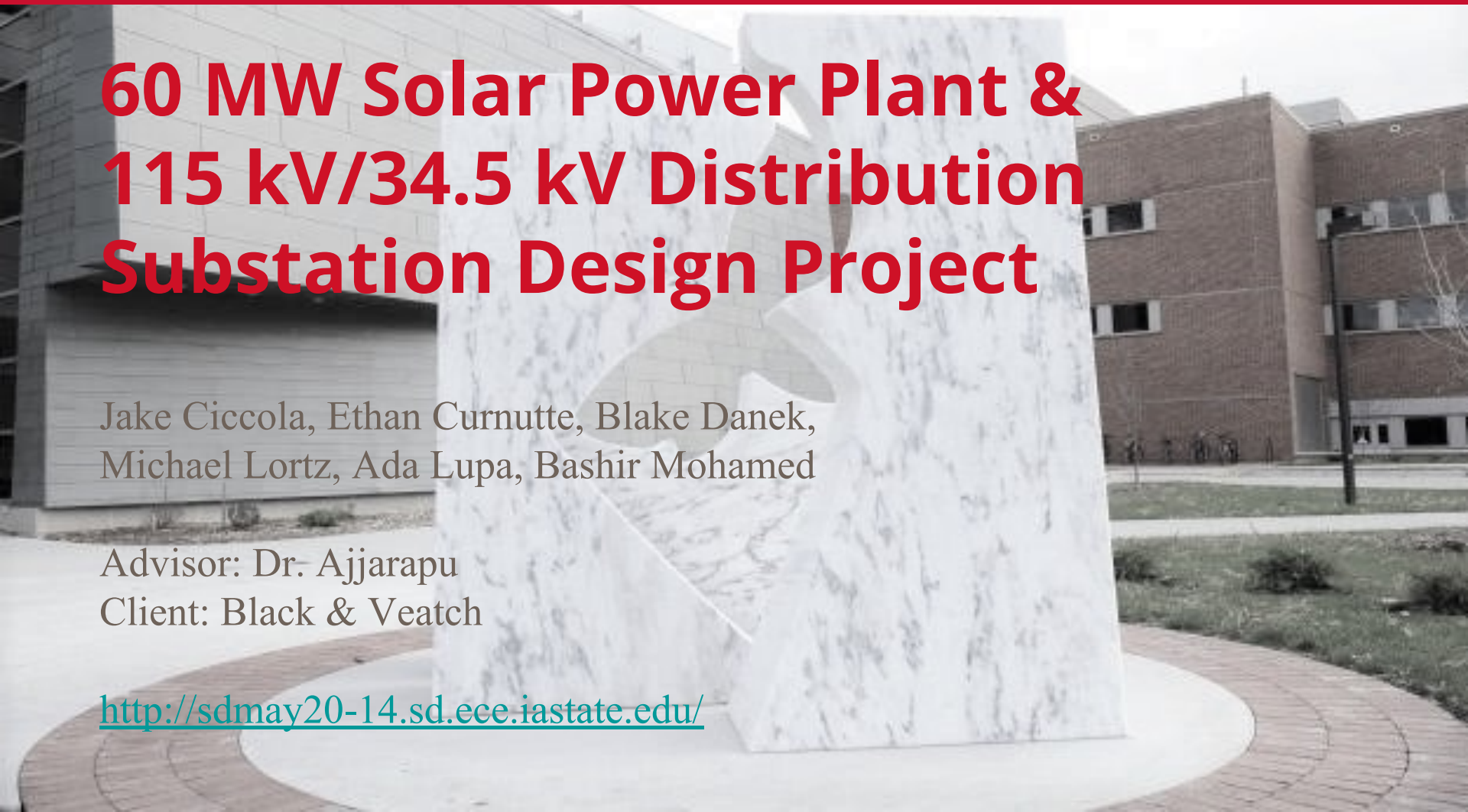
IOWA STATE UNIVERSITY

EE 492 | Spring 2020 | sdmay20-14



60 MW Solar Power Plant & 115 kV/34.5 kV Distribution Substation Design Project

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Advisor: Dr. Ajjarapu
Client: Black & Veatch

http://sdmay20-14.sd.ece.iastate.edu/

Project Plan

- High level overview of project
- Problem Statement
- Conceptual Sketch
- Functional Requirements
- Technical/Other Constraints
- Potential Risks and Mitigation
- Resource/Cost Estimate
- Project Milestones/Schedule

