53
DCB3	16	222.24	141	600	0.0241	0.003	1.510	0.10	7.92	1500	0.53
DCB4	16	222.24	131	600	0.0241	0.003	1.403	0.09	7.81	1500	0.52
DCB5	16	222.24	121	600	0.0241	0.003	1.296	0.09	7.70	1500	0.51
DCB6	16	222.24	111	600	0.0241	0.003	1.189	0.08	7.60	1500	0.51
DCB7	16	222.24	101	600	0.0241	0.002	1.082	0.07	7.49	1500	0.50
DCB8	16	222.24	91	600	0.0241	0.002	0.975	0.06	7.38	1500	0.49
DCB9	16	222.24	81	600	0.0241	0.002	0.868	0.06	7.27	1500	0.48
DCB10	16	222.24	71	600	0.0241	0.002	0.761	0.05	7.17	1500	0.48
DCB11	16	222.24	61	600	0.0241	0.001	0.653	0.04	7.06	1500	0.47
DCB12	14	222.24	51	600	0.0241	0.001	0.546	0.04	6.95	1500	0.46
DCB13	14	222.24	41	600	0.0241	0.001	0.439	0.03	6.85	1500	0.46
DCB14	16	222.24	82	600	0.0241	0.002	0.878	0.06	7.29	1500	0.49
DCB15	16	222.24	92	600	0.0241	0.002	0.986	0.07	7.39	1500	0.49
DCB16	16	222.24	102	600	0.0241	0.002	1.093	0.07	7.50	1500	0.50
DCB17	16	222.24	112	600	0.0241	0.003	1.200	0.08	7.61	1500	0.51
DCB18	16	222.24	122	600	0.0241	0.003	1.307	0.09	7.71	1500	0.51
DCB19	16	222.24	132	600	0.0241	0.003	1.414	0.09	7.82	1500	0.52
DCB20	16	222.24	142	600	0.0241	0.003	1.521	0.10	7.93	1500	0.53
DCB21	16	222.24	152	600	0.0241	0.004	1.628	0.11	8.04	1500	0.54
DCB22	16	222.24	162	600	0.0241	0.004	1.735	0.12	8.14	1500	0.54
DCB23	16	222.24	172	600	0.0241	0.004	1.842	0.12	8.25	1500	0.55
DCB24	16	222.24	182	600	0.0241	0.004	1.950	0.13	8.36	1500	0.56
										Average of worst-case DCB Voltage drop (%)	0.51

[Figure 5.2.1: Horizontal Array DC Voltage Drop]

Voltage-Drop Calculation = <3%

Resources	NEC Table 8 Conductor Properties
	NEC AWG Chart

16 racks Combiner box (Vertical Array)

DCB	Strings per rack	ISC for string	String length	String wire size	String conductor resistance	String resistance	Voltage drop of string (AWG=12)	Voltage drop of string
DCB#-##	per rack	Amp	feet	AWG	ohm/kft	ohm	Volts	%
DCB1-01	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-02	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-03	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-04	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-05	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-06	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-07	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-08	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-09	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-10	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-11	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-12	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-13	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-14	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-15	1	13.89	93	10	1.24	0.11532	3.204	0.214
DCB1-16	1	13.89	93	10	1.24	0.11532	3.204	0.214

