115/34.5KV Solar Plant & Substation Design Project

DESIGN DOCUMENT

Team Number: 41

Client: Black & Veatch

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Revised: November 6th 2024

1. Introduction

1.1 PROBLEM STATEMENT

Nowadays, the world faces growing concerns over climate change and the increase of non-renewable energy resources, the need for sustainable energy solutions has become increasingly urgent. Traditional energy sources, such as coal and natural gas, contribute significantly to environmental degradation and greenhouse gas emissions. As global attention shifts toward renewable energy to mitigate these effects, large-scale solar power plants have emerged as a crucial solution. The 115/34.5 kV Solar Plant & Substation Senior Design Project will be implemented in Luna County, New Mexico. Our clients Black & Veatch aims to address the challenges associated with transitioning to cleaner energy. Black & Veatch is a consulting company and working in collaboration with us ISU students (group41) for designing this solar plant to generate clean, sustainable electricity that can be efficiently integrated into the local power grid. Luna County, with its abundant solar resources, provides the ideal environment for implementing solar energy on a large scale.

This project not only contributes to minimizing carbon emissions or provide job opportunities in New Mexico, but also supports the global shift toward renewable energy. Using engineering concepts, we will implement an additional way to generate renewable energy and integrate it into the electrical systems by designing a 60MW solar farm and substation. We will be focusing on designing the solar plant for the first semester, then work on the substation for the second semester.

1.2 INTENDED USERS

1.2.1. Utility Companies

- Description: Utility companies responsible for distributing electricity to residential, commercial, and industrial sectors.

- Need: As part of the energy transition, utility companies require reliable, sustainable power sources to meet demand, reduce emissions, and comply with renewable energy regulations.

- Benefit: The solar plant will provide a consistent, renewable power supply that utility companies can distribute to their customers. This supports their goals of reducing environmental impact while ensuring a stable energy supply. Additionally, utility companies can benefit from lower operational costs due to the long-term savings associated with solar energy.

1.2.2. Black & Veatch Clients

- Description: Corporations, municipalities, or governments that engage Black & Veatch to develop renewable energy solutions.

- Need: These clients seek to invest in sustainable infrastructure projects that align with their environmental goals and corporate social responsibility initiatives. They also require innovative, cost-efficient designs that can be scaled or replicated for future projects.

- Benefit: Through this project, clients of Black & Veatch will gain a model for developing large-scale solar plants, benefiting from the company's engineering expertise and track record in renewable energy.

1.2.3. Local Communities in Luna County

- Description: Residents and businesses in the Luna County region who will directly benefit from the availability of clean energy.

- Need: Access to affordable, reliable, and clean electricity is a growing concern for local communities, especially in regions where energy costs are high and non-renewable sources dominate.

- Benefit: The solar plant will provide local residents and businesses with a reliable source of clean electricity. This can lead to lower energy bills, reduced dependence on non-renewable resources, and a smaller environmental footprint for the community. The project also enhances local job opportunities during the construction and operation phases.

2. Requirements, Constraints, And Standards

2.1. REQUIREMENTS & CONSTRAINTS

- Equipment sizing calculations (solar panels, inverters, 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
- Additional calculations (AC, DC, lightning protection, etc.) – Excel files
- Simulation of designed substation – SIMULATION SOFTWARE – STUDENT LICENSE [ETAP/SKM/ASPEN]
- Load Flow Analysis / AC Arc Flash Study / Protection Element Analysis – SIMULATION SOFTWARE – STUDENT LICENSE
[ETAP/SKM/ASPEN]
- Creation of solar/substation conceptual design-optimizing tool – Microsoft Access/TBD

2.2. ENGINEERING STANDARDS

1. **NEC2020- (National Electrical Code)**

   This is a comprehensive set of safety standards developed to ensure safe electrical design, installation, and inspection practices across a wide range of electrical systems, including substations. We believe it is relevant to our project because it covers wiring and protection, equipment for general use, grounding, and bonding, along with other electrical installations. The goal is to protect people and property from electrical hazards by defining standards that minimize the risk of fires, electrical shock, and failures in power systems.

2. **IEEE 1547.3-2023**

   This standard focuses on the **interconnection of distributed energy resources (DERs),** such as solar arrays with the electrical grid. We believe that this is relevant to our project because according to our model, we might potentially have 15 solar arrays in our design project and this standard will ensures that our solar plants can connect to the grid while maintaining stability. In addition, the standard addresses how to keep voltage levels within acceptable limits during power transfers to and from the grid, ensuring reliable and safe grid operations, especially with increasing renewable energy integration.

3. **IEEE 2778-2020**

   This standard guides the **grounding system design for utility-scale photovoltaic (PV) solar power plants**. Grounding is crucial for ensuring safety and operational integrity by minimizing the risks of electrical faults, overvoltage, and shock hazards. We believe that this standard is relevant because it is designed for solar power plants larger than 5 MW, (which is our case) helping utilities design safe and efficient grounding systems that comply with regulatory requirements and improve the overall resilience of the plant.

