115/34.5kV Solar Power Plant & Substation Design Project

DESIGN DOCUMENT

Team Number: 18
Client: Black & Veatch
Advisers: Venkataramana Ajjarapu
Team Members/Roles:
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Executive Summary

Development Standards & Practices Used

We will use our knowledge in power systems as well as programs such as ETAP, Bluebeam, and AutoCAD to design a 115/34.5 kV substation and solar field. We will use IEEE standards, as well 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 Power System

EE455 Distribution System

EE456 Power System 1

EE457 Power System 2

New Skills/Knowledge acquired that was not taught in courses

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

CAD – 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)

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 a couple of the other members in the group 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 also keeping my grades up and communicating effectively with my employer. I have knowledge in creating a Bill of Materials and being able to help schedule who does what, 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, as well as effective communications skills necessary for collaboration between different design departments.

Siti Mohd Radzi: I have numerous experiences working in a team, from various work environment, from working for technical projects, student organization, volunteering programme, and fundraising, I believe I would be able to contribute to create 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 in order to keep everyone in the loop and make sure that nobody has more power than anyone else. People voice their opinions and concerns freely to avoid

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 team is attempting to to design and simulate a 60 MW solar farm as well as the substation that connects it to the grid. We will design the solar farm during the first semester and the substation the second semester.

2.2 Requirements and constraints

In this project, we are required to design the solar power plant and the substation plant by 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 are required to have all of the documentation that goes along with the design work. Here are a few deliverables we need to provide as well:

- Equipment sizing calculations (breakers, transformers, etc) using Excel files
- Solar layout drawings provided with Bluebeam/CAD/PDF editor
- Solar panel string sizing design done with Excel files
- Electrical layout drawings (substation equipment) printed using Bluebeam/CAD/PDF editor
- Grounding analysis and ground-grid developed with IEEE-80 also can be conducted using Excel files
- Bus calculations for substation design with Excel files
- Additional calculations of DC battery bank and lightning protection calculated using Excel files
- Creation of solar/substation design-optimizing tool can be done with ACAD/ETAP/new program
- Simulation of designed substation connection with a simulation software known as ETAP using the student license
- Coordination Study, AC Arc Flash Study, and Protection Element Analysis also using ETAP
- Load Flow Scenario Wizard and Configuration Manager done using ACAD/ETAP.

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

There are two groups that 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 are able to take our design and compare it to other senior design groups and also 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 are a group that are interested in the design and implementation of solar power plants and substations. Renewable energy advocacy groups would also be interested in the design and creation of a solar power plant. Black & Veatch could take the design of our project and implement our design if the situation makes sense and is applicable to a specific location.

3 Project Plan

3.1 Task Decomposition

In order to solve the problem at hand, it helps to decompose it into multiple tasks and subtasks and to understand interdependence among tasks. This step might be useful even if you adopt agile methodology. If you are agile, you can also provide a linear progression of completed requirements aligned with your sprints for the entire project. At minimum, this section should have a task dependence graph, description of each task, and a justification of your tasks with respect to your requirements. You may optionally also include sub-tasks.

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 is using agile methodology for communication and leadership between group members. The waterfall method emphasizes the completion of 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 distinct 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. Typical waterfall style suggests not returning to previous phases once completed but the group will most likely have some crossover between phases in order to revise and make sure everything is completed properly.

Our gantt chart for tracking of tasks and process of design loosely follows this waterfall style of design. 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 of making frequent check-ins with group members and also 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