AWG= 600, diameter = 22-32mm

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	16	222.24	607	600	0.0214	0.013	5.774	0.38	12.181	1500	0.81
DCB2	16	222.24	585	600	0.0214	0.013	5.564	0.37	11.972	1500	0.80
DCB3	16	222.24	563	600	0.0214	0.012	5.355	0.36	11.762	1500	0.78
DCB4	16	222.24	541	600	0.0214	0.012	5.146	0.34	11.553	1500	0.77
DCB5	16	222.24	519	600	0.0214	0.011	4.937	0.33	11.344	1500	0.76
DCB6	16	222.24	497	600	0.0214	0.011	4.727	0.32	11.135	1500	0.74
DCB7	16	222.24	440	600	0.0214	0.009	4.185	0.28	10.592	1500	0.71
DCB8	16	222.24	418	600	0.0214	0.009	3.976	0.27	10.383	1500	0.69
DCB9	16	222.24	396	600	0.0214	0.008	3.767	0.25	10.174	1500	0.68
DCB10	16	222.24	374	600	0.0214	0.008	3.557	0.24	9.965	1500	0.66
DCB11	16	222.24	352	600	0.0214	0.008	3.348	0.22	9.755	1500	0.65
DCB12	14	222.24	330	600	0.0214	0.007	3.139	0.21	9.546	1500	0.64
DCB13	14	222.24	258	600	0.0214	0.006	2.454	0.16	8.861	1500	0.59
DCB14	16	222.24	236	600	0.0214	0.005	2.245	0.15	8.652	1500	0.58
DCB15	16	222.24	214	600	0.0214	0.005	2.036	0.14	8.443	1500	0.56
DCB16	16	222.24	192	600	0.0214	0.004	1.826	0.12	8.233	1500	0.55
DCB17	16	222.24	170	600	0.0214	0.004	1.617	0.11	8.024	1500	0.53
DCB18	16	222.24	148	600	0.0214	0.003	1.408	0.09	7.815	1500	0.52
DCB19	16	222.24	91	600	0.0214	0.002	0.866	0.06	7.273	1500	0.48
DCB20	16	222.24	113	600	0.0214	0.002	1.075	0.07	7.482	1500	0.50
DCB21	16	222.24	135	600	0.0214	0.003	1.284	0.09	7.691	1500	0.51
DCB22	16	222.24	157	600	0.0214	0.003	1.493	0.10	7.901	1500	0.53
DCB23	16	222.24	179	600	0.0214	0.004	1.703	0.11	8.110	1500	0.54
DCB24	16	222.24	201	600	0.0214	0.004	1.912	0.13	8.319	1500	0.55
										Average of worst-case DCB Voltage drop	0.63

[Figure 5.2.2: Vertical Array DC Voltage Drop]

5.2 Interface Testing

The design of our solar power plant and substation does not follow many of the same processes as software design and testing. The testing sections are harder to interpret in terms of our project. Our project is split up into two major phases of design. The solar power plant is being designed in the fall semester, and the substation will be designed in the spring semester. Speaking in terms of our solar power plant design, there are a couple of "interfaces" that we are testing during design. One interface could be the wiring and design of the solar array itself. The second interface of the solar power system is the current inversion in the skid inverters and the feeders from the inverters to the substation.

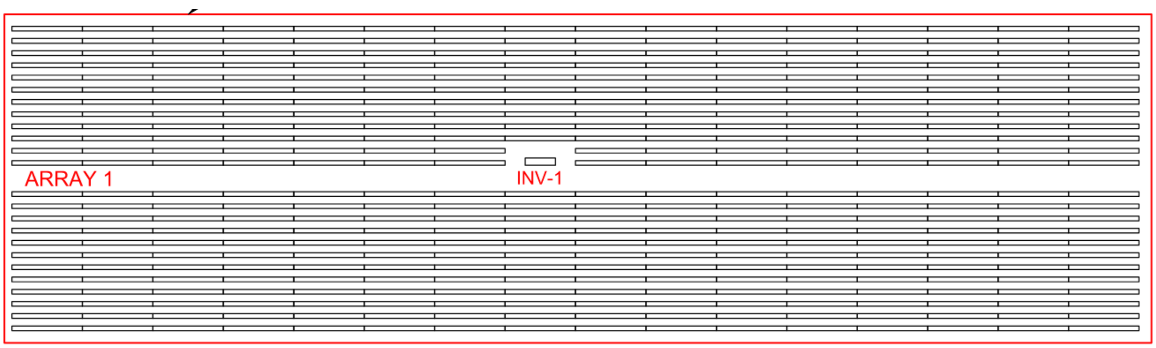
Calculations must be made to determine voltage drop and power being delivered from the solar strings to the combiner box. Then, the current and power are delivered to the inverter. After the current is inverted to AC. The voltage drop must be calculated from the feeder lengths between the substation and the inverters. There is very little the group can do to "test" the design of our solar power plant. However, the group does need to calculate voltage drop and voltage differences to ensure code compliance and maximum power usage of our system.