After discussing with the team, some of my team members have chosen other standards, such as **IEEE 519-2014**, which focuses on harmonics in electrical systems. This is critical in managing the power quality in our solar plant. Others have also referenced **IEC 62109**, which deals with the safety of power converters used in solar installations, ensuring that inverters and similar equipment meet global safety requirements. Finally, based on the above standards, we plan to make the following modifications to our project design:

- **Grounding system adjustments**: We will incorporate the guidelines from **IEEE 2778-2020** to ensure that our grounding system is strong enough for utility-scale operation, with a special focus on safety during fault conditions.
- **Grid interconnection features**: We will apply **IEEE 1547.3-2023** to properly ensure that our solar plant maintains voltage stability and power quality while exporting power to the grid.
- **NEC 2020 compliance**: We will make sure that all electrical installations within the substation conform to **NEC 2020** to prevent electrical hazards, optimizing the layout and wiring based on safety standards.

3. Project Plan

3.1. PROJECT MANAGEMENT/TRACKING PROCEDURES

Our team has adopted the Waterfall project management style to structure and guide the progression of our senior design project. The Waterfall method emphasizes a sequential, linear approach where each phase must be completed before advancing to the next. This ensures that every stage, from requirements to design, implementation, verification, and maintenance, is thoroughly addressed before moving forward.

While we are not strictly following an Agile methodology, our advisor stressed the importance of leadership and adaptability, key Agile principles. In response, we've implemented a rotating leadership structure, allowing team members to take on leadership roles at different stages of the project. This not only promotes a shared sense of responsibility but also gives each team member the opportunity to guide specific aspects of the project. This role rotation helps us remain flexible and dynamic, fostering collaboration and responsiveness to challenges, much like Agile's focus on adaptability.

Although our project flow remains rooted in the Waterfall method, this approach to leadership ensures we maintain open communication and can quickly address any issues that arise. In practice, we recognize that it's common to revisit earlier phases to refine designs or resolve problems, and our team is prepared to allow for some overlap between phases if needed.

One of the key reasons we chose the Waterfall methodology is its structured, sequential approach through the project phases. The clear milestones and well-defined deliverables at each stage help us maintain focus and direction, while minimizing the need for frequent iterations once the initial designs are finalized. This approach offers more predictability, a well-ordered schedule of tasks, and comprehensive documentation, making it easier to detect potential issues early in the planning or design stages. As a result, the Waterfall method offers the control and structure that suits the complexity of our project.

Our Gantt chart reflects this waterfall structure, helping us track tasks and design progression in a clear and organized manner. Additionally, the group will use SMS for quick communication and Cybox for file management and updates, ensuring seamless tracking of design phases and task assignments. Although we aren't using Agile in its pure form, we incorporate its principles by emphasizing regular check-ins and early detection of obstacles, allowing for a smooth progression through the phases of our senior design project.

3.2. TASK DECOMPOSITION

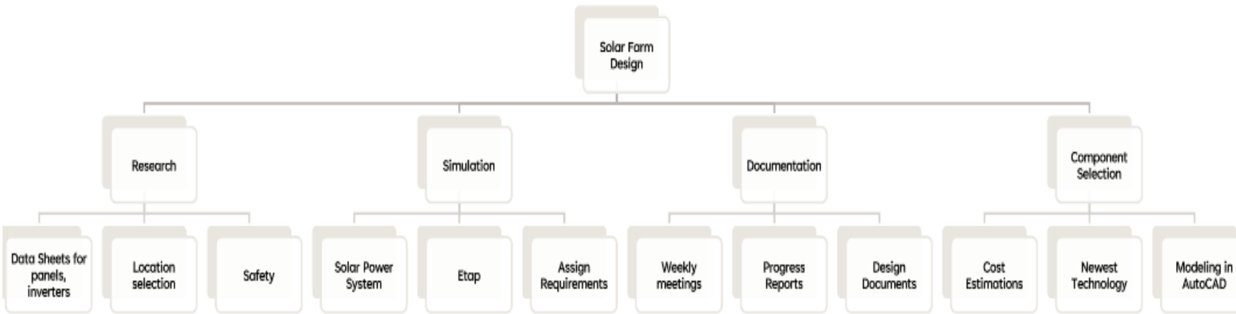
Our team has decomposed our project into many different tasks. These tasks can be applied throughout every step of our waterfall project management style. The decomposition of the tasks helps us understand what needs for the project. This includes: research, simulation, documentation, and component selection.

For the research component of our decomposition, we have broken it down into 3 parts: component data sheets, location, and safety. These are the main things that we have started our project with. We are unable to progress through the waterfall if we do not do our research on these things as everything we do will depend on them. There are other tasks that fall under the research category such as our weekly safety moments and new technologies. These are a short part of our weekly presentation that give us insight into the industry. As we continue through our project there will be other things to research such as how to use software and how to do certain calculations.

Moving to the simulation component this mostly applies to the later part of both our solar farm and substation design. We will be doing a separate simulation for each of these things using ETAP. We will be able to ensure our design meets the set requirements and operates as intended. This task is very important because if it does not function as intended then we must go back and redesign our project to get it up to standard.

Our project also involves large amounts of documentation for everything. We have weekly meetings, progress reports, and design documents to make. These tasks are separate from the waterfall progression of our project. These are to keep us up to date and on target for the tasks that make up the waterfall. For our weekly meetings we take notes and send them to all attendees to make sure we are on the same page for what we have to do. Relating to the main tasks of the project we have to document all research that we do in order to complete them. We also create drawings and have excel spreadsheets for calculations. This falls under things we are documenting as they are the key deliverables of the project.