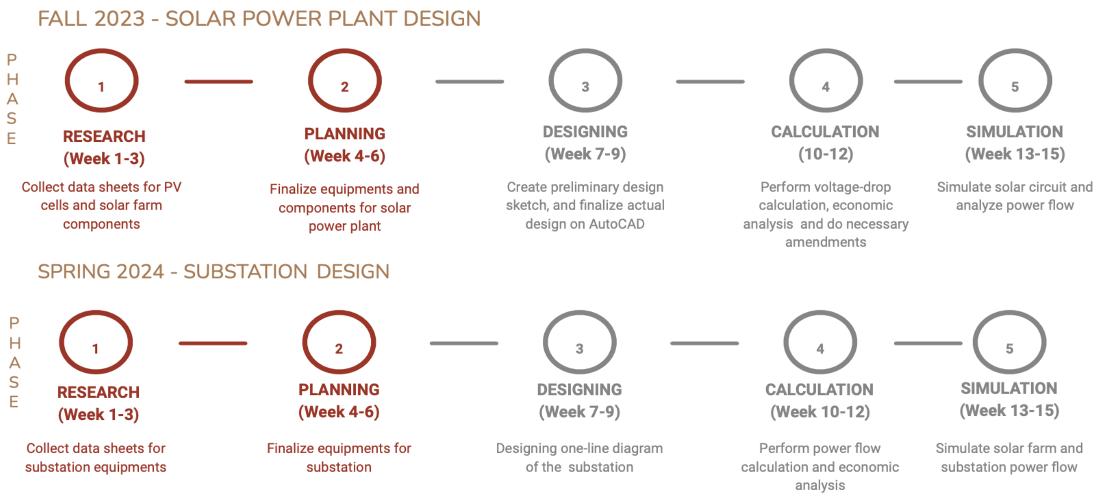
- Research Equipment
  - Collect 3 data sheets for PV panels, combiner boxes, and solar inverters
  - Research necessary components and present our understanding of them
- Select Components
  - Finalize component selection

    - Find appropriate location for construction
- Array Parameters
    - Use array calculation tool to select solar farm sizing (number of panels, combiner boxes, inverters, ect)
    - 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

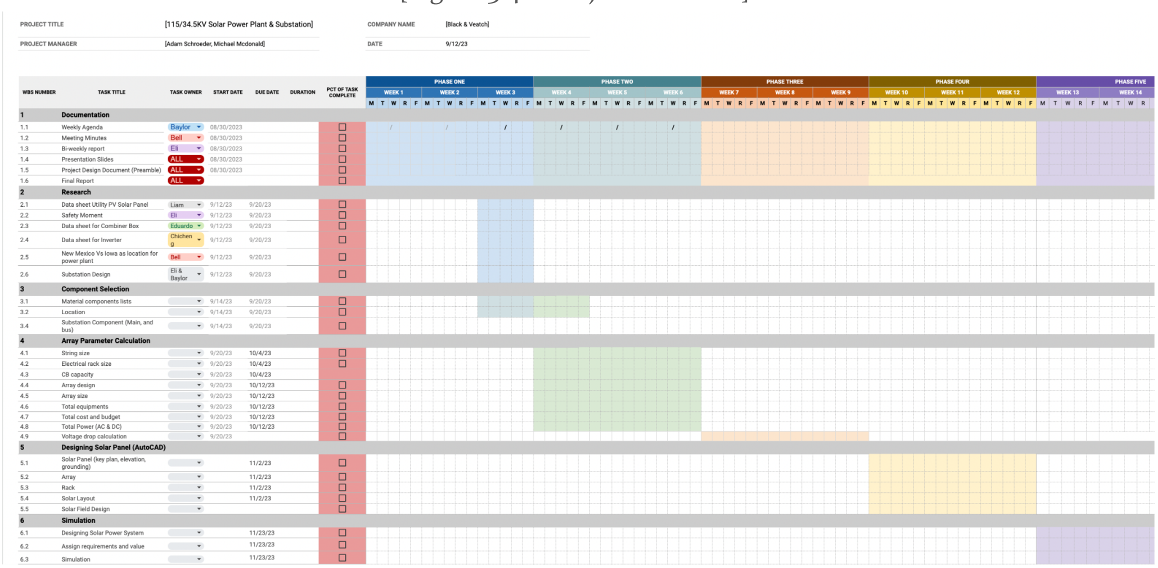
3.4 Project Timeline/Schedule

A realistic, well-planned schedule is an essential component of every well-planned project. Most scheduling errors occur due to either not properly identifying all of the necessary activities (tasks and/or subtasks) or not properly estimating the amount of effort required to correctly 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. For agile, a sprint schedule with specific technical milestones/requirements/targets will work.