The tools we will use will be calculating spreadsheets to find voltage drop and power flow. Furthermore, the group will be using ETAP for power simulation to ensure our calculations are correct. Ensuring calculations and simulations are important to ensure safety and maximum use of power available.

5.3 Integration Testing

Some important paths in our project would be the paths from the solar panels to the inverters and the grid interconnection. We also have monitoring and control systems and safety and protection systems. For the path from the solar panels to the inverters, we have to test the efficiency of the panels, combiner boxes, and inverters, all under various conditions of input and other weather conditions. We also would test the panels' durability if we could have a physical panel. We plan to test the grid interconnection's power quality to see how well the substation would respond to a short circuit or possible lightning strikes. We also will test the entire system for anti-islanding protection. Anti-islanding protection protects system elements from blackouts. We will also test our monitoring and control systems with data accuracy and communication reliability. Then, we will test the safety and control systems with grounding calculations and add some circuit breakers for voltage spike protection.

5.4 System Testing



[Figure 5.4.1: Single Array]

The group has decided to integrate all system parts into one large test for the system testing. We will start with one array and then move to combining them. We start the system testing by calculating the voltage drop for each row. Then we combine the rows with each inverter. Once we have the full voltage drop for one array, we can use those values to calculate the AC voltage drops from the inverters to the substation. After calculating those units, we can start with the integration testing for the inverter and panel efficiencies for various weather conditions.

5.5 Regression Testing

To ensure that new features of our designs do not compromise previous ones, our team calculates new values to compare against the requirements of our project. Certain values of our project are set, such as the 60 MW output of the solar farm and the operating voltages of the substation. Our team uses calculations from equipment specifications to ensure that the overall parameters of the project are met and that each component fits within the acceptable operating range of every other component in the design. Values such as component voltage and current must combine to meet the overall requirements while also fitting within the requirements of each component. Any new components or layouts are tested via calculations to determine if they meet both of these requirements.

5.6 Acceptance Testing

Our team creates weekly presentations to keep our industry clients up-to-date on our design choices. In doing so, we present our calculations demonstrating the effectiveness of our designs as well as explaining our reasons for making each design decision. Most of our projects' design choices are numerical tolerances and individual/overall output values. These design choices are simple to demonstrate, relying on numerical analysis of component values and overall outputs. Other design choices, such as component spacing and layout, are less reliant on numerical analysis and are based on ease of access and design simplicity. These design choices are shown to our industry clients for review, allowing them to confirm their acceptance of the design or offer changes that they think would improve it.

5.7 Results

The results of the group testing will ensure that there will not be any additional work or redesign if someone wants to construct this solar array. The group cannot test physical components due to the size of the project, but ETAP will be used to compare the hand calculations of the voltage drops and currents of each component the group tests. Another result from the system testing was that the percentage of our voltage drops was in range with the NEC and what they expect from solar designs. We are happy that we could design something within specification on our first try.

6 Implementation

Our engagement with the project implementation will be indirect. The two semesters were dedicated to distinct but interconnected design projects, leaving us insufficient time to witness the solar farm or substation construction based on our designs. The entire implementation process will be managed by Black & Veatch.

7 Professionalism

This discussion concerns 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

7.1 Areas Of Responsibility

Area of Responsibility	Definition	NSPE Canon	IEEE Code of Ethics	Difference from NSPE Version
Work Competence	Perform work of high quality, integrity, timeliness, and	Perform services only in areas of their competence;	Ensure high standards of competence and strive for high-quality	The IEEE Code emphasizes both competence and high-quality performance,

	professional competence.	Avoid deceptive acts.	performance in their professional work.	aligning with the NSPE Canon.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees	Be accurate and honest in all professional interactions, including financial aspects. Strive to deliver products and services at a reasonable cost while maintaining quality and value.	Similarities in terms of honesty and integrity in financial dealings, with IEEE emphasizing accuracy and honesty.
Communication Honesty	Report works truthfully, without deception, and is understandable to stakeholders.	Issue public statements only objectively and truthfully; Avoid deceptive acts.	Be honest and realistic in stating claims or estimates based on available data.	A similar emphasis on honesty, but IEEE specifically mentions being realistic in statements, aligning closely with the NSPE Canon.
Health, Safety, Well-Being	Minimize risks to the safety, health, and well-being of stakeholders	Hold paramount the safety, health, and welfare of the public.	Consider the safety, health, and welfare of the public and the impacts of work on society. Strive to minimize negative impacts.	Both codes prioritize safety and well-being, but the IEEE Code broadens the focus to consider societal impacts, aligning closely with the NSPE Canon.
Property Ownership	Respects clients' and others' property, ideas, and information.	Act for each employer or client as faithful agents or trustees	Respect the proprietary information and intellectual property of others and protecting it appropriately.	Both codes emphasize respect for property and information, with IEEE specifically addressing intellectual property.