The final part of the decomposition is component selection. This comes after a lot of our research and also applies to both the solar farm and substation. From our research on components, we need and their data sheets, we will select the components we think will work best for our design. We also consider factors such as cost, and how new the technology is. After we do this, we can begin our initial design with these components and make models on AutoCAD.



3.3. PROJECT PROPOSED MILESTONES, METRICS, AND EVALUATION CRITERIA

Throughout our project we will be using many different milestones and metrics to track our progress. Many of these milestones apply to both the solar array and substation part of our project. There are some that are task specific but can still fall under the same categories. We are able to numerically evaluate many parts of our project and that gives us very specific metrics that we can follow.

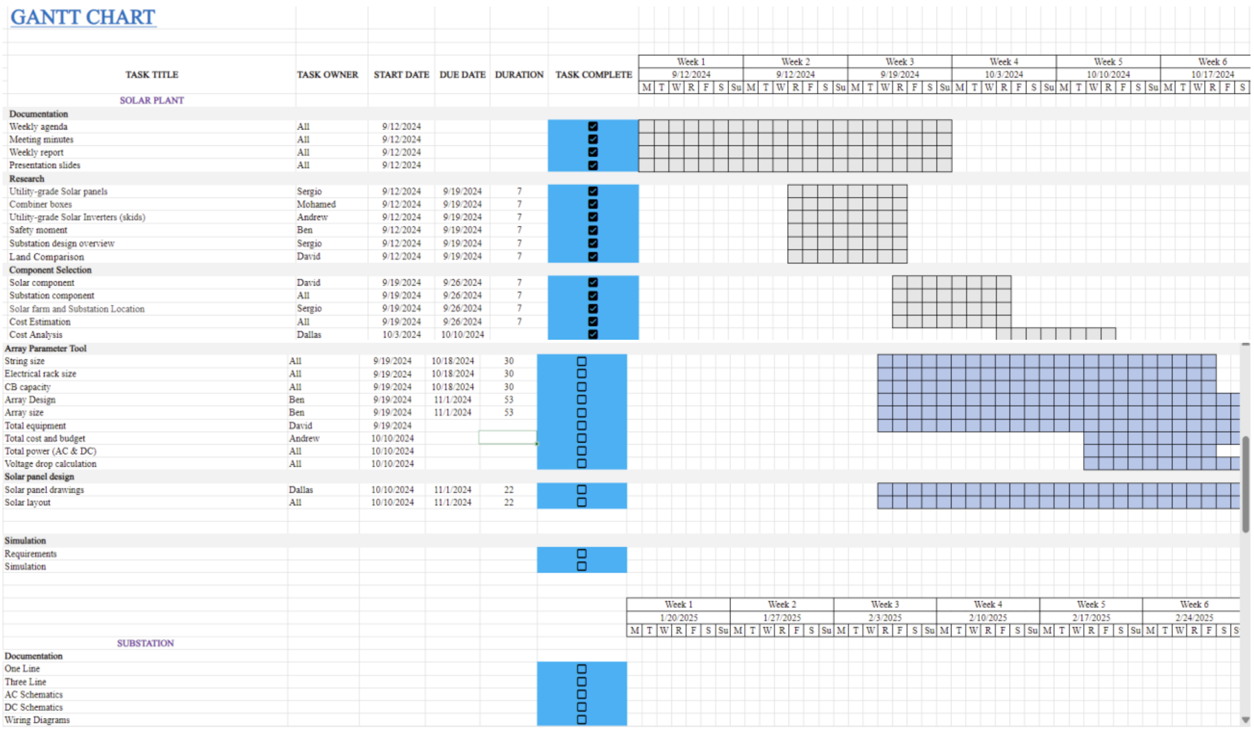
For the solar array we have requirements such as the power output, voltage drop throughout the array, and efficiency of our array. The solar array is required to output 60MW of AC power at peak production with less than a 5% voltage drop throughout the array. We also want to avoid losses of power so we want the array to be efficient. We do this through component selection, location selection, and site design. For example, we have chosen our site to be in Luna County, New Mexico. This provides us with higher irradiance which allows us to generate more power. The site also has a higher average of sunshine per year than other places in the U.S. such as Ames. We have also chosen to have our panels face south with a 30-degree tilt which optimizes the sunlight hitting the panels year-round. With these things together we are aiming to have a 75% efficiency of how much power the array is generating compared to if it was generating 60MW all the time.

For the substation part of the project, we have different milestones and metrics that we will be using. Our major milestones for this part include completion of detailed drawings, calculations, simulations, and cost and component analysis. We will be following similar metrics to the solar array part of the project such as efficiency, power, and voltage drop requirements. We don't have exact numbers because we haven't started this part of the project but as we work on it, we will be able to develop our metrics we want.

Finally, for our complete project we will be able to evaluate our work as it relates to IEEE standards and other industry standards. We will be following these standards as we work but we will want to ensure compliance with these for our final product. We also are able to have our industry and academic advisors review our work to ensure that it is standard for what is done by experienced engineers.