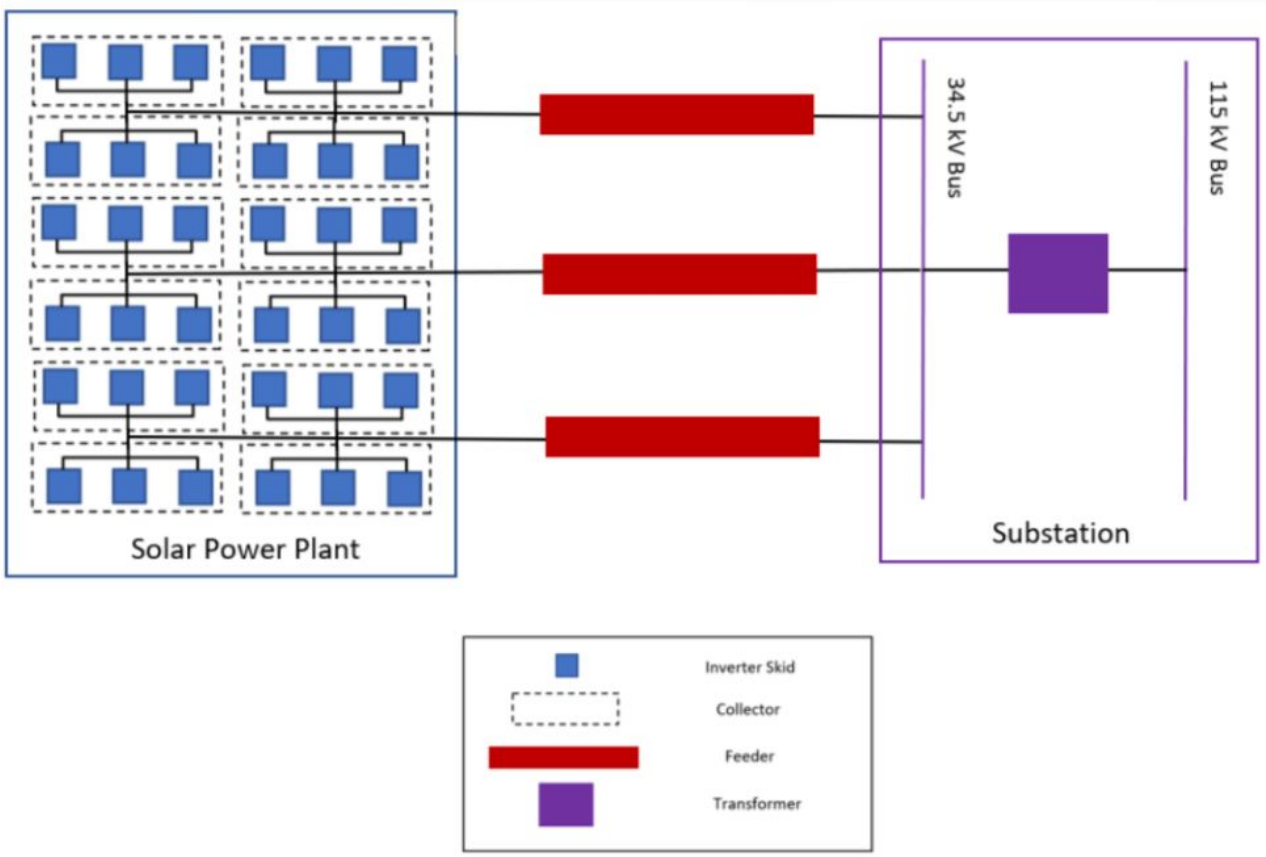
High Level Overview

- Substation Design
- Substation components & bus types
  - One line diagram
  - Grounding calculations
  - Spacing calculation
  - Bus plan diagram

Problem Statement

- In the grid energy market traditional energy sources are being significantly replaced with renewable energy sources (RES) such as wind and solar.
- Our solution in helping Black and Veatch move to clean energy is working on a 60 MW Solar Power Plant and a 34.5 kV/115 kV Distribution Substation
- Our goal for this project is to have a completely finished and functional substation design including calculations and schematics (one-line & bus plan)

Conceptual Sketch



Functional Requirements

- One-line diagram
- Zones of protection defined and labeled
- Spacing calculations
- Grounding calculations
- Bus calculations
- CAD drawings

Technical Constraints

- **Cost**

  Making sure that the way we chose to layout the station and the equipment decided upon is within reasonable budget.