Sustainability:	Protect the environment and natural resources locally and globally		Contribute to the progress and application of technology for the benefit of society. Consider environmental impact and promote sustainable practices.	The IEEE Code explicitly addresses sustainability and the environmental impact of technology, which is not explicitly mentioned in the NSPE Canon.
Social Responsibility	Produce products and services that benefit society and communities	Conduct themselves honorably, responsibly, ethically, and lawfully to enhance the honor, reputation, and usefulness of the profession.	Strive to enhance the quality of life for society and communities by applying technology. Act responsibly to foster public trust and confidence.	Both codes stress the importance of benefiting society, with the IEEE Code specifying the role of technology in enhancing quality of life and public trust.

[Table 7.1.1: Area of Responsibility]

7.2 Project Specific Professional Responsibility Areas

Work Competence:

- Applicability: This is highly relevant as the design and implementation of a solar power plant and substation require a high level of engineering competence.
- Team Performance: The team consists of EE students under the supervision of Faculty and Advisor, with the clients of a solar company, Black and Veatch. The team's performance in this area is expected to be high.

Financial Responsibility:

- Applicability: This is relevant, especially considering the cost analysis aspect of your project. Design decisions can impact costs, and delivering value within budget constraints is crucial.-
- Team Performance: Cost analysis is done, and the result is seen based on the Return of Investment (ROI) in 10 years. The project can be implemented in real life if the overall cost analysis shows a positive outcome. The performance is expected to be medium to high.

Communication Honesty:

- Applicability: Truthful and clear communication is crucial in engineering projects, especially when presenting designs and analysis results to the faculty and clients.
- Team Performance: The team ensures that communication is honest, clear, and realistic in presenting claims or estimates based on available data. The performance should be at a high level.

Health, Safety, Well-Being:

- Applicability: Safety considerations are vital, especially in a solar power plant's construction and operation phases. This includes the safety of workers during installation and the impact on the community's well-being.
- Team Performance: The team is actively considering and minimizing risks to safety, health, and well-being, the performance should be high.

Property Ownership:

- Applicability: Respect for intellectual property is crucial, especially in the design phase where proprietary information and innovative solutions may be involved.
- Team Performance: The project will adhere to local policies and rules. The team appropriately respects and protects intellectual property, and the performance should be high.

Sustainability:

- Applicability: Sustainability is highly relevant since the project involves a solar power plant. The team needs to consider the environmental impact and promote sustainable practices.
- Team Performance: The team actively considers and incorporates sustainability practices in the design. The performance should be high.

Social Responsibility:

- Applicability: The project has a direct impact on society by providing electricity to local demand, residential, industrial factories, commercials, and public needs.
- Team Performance: The team is conscious of the societal impact, strives to enhance the quality of life through technology, and acts responsibly to foster public trust. The performance should be high.

In summary, the team's performance in each of the seven professional responsibility areas seems to depend on the team's awareness, commitment, and implementation of ethical considerations. Given the nature of the project, with a focus on sustainability and societal impact, the team has the potential to perform at a high level in these professional responsibility areas. However, ongoing vigilance and commitment to ethical considerations will be essential as the project progresses.

7.3 Most Applicable Professional Responsibility Area

For the project of designing a 60 MW solar power plant and a 115/34.5 kV substation, the most applicable professional responsibility area is likely Sustainability.

Given that the project involves the development of a solar power plant, a sustainable and renewable energy source, the team's actions and decisions directly impact environmental sustainability. The team must consider the long-term environmental effects, minimize the carbon footprint, and promote sustainable practices in designing and implementing the solar power plant. This includes aspects such as the selection of materials, energy efficiency, and the overall ecological impact of the project.