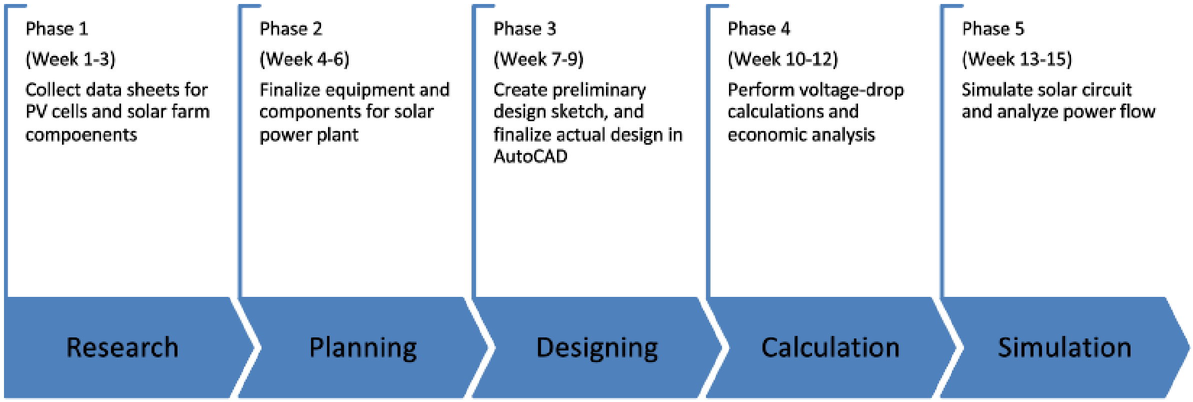
3.4. PROJECT TIMELINE/SCHEDULE

The Gantt chart serves as a crucial tool for our project, serving as a visual representation of our schedule. It clearly lists the duration and sequence of each task, ensuring that our client will have an understanding of the project's progression within the defined timeframe. This chart will be regularly referenced and summarized within project documentation to emphasize key milestones and deliverables across both semesters. By doing so, it will ensure there is a clear alignment between individual tasks and the project's overarching objectives. Including this chart in presentations and reports will facilitate effective communication, help track project progress, and allow for timely adjustments. This will overall enhance the strategic execution of our project and set our team up for a successful completed project.

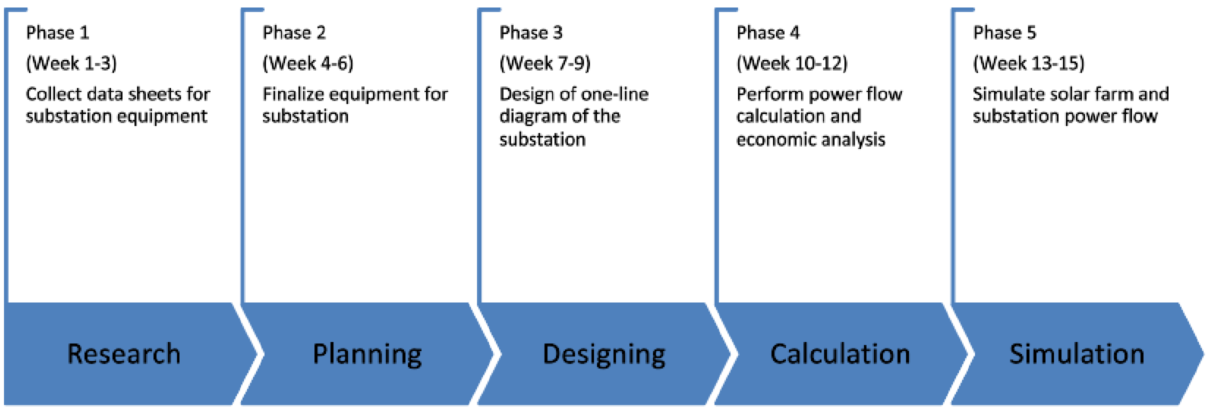


GANTT CHART

TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	TASK COMPLETE
SOLAR PLANT					
Documentation					
Weekly agenda	All	9/12/2024			☑
Meeting minutes	All	9/12/2024			☑
Weekly report	All	9/12/2024			☑
Presentation slides	All	9/12/2024			☑
Research					
Utility-grade Solar panels	Sergio	9/12/2024	9/19/2024	7	☑
Combiner boxes	Mohamed	9/12/2024	9/19/2024	7	☑
Utility-grade Solar Inverters (skids)	Andrew	9/12/2024	9/19/2024	7	☑
Safety moment	Ben	9/12/2024	9/19/2024	7	☑
Substation design overview	Sergio	9/12/2024	9/19/2024	7	☑
Land Comparison	David	9/12/2024	9/19/2024	7	☑
Component Selection					
Solar component	David	9/19/2024	9/26/2024	7	☑
Substation component	All	9/19/2024	9/26/2024	7	☑
Solar farm and Substation Location	Sergio	9/19/2024	9/26/2024	7	☑
Cost Estimation	All	9/19/2024	9/26/2024	7	☑
Cost Analysis	Dallas	10/3/2024	10/10/2024		☑
Array Parameter Tool					
String size	All	9/19/2024	10/18/2024	30	☐
Electrical rack size	All	9/19/2024	10/18/2024	30	☐
CB capacity	All	9/19/2024	10/18/2024	30	☐
Array Design	Ben	9/19/2024	11/1/2024	53	☐
Array size	Ben	9/19/2024	11/1/2024	53	☐
Total equipment	David	9/19/2024			☐
Total cost and budget	Andrew	10/10/2024			☐
Total power (AC & DC)	All	10/10/2024			☐
Voltage drop calculation	All	10/10/2024			☐
Solar panel design					
Solar panel drawings	Dallas	10/10/2024	11/1/2024	22	☐
Solar layout	All	10/10/2024	11/1/2024	22	☐
Simulation					
Requirements					☐
Simulation					☐
SUBSTATION					
Documentation					
One Line					☐
Three Line					☐
AC Schematics					☐
DC Schematics					☐
Wiring Diagrams					☐