- **Size**

  Fit the plot of land that we chose.

- **Challenges associated with the datasheets and IEEE documents**

  Difficulties with understanding the equations relevant to the bus, grounding, and spacing.

Potential Risks & Mitigation

Risks

- Misplaced components
- Field errors and problems
- Voltage drop
- Component failure
- Miscommunication

Mitigation

- Strict guidelines to reduce confusion
- Checking codes and regulations
- Simulations
- Test equipment before use
- Weekly meetings with employer with safety topics

Cost/Resource Estimate

Solar Plant Cost	Quantity	Cost/Unit	Total Cost
Solar Panels	163072	$198.68	$32,399,927.71
Combiner Boxes	368	$900.00	$331,200.00
Inverters	16	$155,000.00	$2,480,000.00
		Total Cost	$35,211,127.71

- Land Cost - $109,000
- $1/watt for installation means our farm would be $60 million in installation
- Brings total solar farm cost to about $95.3 million

Project Milestones/Schedule

- Gantt Chart
  - One-line diagram: 1/30/20
  - Zones of protection: 2/6/20
  - Grounding design layout (CAD): 2/20/20
  - Grounding calculations: 3/12/20
  - Grounding calculation report: 4/2/20
  - Bus calculation report: 4/16/20
  - Battery calculation report: 4/23/20

System Design

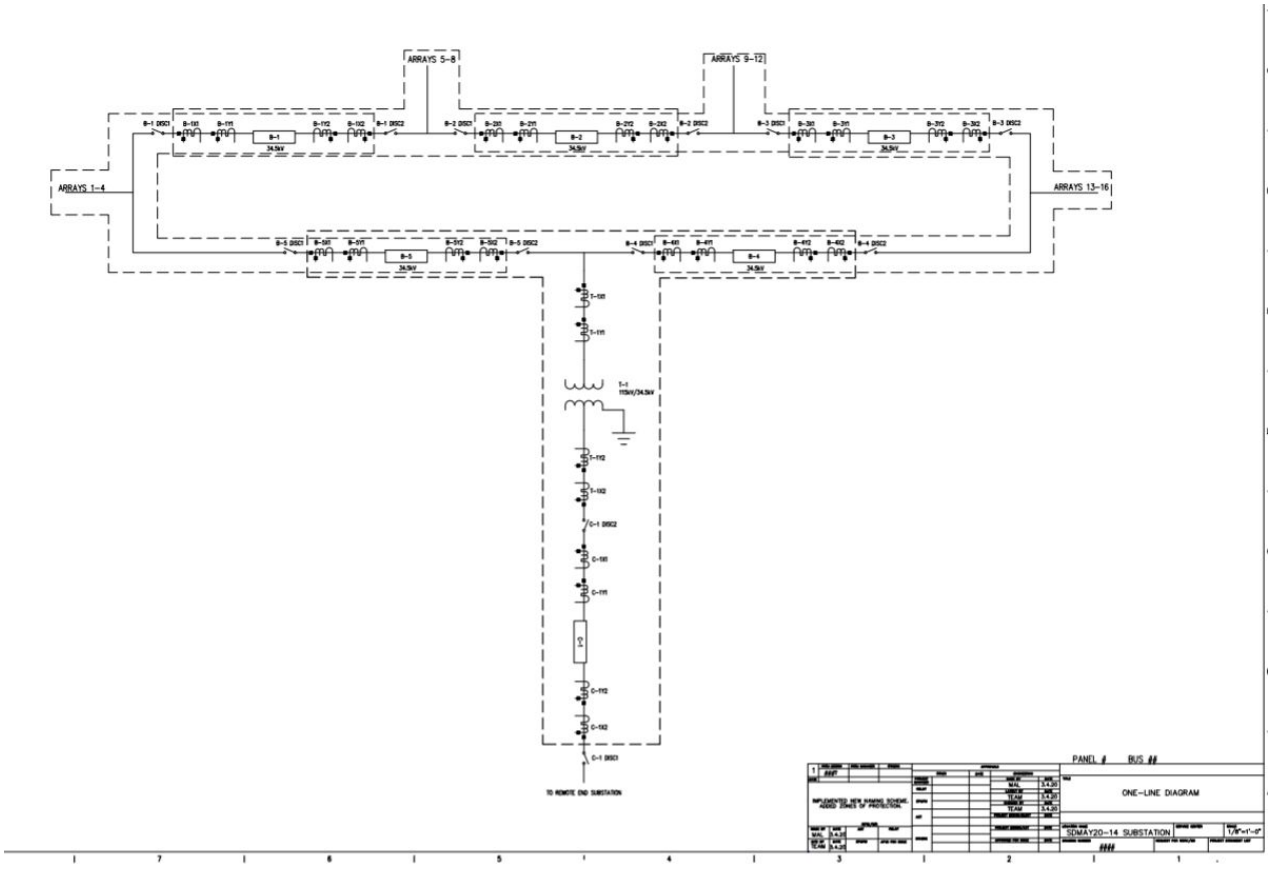
- Functional Decomposition
- Detailed Design
- HW/SW/Technology Platforms used
- Test Plan
- Prototype Implementations
- Engineering Standards & Design Practices