Sustainability aligns closely with the goals of designing and implementing solar energy projects, making it a key professional responsibility area for the team. It reflects the broader societal and global context of environmental awareness and the need for responsible engineering practices to address climate change and promote a sustainable future.

8 Closing Material

8.1 Discussion

Our project goal was to design a 60 MW solar farm and a 115/34.5 kV substation along with it. Our group thinks that we met our project goal and other project deliverables along the way. We worked directly with our clients to meet their needs and expectations. Using different sections of code, general knowledge, and input from our industry professionals and academic advisors, we designed a well-laid-out project that gives us room to expand. We have completed drawings for construction and a few for conceptual purposes so that we understood what we were building and the people building it understood what was being built.

8.2 Conclusion

During the initial semester, we accomplished the selection and sizing of components for the solar farm, scrutinized voltage drop, and explored various layout options. We have designed the whole solar farm layout and a simple one-line diagram of the substation. Additionally, we conducted a cost analysis to assess the return on investment over 10 years, and the outlook appears promising. Next semester, we will enhance the economic analysis by incorporating substation equipment, construction, and operational costs. Despite the supplementary cost associated with the substation, the project still exhibits a positive return on investment after a decade. The substation's design encompassed one-line diagrams detailing bus configuration, grounding, and overall substation layout, including breakers, lighting, and a transformer. These design specifications were meticulously chosen based on calculations to ensure the solar farm's safe and efficient operation. We are confident that this solar farm represents a robust investment for those seeking to contribute more renewable energy to US power.

8.3 References

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8.4 Appendices

TABLE 8 Conductor Properties

Size (AWG or kcmil)	Area		Conductors								Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall					Copper					
				Diameter		Diameter		Area			Uncoated		Coated		Aluminum	
	mm²	Circular mils	Quantity	mm	in.	mm	in.	mm²	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

Notes:

1. These resistance values are valid **only** for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.
2. Equation for temperature change: $R_2 = R_1 [1 + \alpha (T_2 - 75)]$ where $\alpha_{cu} = 0.00323$, $\alpha_{AL} = 0.00330$ at 75°C.
3. Conductors with compact and compressed stranding have about 9 percent and 3 percent, respectively, smaller bare conductor diameters than those shown. See Table 5A for actual compact cable dimensions.
4. The IACS conductivities used: bare copper = 100%, aluminum = 61%.
5. Class B stranding is listed as well as solid for some sizes. Its overall diameter and area is that of its circumscribing circle.

Informational Note: The construction information is in accordance with NEMA WC/70-2009 or ANSI/UL 1581-2001. The resistance is calculated in accordance with National Bureau of Standards Handbook 100, dated 1966, and Handbook 109, dated 1972.

[Figure 8.4.1: NEC Table 8 Conductor Properties]

1	**Documentation**			
1.1	Weekly Agenda	Baylor	08/30/2023	
1.2	Meeting Minutes	Bell	08/30/2023	
1.3	Bi-weekly report	Eli	08/30/2023	
1.4	Presentation Slides	ALL	08/30/2023	
1.5	Project Design Document (Preamble)	ALL	08/30/2023	
1.6	Final Report	ALL		
2	**Research**			
2.1	Data sheet Utility PV Solar Panel	Liam	9/12/23	9/20/23
2.2	Safety Moment	Eli	9/12/23	9/20/23
2.3	Data sheet for Combiner Box	Eduardo	9/12/23	9/20/23
2.4	Data sheet for Inverter	Chicheng	9/12/23	9/20/23
2.5	New Mexico Vs Iowa as location for power plant	Bell	9/12/23	9/20/23
2.6	Substation Design	Eli & Baylor	9/12/23	9/20/23
3	**Component Selection**			
3.1	Material components lists		9/14/23	9/20/23
3.2	Location	Bell	9/14/23	9/20/23
3.4	Substation Component (Main, and bus)	Eduardo	9/14/23	9/20/23

[Figure 8.4.2: Fall 2023 Gantt Chart Part A]