Project Timeline/Schedule



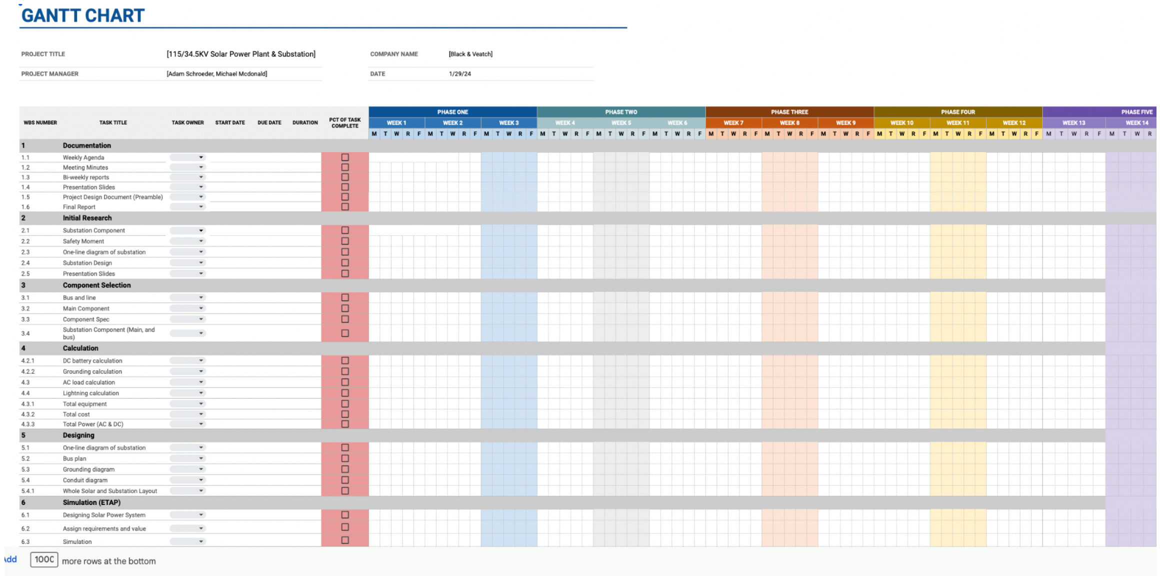
[Figure 3.4.1: Project Timeline]



PROJECT TITLE [115/34.5KV Solar Power Plant & Substation] COMPANY NAME [Black & Veatch]
PROJECT MANAGER [Adam Schroeder, Michael Mcdonald] DATE 9/12/23

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
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		9/14/23	9/20/23		☐
3.4	Substation Component (Main, and bus)		9/14/23	9/20/23		☐
4	**Array Parameter Calculation**					
4.1	String size		9/20/23	10/4/23		☐
4.2	Electrical rack size		9/20/23	10/4/23		☐
4.3	CB capacity		9/20/23	10/4/23		
4.4	Array design		9/20/23	10/12/23		☐
4.5	Array size		9/20/23	10/12/23		☐
4.6	Total equipments		9/20/23	10/12/23		☐
4.7	Total cost and budget		9/20/23	10/12/23		☐
4.8	Total Power (AC & DC)		9/20/23	10/12/23		☐
4.9	Voltage drop calculation		9/20/23			☐
5	**Designing Solar Panel (AutoCAD)**					
5.1	Solar Panel (key plan, elevation, grounding)			11/2/23		☐
5.2	Array			11/2/23		☐
5.3	Rack			11/2/23		☐
5.4	Solar Layout			11/2/23		☐
5.5	Solar Field Design					☐
6	**Simulation**					
6.1	Designing Solar Power System			11/23/23		☐
6.2	Assign requirements and value			11/23/23		☐
6.3	Simulation			11/23/23		☐

[Figure 3.4.2: Gantt Chart for Solar Power Plant Design for Fall 2023]



[Figure 3.4.3: Gantt Chart for Substation Design for Spring 2024]

3.5 Risks and Risk Management/Mitigation

There are a lot of different risks that we have in our project. Some of them include technical risks, land and site risks, construction risks, financial risks, and policy risks. We can see that all of these risks can add up and cause a lot of potential mistakes that can happen in our project or in the future. For our technical risks, we have technology selection and system design. This risk would be when we design something and we 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 to happen. Another possible risk would be construction risks. This is a risk that is out of project scope, but one that we need to consider in our design work. An example of this would be if a maintenance team was working 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 think we need, so it shouldn't be an issue if we give a little extra space in the arrays.

We also have some hypothetical risks because we won't actually be constructing this array. We have pointed out some land and site risks, financial risks, and policy risks. Some of the 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 Sim	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

N/A

4 Next Section