Spring 2025 – Substation Design



Shown in the figure above is a structured, semester-wise timeline for the design phases of our solar power plant and a substation project, spanning Fall 2024 and Spring 2025. Each semester is divided into five distinct phases—Research, Planning, Designing, Calculation, and Simulation. In Fall 2024, the focus is on designing the solar power plant, starting with the research and collection of data sheets for photovoltaic cells and other components, moving through planning and selection of equipment, then leading to detailed AutoCAD design and simulation of circuit performance and power flow. Spring 2025 shifts focus to the substation, following a similar phase structure, beginning with the research of substation equipment, to planning and finalizing the equipment, creating detailed one-line diagrams, and performing necessary calculations and simulations to ensure efficient operation and profitability. Each phase is planned to ensure a seamless transition from research to practical design and operational testing, laying a strong foundation for a successful project.

3.5. RISKS AND RISK MANAGEMENT/MITIGATION

One significant risk is inaccurate calculations for arrays and inverters, which could lead to performance issues. With a moderate-to-high chance, we'll address this by regularly validating calculations and, if necessary, using advanced software. Dedicated sprints will refine these calculations and verify performance. There's also a risk of non-compliance with local standards, which could cause delays. To manage this, we'll keep up with compliance checks, assign team members to research regulations, and use standard templates if needed.

Data entry errors in the array tool also pose a risk, affecting sizing and load calculations. To reduce this, we'll use automated data validation in the tool and rely on weekly reviews to catch errors early. This agile approach allows us to focus each sprint on high-priority risks, using weekly Black & Veatch reviews for oversight, to keep the project aligned with technical goals and regulations.

3.6. PERSONNEL EFFORT REQUIREMENTS

Task	People	Expected Person hours
Utility-Grade Solar panel Research	Sergio	7
Combiner Box Research	Mohamed	7
Utility-Grade Solar Inverters (skids) Research	Andrew	7
Substation Design Overview	Sergio	7
Land Comparison	David	7
Solar Component Selection	David	7
Substation Component Selection	All	7
Solar Farm and Substation Location	Sergio	7
Cost Estimation	All	7
Cost Analysis	Dallas	10
String Sizing	All	30

Electrical Rack Sizing	All	30
CB Capacity Selection	All	30
Array Design	Ben	25
Array Sizing	Ben	25
Total Equipment Estimation	David	25
Total Cost & Budget Estimation	Andrew	22
Voltage Drop Calculations	All	22
Solar Panel Drawings	Dallas	22
Solar Layout	All	22

The table presented above details the distribution of tasks, assigns responsibilities to specific team members, and estimates the person-hours required for each task within our project framework. This approach ensures clarity in roles and expectations for each team member. This allows for effective management and coordination across various project segments. By allocating tasks and estimating the time each team member will spend on their assigned duties, we aim to optimize productivity and maintain a clear roadmap towards successful project completion. This organization will improve operational efficiency and also allows for transparent monitoring and adjustment of resources as needed throughout the project lifecycle.

3.7. OTHER RESOURCE REQUIREMENTS

To help us with our design and tasks, we have utilized AutoCAD, BlueBeam, and Excel. We are using AutoCAD to draft our technical drawings of the farm. We have drafted our sonar panels, the array layouts, and the farm layout. Our one-line drawings are also being implemented on AutoCAD. Bluebeam will be used for our clients to give us feedback on our AutoCAD drawings so it is easier to comment on. Our clients have been giving us certain Excel spreadsheets to aid us with our calculations throughout our design process and layout. ETAP will help us with our substation simulations and design.

4. Design

4.2. DESIGN EXPLORATION

4.2.1 Design Decisions

In designing our solar farm and substation in Deming, New Mexico, we've had to make several critical decisions to ensure the project's success. Here are three of the most important:

- Location Choice (Deming, New Mexico)

We started by comparing two proposed locations—Iowa and New Mexico—and ultimately chose Deming, New Mexico. It offers some of the best solar potential in the U.S., with high sunlight exposure and few cloudy days. The solar irradiance levels in Deming range from 5.75 to over 6.50 kWh/m² daily, making it one of the most promising areas for solar energy production. With more sunny days and a climate well-suited to solar, Deming provides both higher energy production and a better return on investment.

Additionally, land costs are low at $6,000 per acre, and financial incentives like the Federal Investment Tax Credit (30%) and New Mexico's state-level tax credit (up to 10%) make the location even more financially attractive.

- Proximity to High-Voltage Transmission Lines

One major advantage of the Deming site is its closeness to existing high-voltage transmission lines, which minimizes the infrastructure we'd need to connect to the grid. These connections make it easier to transport energy to nearby cities like Albuquerque and Santa Fe, lowering both transmission costs and logistical challenges. With quick access to major routes like I-10 and U.S. Route 180, getting materials and deploying the workforce is also simpler and more efficient.