4	**Array Parameter Calculation**			
4.1	String size	Baylor	9/20/23	10/4/23
4.2	Electrical rack size	Liam	9/20/23	10/4/23
4.3	CB capacity	Liam	9/20/23	10/4/23
4.4	Array design	Liam	9/20/23	10/12/23
4.5	Array size	Liam	9/20/23	10/12/23
4.6	Total equipments	Liam	9/20/23	10/12/23
4.7	Total cost and budget	Bell	9/20/23	10/12/23
4.8	Total Power (AC & DC)	Liam	9/20/23	10/12/23
4.9	Voltage drop calculation	Bell	9/20/23	
4.1	Economic analysis	Bell		
5	**Designing Solar Panel (AutoCAD)**			
5.1	Solar Panel (key plan, elevation, grounding)	Liam		11/2/23
5.2	Array	Eduardo		11/2/23
5.3	Rack	Eduardo		11/2/23
5.4	Solar Layout	ALL		11/2/23
5.5	Solar Field Design	Eli & Baylor		
6	**Simulation (ETAP)**			
6.1	Designing Solar Power System	ALL		11/23/23
6.2	Assign requirements and value	ALL		11/23/23
6.3	Simulation	ALL		11/23/23
7	**Final Presentation**			
7.1	Black & Veatch Presentation	ALL		11/29/23
7.2	Faculty Presentation	ALL		12/6/23

[Figure 8.4.3: Fall 2023 Gantt Chart Part B]

1	**Documentation**	
1.1	Weekly Agenda	Baylor
1.2	Meeting Minutes	ALL
1.3	Bi-weekly reports	Eli
1.4	Presentation Slides	ALL
1.6	Final Report	ALL
2	**Initial Research**	
2.1	Substation Component	ALL
2.2	Safety Moment	ALL
2.3	One-line diagram of substation	ALL
2.4	Substation Design	ALL
2.5	Presentation Slides	ALL
3	**Component Selection**	
3.1	Bus and line	Liam
3.2	Main Component	Eduardo
3.3	Component Spec	Bell
3.4	Substation Component (Main, and bus)	Chicheng
4	**Calculation**	
4.2.1	DC battery calculation	Eduardo
4.2.2	Grounding calculation	Chicheng
4.3	AC load calculation	Baylor
4.4	Lightning calculation	Eli
4.3.1	Total equipment	Bell
4.3.2	Total cost	Bell
4.3.3	Total Power (AC & DC)	Liam

[Figure 8.4.4: Spring 2024 Gantt Chart Part A]

5	**Designing**	
5.1	One-line diagram of substation	ALL
5.2	Bus plan	ALL
5.3	Grounding diagram	ALL
5.4	Conduit diagram	ALL
5.4.1	Whole Solar and Substation Layout	ALL
6	**Simulation (ETAP)**	
6.1	Designing Solar Power System	ALL
6.2	Assign requirements and value	ALL
6.3	Simulation	ALL
7	**Final Presentation**	
7.1	Black & Veatch Presentation	ALL
7.2	Faculty Presentation	ALL

[Figure 8.4.5: Spring 2024 Gantt Chart Part B]

8.4.1 Team Contract

Team Members:

1) Baylor Clark
2) Elymus Schaffer
3) Eduardo Jimenez-Tzompaxtle
4) Chicheng Tang
5) Liam Gozzman
6) Siti Mohd Radzi

8.4.1.1 Team Procedures

8.4.1.1.1 Day, time, and location (face-to-face or virtual) for regular team meetings:

3 o'clock on Wednesdays in the library, room dependent.

8.4.1.1.2 Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face):

Discord for online meetings and regular updates (reminders, issues)

Email will be used as a communication channel between clients, TA, and project advisor.

8.4.1.1.3 Decision-making policy (e.g., consensus, majority vote):

Majority vote while considering situations and cases by creating issues on GitLab.

Gitlab for team progress tracking and task delegation

8.4.1.1.4 Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived):

Meetings will be recorded through meeting minutes and shared in the Google Drive and GitLab by Siti Nabila (Bell)

8.4.1.2 Participation Expectations

8.4.1.2.1 Expected individual attendance, punctuality, and participation at all team meetings:

Record all meeting minutes with any meeting you have with anyone, you and the group or you and any advisor or client.