Functional Decomposition

Component	Function	Input	Output
Solar Modules	Convert sunlight into DC power	Sunlight	DC power
Combiner Boxes	Combine the currents before sending it to the inverter	Current from string	Combined currents
Inverters	Convert DC voltage to AC voltage	DC voltage from array	AC voltage
Transformers in Inverter Skids	Step-up the voltage	Voltage from inverter	Voltage proportional to input voltage that goes to the feeders
Transformer in Substation	Step-up the voltage	Voltage from feeders	Voltage proportional to input voltage that goes to the grid
Relays	Measure the current in a line	Current in a line	Signal to circuit breaker
Circuit Breaker	Protects circuit from damage caused by excess current from an overload or short circuit	Signals from relays	Disconnect faulted lines
Communication Devices	Allows communication between substation equipment and SCADA	Signals from different substation equipment	Signals to SCADA

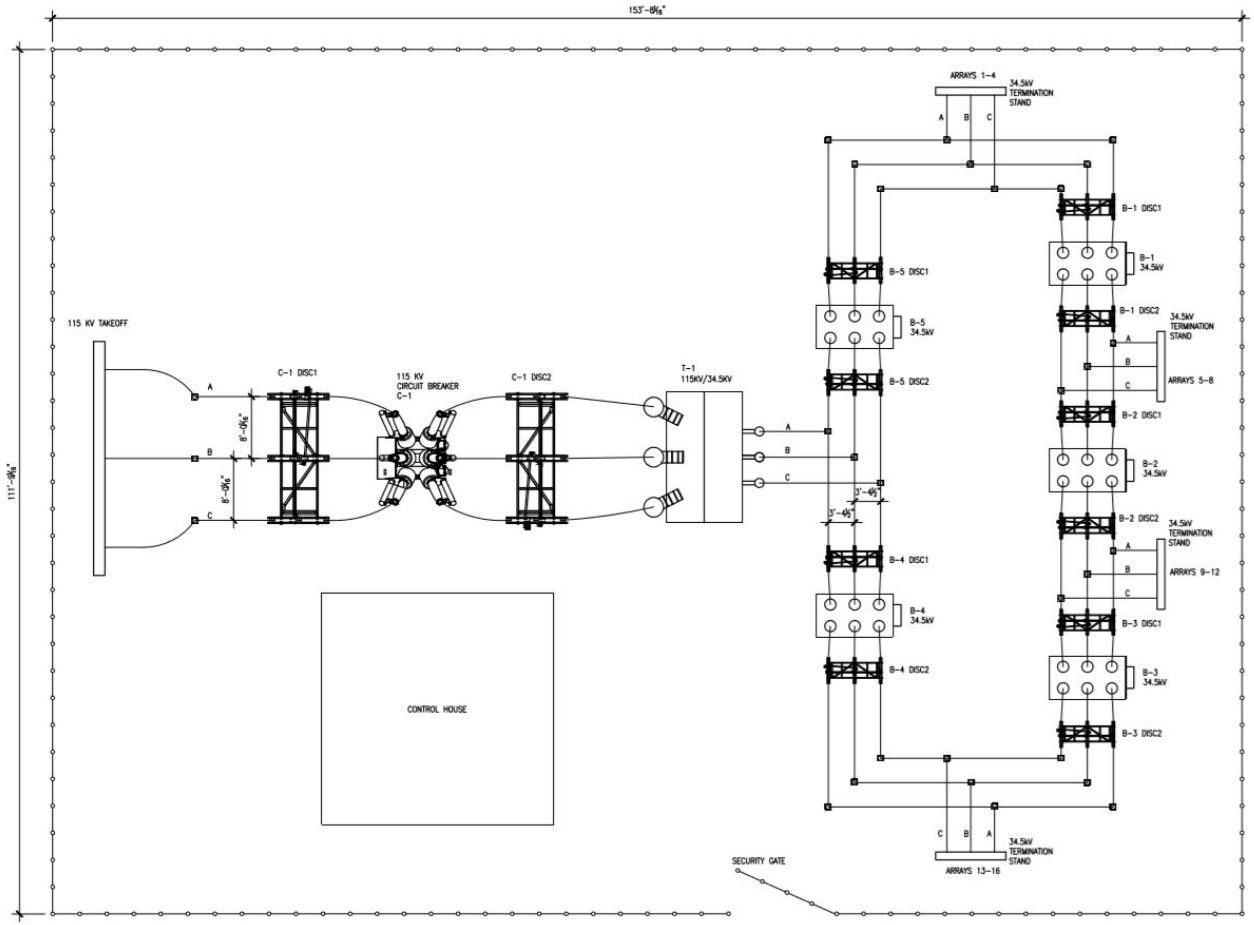
Detailed Design

- CAD drawings for one-line diagram



Detailed Design

- CAD drawings for the bus plan



Technology Platforms Used

- Excel - Calculations

- Autocad - Design and Layout

- EnerSys - Battery Sizing
- SEL (Schweitzer Engineering Laboratories) - Relay Specifications

Test Plan

- Using excel to constantly update calculated values
- Continuously checking with client that their needs are filled and that everything is done with high quality
- Checking that all our requirements are within client and IEEE codes

Prototype Implementations

- Researched various layouts and used data from solar plant to create one-line diagram and bus plan.