- Site Layout and Room for Expansion

We're designing the layout to include space for the solar farm and a substation, along with room for future expansions. This flexibility is key for adapting to future demand. By planning for growth now, we ensure that the project can expand without significant restructuring later on. Deming's climate also brings a relatively low risk of hail, so with the right layout, we can improve the plant's durability and long-term reliability while keeping maintenance costs manageable.

These choices help set our solar farm project up for both immediate efficiency and future growth. Together, they create a strong foundation for a successful and sustainable solar installation in Deming.

4.2.2 Ideation

Our primary decision was to select Deming, New Mexico, as the location for our solar farm. We evaluated Iowa and New Mexico across several vital factors to make an informed choice. This structured approach allowed us to identify sub-options that would determine the project's feasibility and return on investment in each location.

We applied structured analysis to identify options by evaluating both Iowa and New Mexico based on the following five critical criteria:

- Solar Radiation and Energy Production

We considered two main options for maximizing power output: selecting a location with high solar irradiance or exploring alternative solar technologies to boost efficiency. Ultimately, we chose New Mexico, which has daily solar irradiance levels between 5.75 and 6.50 kWh/m²—

significantly higher than Iowa. This choice provides a substantial increase in energy production potential and a promising return on investment.

- Land Availability and Cost

We considered two options to secure land for the solar installation: purchasing affordable land or exploring leasing opportunities, particularly in high-cost areas. In New Mexico, the cost of land was $6,000 per acre, which provided a financially attractive option for large-scale development. Given its affordability and ample availability for expansion, New Mexico emerged as the most viable choice, supporting both current project needs and future growth potential

- Proximity to High-Voltage Transmission Lines

We considered two options for grid access: selecting a site near existing transmission lines to reduce infrastructure costs or investing in additional infrastructure for locations farther from the grid. Deming's proximity to high-voltage transmission lines offered a straightforward and cost-effective solution for grid connectivity, making it the optimal choice for our project.

- Weather and Environmental Resilience

We evaluated two options to ensure reliable solar energy production: selecting a location with consistently favorable weather year-round or considering areas with mild climate risks and minimal severe weather. Deming, New Mexico, stood out with its low risk of hail and other adverse weather conditions, which promises reduced maintenance needs and greater reliability for energy production

- State Financial Incentives

Regarding the project's financial viability, we considered two options: selecting a location with strong state incentives or relying solely on federal incentives where state support was limited, as in Iowa. New Mexico offered a 10% state tax credit in addition to the federal credit, making it a more attractive choice by significantly boosting the project's potential returns

4.2.3 Decision-Making and Trade-Off

For selecting the main component for our project especially the combiner boxes, inverter and solar panels we compared different options to find the best fit based on performance, cost, durability, and scalability. Here's how we approached the decision-making process and arrived at our final choices.

Identifying Key Factors:

> **Efficiency**: Higher efficiency means we need fewer components and less land, which can lower costs.
> **Cost**: We looked at both the upfront cost and long-term savings from reliable components.

Weighing Trade-Offs:

PV Modules:

Monocrystalline: These are the most efficient, meaning we need fewer panels to reach our power target, saving on land costs. Although they cost a bit more upfront, they're reliable and have a longer lifespan, making them more cost-effective over time.
Polycrystalline: These are cheaper but less efficient, so we would need more panels and land, which would increase maintenance costs.
Thin-film: These are the least expensive per watt, but they're much less efficient, meaning we'd need even more land and they would degrade faster, leading to higher long-term costs.

Combiner Boxes:

NEMA4 This option offers high protection against weather, which is crucial for an outdoor, utility-scale setup. It's a bit more costly, but the durability justifies the expense by reducing the need for repairs.
NEMA 3R: A more affordable option, but with lower protection ratings, meaning it might not hold up as well in harsh outdoor conditions.

Inverters:

High-Capacity Inverter: This inverter is highly efficient and scalable, meaning it can handle large power loads and allows for potential future expansion.
Moderate-Capacity Inverter: This option is less costly but less efficient and not as flexible.

Final decision:
Monocrystalline PV Modules for their high efficiency and long-term cost savings.
NEMA 4 Combiner Boxes for their durability and protection, making them reliable in outdoor settings.
High-Capacity Inverters for their efficiency, scalability, and low harmonic distortion, which aligns with our utility-scale needs.