Team members are expected to attend all meetings (regular, TA meetings, Advisor meetings, and client meetings) and be punctual for meetings; in case of absence or late, notice should be given to the whole team.

8.4.1.2.2 Expected responsibility for fulfilling team assignments, timelines, and deadlines:

Tasks will be assigned in GitLab with a date attached to it to create a time frame and deadlines for the assignments.

Individual progress will be tracked weekly or daily, depending on the time frame for each assignment.

Teams are expected to keep up with everyone's progress on individual tasks.

Loose deadlines will be set up to ensure that hard deadlines can be met.

8.4.1.2.3 Expected level of communication with other team members:

Response within a day is expected.

8.4.1.2.4 Expected level of commitment to team decisions and tasks:

Varying upon weeks but ensuring that everyone is included in team decisions.

8.4.1.3 Leadership

8.4.1.3.1 Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):

Baylor: Team Organizer

Bell: Recorder and Testing

Liam: Client Correspondent

Chicheng: Research and Testing

Eduardo: Submission

Eli: Team Lead

8.4.1.3.2 Strategies for supporting and guiding the work of all team members:

If someone asks for help, you help them with the preface of you're working on something else first then can help them.

8.4.1.3.3 Strategies for recognizing the contributions of all team members:

Voicing your opinions on team issues and then weekly recognition from the Issues Board.

8.4.1.4 Collaboration and Inclusion

8.4.1.4.1 Describe the skills, expertise, and unique perspectives each team member brings.

Baylor Clark: I have experience with project management and team communication through internships over the past two summers. I also have experience working on projects with a couple of the other group members from previous classes.

Elymus Schaffer: I bring my extrovert personality to help me invoke thought-provoking questions and discussions for our team. I have also worked for companies throughout semesters while keeping my grades up and communicating effectively with my employer. I know about creating a Bill of Materials and being able to help schedule who does what and when.

Eduardo Jimenez-Tzompaxtle: I have experience working with a group and communicating with people. I have taken some classes in transmission and power

Chicheng Tang: I have experience collaborating with team members to complete the work. And I have taken a class about distribution and transmission systems.

Liam Gossman: I have experience with substation design and general operations through my internships at MidAmerican Energy. I also have experience with distribution systems design and effective communication skills necessary for collaboration between different design departments.

Siti Mohd Radzi: I have numerous experiences working in a team, from various work environments, from working for technical projects, student organizations, volunteering programmes, and fundraising; I believe I would be able to contribute to creating a healthy work environment within the team, by ensuring the expectation and performance of the team is consistent and good.

8.4.1.4.2 Strategies for encouraging and supporting contributions and ideas from all team members:

Asking everyone what they think on each topic and congratulating each other when a task gets completed.

8.4.1.4.3 Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment obstructs their opportunity or ability to contribute?)

Talk to the group during the weekly meetings, knowing that not everyone is perfect. Google survey about weekly personal performance.

8.4.1.5 Goal-Setting, Planning, and Execution

8.4.1.5.1 Team goals for this semester:

Making sure everyone is on the same page and making sure that we communicate well and know what we are doing.

8.4.1.5.2 Strategies for planning and assigning individuals and teamwork:

Ensuring everyone has a task for the week and ensuring they are mostly even.

8.4.1.5.3 Strategies for keeping on task:

Setting "loose" deadlines for tasks as well.

8.4.1.6 Consequences for Not Adhering to Team Contract

8.4.1.6.1 How will you handle infractions of any of the obligations of this team contract?

Bring the problems up in the group meetings and find a way to solve the problem.

Give the individual or team a time frame to settle the issue and track the progress until the issue is resolved.

8.4.1.6.2 What will your team do if the infractions continue?

Bring it up to the professor if continuous for an extended period.

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) ____Elymus Schaffer________________________________ DATE ___12/02/2023______

2) ____Baylor Clark___________________________________ DATE __12/02/2023_______

3) ____Chicheng Tang_________________________________ DATE __12/02/2023_______

4) ____Liam Gossman_________________________________ DATE __12/02/2023_______

5) ____ Eduardo Jimenez-Tzampotxle___________________ DATE __12/02/2023_______

6) ____Siti Mohd Radzi ________________________________ DATE __12/02/2023_______