- One-line diagram in conjunction with bus plan design can be implemented into ground grid.

Engineering Standards & Design Practices

- Adhere to NEC guidelines and practices
  - Conductor sizing requirements
  - Loading factors
- Black & Veatch standards
  - Safety tolerances
  - Company-specific design tools
  - Project design flow
- IEEE Standards

Conclusion

- Task contributions of each project member
- Current Project Status

Task Contributions

Ethan

- Ran meetings with client and advisor
- Created and filled out necessary documents per client request
- Dealt with finalizing documents and assignments to ensure quality

Blake

- Helped design one-line diagram; specifically focused on zones of protection and CB positions
- Worked on substation calculations
- Recorded meeting minutes when necessary

Jake

- Created meeting agendas for client
- Recorded and sent meeting minutes
- Created detailed schedule and helped keep team on task

Ada

- Worked on the grounding and spacing calculations
- Updated the website
- Helped with the creation of the one-line diagram

Michael

- Created one line diagram in AutoCAD
- Drafted substation layout using AutoCAD
- Implemented design input from client

Bashir

- Helped create one line diagram.
- Worked on spacing and insulation calculations
- Helped finalize substation calculations

Current Status

First Semester:

- Chose location of plant
- Designed solar farm
- Calculations of voltage drops

Second Semester:

- Created a one-line diagram
- Bus calculations
- Grounding calculations/ spacing
- DC battery calculations
- Relaying

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