4.3 PROPOSED DESIGN

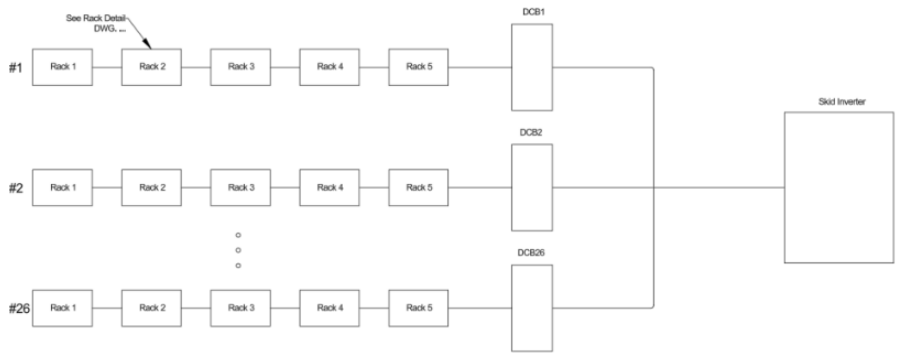
4.3.1 Overview

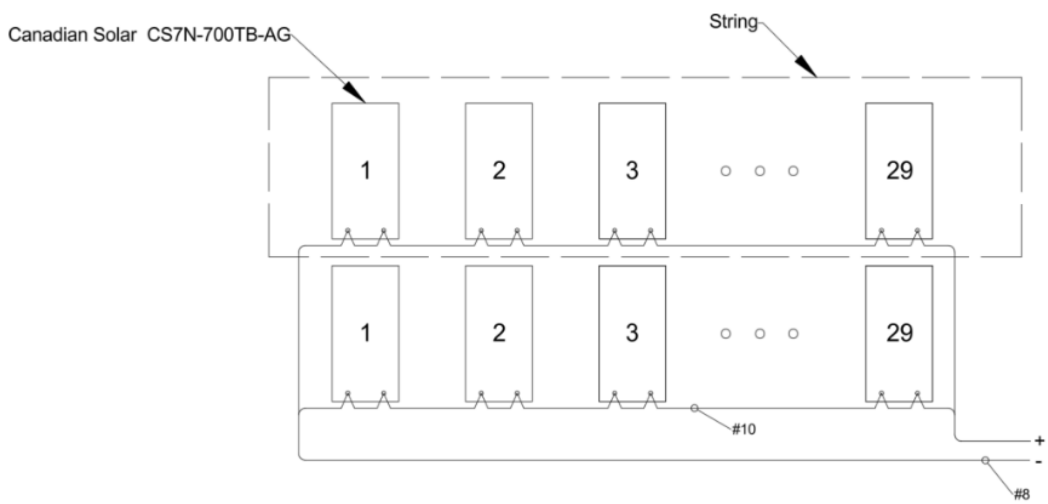
We are beginning our project by designing a solar array. This has many key components making it up. Starting at the lowest level you have a photovoltaic (PV) module. This is what makes up a solar panel. Solar panels can be connected in series or parallel to make a string. In our design we connected two strings to create a rack of panels. The rack is designed to have a certain voltage and current rating that relates to the DC combiner box. The DC combiner box takes multiple rack outputs and combines them into a single output. The array is designed to output a certain amount of power, in our case 60 MW. To reach this power requirement we have several arrays and therefor a large number of combiner boxes. The outputs of the combiner boxes are brought to a central inverter where the DC current and voltage is converted to AC. They are also combined into a single AC output. In our design we have 15 inverters, these 15 inverter outputs are brought together inside the substation.

Once the solar array design is completed, we will move into the substation design. We will be doing research on design philosophies for the substation. We know that we will be using circuit breakers, buses, switches, and transformers inside our substation. The main purpose is to step up the 34.5kV voltage to 115kV while also having protection elements for the rest of the power grid. To protect the rest of the grid we will have relays watching the currents flowing through the substation. If there is an overcurrent or current flowing in the wrong direction the circuit breakers will open to prevent problems in the rest of the grid.

4.3.2 Detailed Design and Visual(s)

There are a large number of calculations that go into designing a solar array. Black & Veatch has provided us with an array parameter tool to aid with the calculations. We start by selecting a solar panel and using its data sheet to extract key values we need for our design. We will use the open circuit voltage, and short circuit current to design our array. Based on the ratings of our combiner box we will design our rack to correspond to that. Our combiner box is rated for 1500V and 320A. We will design our string to have 1500V which takes 29 modules to achieve. Using the short circuit current we find that we can connect 11 strings to each combiner box (max current divided by short circuit current). Then we use the ratings of the inverter we selected we can find the number of racks we need in each array. Due to losses inside the inverter, we want the DC power the be 30% higher than the AC output we want. We achieve this by adding more racks into the array. In our design the inverter is rated for 4095 kW and our DC power per array is 5274 kW. To reach the 60 MW we want we will have 15 arrays and inverters in our total design.





These two drawings give an idea into how the solar farm is laid out. It shows how the racks connect to the combiner box and then the combiners boxes go into the inverter. In the more detailed drawing, you can see how the panels are individually connected to make a string. You can also see the size of cable we will be using and the number of panels.

The cable sizing comes from the voltage drop calculations we will be performing. This will affect the placement of all the components in our array and it will help us decide what cable sizes we will be using to connect everything. We have another tool from Black & Veatch to do this. We input various parameters of our array like the number of racks per combiner box, and distances between components. Based on the voltage, current, and length we will be able to calculate the voltage drop through the cables. This comes from the equation: V*I*R*L/1000. If the voltage drop is too high, we will increase the cable size which decreases the resistance through the cables.

4.3.3 Functionality

Our design of the 115/34.5 kV Solar Plant and Substation in Luna County, New Mexico, aims to operate seamlessly in a real-world setting, providing clean energy to utility companies and local communities. Here's how it works:

How Users Interact: Utility companies, Black & Veatch clients, and local residents benefit from the system without directly managing it. The solar plant generates renewable energy that's fed into the local grid, offering these groups reliable, eco-friendly electricity.

How the System Works:

Solar Plant: The solar panels capture sunlight and convert it into direct current (DC) electricity. This electricity then flows to inverters that convert it into alternating current (AC), making it compatible with the grid. These inverters automatically adjust to changing sunlight conditions to keep power output stable and efficient.

Substation: Once converted to AC, the power reaches the substation, where it's stepped up to a higher voltage (115 kV). This step is crucial for long-distance transmission, as higher voltages reduce energy losses. The

Real-World Responses: On sunny days, the solar panels operate at peak efficiency, sending maximum power to the grid. When clouds roll in, the inverters adjust automatically to make the best use of available sunlight.

4.3.4 Areas of Concern and Development

How the Design Meets Requirements and User Needs:

Providing Clean, Reliable Power: The location in New Mexico, with its high solar exposure, allows us to generate the most power possible, so utility companies and the local community can count on a consistent, renewable energy source.

Seamless Grid Integration: With the substation in place to convert and transmit power effectively, our design meets industry standards, ensuring that energy flows safely and efficiently into the grid.

Primary Concerns:

Calculation Accuracy and System Efficiency: To make sure we meet power output and efficiency goals, it's essential that our calculations—like those for panel arrays and voltage drops—are spot-on. Any miscalculations here could compromise the system's ability to deliver the required 60 MW capacity.

Meeting Standards: We need to ensure our project complies fully with NEC, IEEE, and other industry standards, especially for things like grounding and safe grid connections.

Immediate Plans to Address These Concerns:

Frequent Validation and Testing: We'll be validating our calculations regularly and using specialized software to simulate performance. We're also setting up weekly review meetings with Black & Veatch to catch any issues early.

4.4 TECHNOLOGY CONSIDERATIONS

AutoCAD

- **Why We Use It**: AutoCAD helps us create detailed drawings of our design, showing every aspect clearly and precisely.
- **Pros**: It's a professional tool widely used in the engineering field, so our design looks polished and meets industry standards.
- **Cons**: Only one person can work on the design at a time, which is challenging for teamwork. Plus, most of us aren't familiar with CAD, so one team member handles most of it.
- **What We'd Like to Improve**: Ideally, we'd want a more collaborative version of CAD to allow multiple people to work on the drawings together.

Array Parameter Tool:

- **Why We Use It**: This tool is set up in Google Sheets, so the whole team can access it and work on it together. It helps us decide on equipment and track settings for the solar array.
- **Pros**: Everyone can update it in real-time, and it has some formulas pre-set, saving us time and reducing errors.
- **Cons**: We can't easily compare multiple setups at once. To test a different configuration, we have to create a new sheet each time.
- **What We'd Like to Improve**: A tool that lets us quickly compare different setups would make things faster and more flexible.

Voltage Drop Calculations Tool:

- **Why We Use It**: Also in Google Sheets, this tool helps us calculate and organize the voltage drop in different parts of the solar setup, like between the panels and inverters.
- **Pros**: It's organized, easy for everyone to access, and helps keep the calculations straight.
- **Cons**: Like the array tool, it can only handle one scenario at a time. Plus, it doesn't show the calculation steps, so some of us double-check by doing parts by hand to understand better.
- **What We'd Like to Improve**: A more visual tool that shows the steps in calculations would be helpful for both accuracy and learning.

Solar Cost Analysis Tool:

- **Why We Use It**: This Google Sheet, provided by Black & Veatch, helps us track costs and estimate how long it'll take for the project to start making a profit.
- **Pros**: It's very clear for projecting big-picture costs and when we'll break even, which is useful for us and our clients.

- **Cons**: It doesn't give a detailed breakdown of costs, but we'll add that with a Bill of Materials later.
- **What We'd Like to Improve**: More detail in cost tracking would help us see exactly where the money is going.

4.5 DESIGN ANALYSIS

Progress So Far:

Choosing Components with the Array Parameter Tool: We started by analyzing different combinations of parts for the solar field using the Array Parameter Tool. We looked at factors like cost, how much equipment would be needed to reach our power output goal, and whether everything could fit within the land we have available. After comparing several setups, we settled on the best components (PV panels, combiner boxes, and inverters) and arranged them in a layout that met both our needs and the equipment specifications.

Creating Layouts in CAD and Getting Client Feedback: With our chosen configuration, we designed three different layouts in AutoCAD. After presenting these options to our client, we all agreed on the best layout and proceeded with voltage drop calculations to make sure power losses stayed within acceptable limits.

Voltage Drop Calculations and Adjustments: Initially, our voltage drop was too high, which would have impacted efficiency. Our client suggested moving the combiner boxes to the center of the array and choosing wires with a larger capacity. After making these changes, we achieved a voltage drop of 2.81% in the worst-case scenario, which was right on target.

Cost Analysis: Getting accurate cost estimates was a challenge since many companies don't post prices online and only provide quotes for confirmed purchases. However, Black & Veatch provided a Google Sheet tool to help us estimate costs and understand when the project might break even. This tool has been incredibly helpful in mapping out the project's financials.

Testing: We haven't started hands-on testing yet, but it's next on our list.

Next step:

Next semester, we'll work into the substation design, selecting more components and using tools like BlueBeam to collaborate and get feedback on layouts.