IOWA STATE UNIVERSITY
Department of Electrical and Computer Engineering


# 115/34.5kV Solar Plant & Substation Senior Design Project

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# AGENDA

- Safety Moment
- New Technology
- More One-Line Details
- ETAP updates

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# Safety Moment

## Security in Substations


Why it's important? - Substations are critical infrastructure that transmit power to a large population. Any disruption or damage to a substation can result in widespread power outages and impacting essential services.

### Security Measures

- Fences and Locks: Strong fences and/or high walls and use secure locks to keep people out who shouldn't be there

- Cameras: Can watch the substation at all times. Cameras should cover all important areas including the control house
- Badges and Scanners: Should be used so only people with ID badges can get in.
- Bright Lights in Control House: Keep the area well-lit to make it easy to see everything
- Alarms: Should be used at entrance points

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- **New Technology**

## ABB Live Tank Breaker (LTB) with Air Plus

- **Eco-Friendly Alternative** – Uses Air Plus, a $CO_2$ based gas mixture, instead of $SF_6$.
- **Near-Zero Global Warming Impact** – 100%. reduction in greenhouse gas emissions compared to $SF_6$.
- **Same Performance**, Less Maintenance – Matches $SF_6$ breakers while complying with future regulations.

### How We Integrate It in Our Substation?

Replacing $SF_6$ breakers in our 115/34.5 kV substation

Lower environmental impact while maintaining grid reliability

Less lifecycle management and reporting compared to $SF_6$

https://new.abb.com/news/detail/18580/abb-launches-carbon-reducing-high-voltage-breaker

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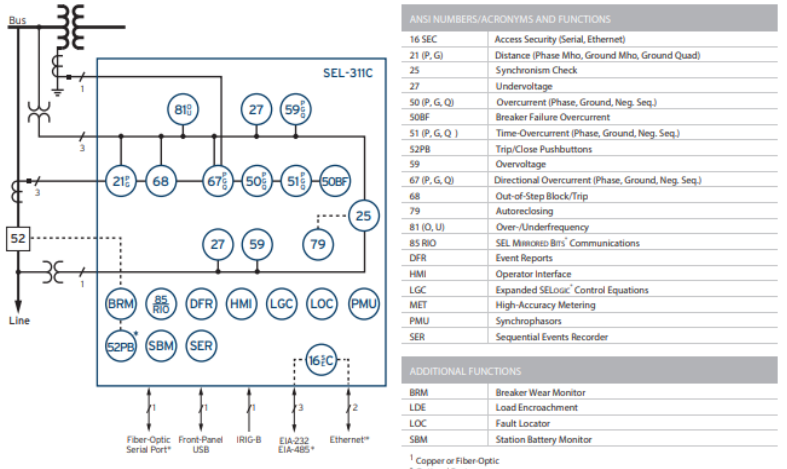
# Line Relaying

- **Primary Line Relaying – SEL 311C**
  - More complex protection features such as distance protection, load shedding, breaker failure detection and reclosing
- **Secondary Line Relaying – SEL 311L**
  - Simpler protection features serving as a distance and overcurrent backup

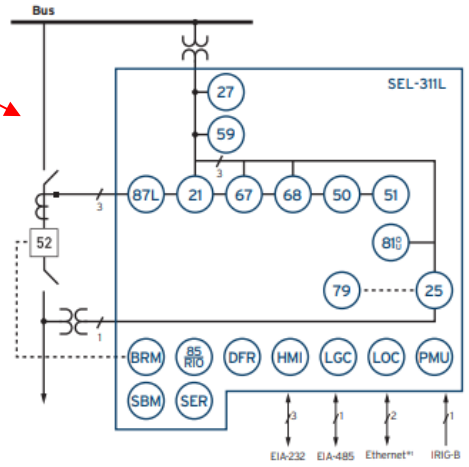



| ANSI NUMBERS/ACRONYMS AND FUNCTIONS | |
|---|---|
| 16 SEC | Access Security (Serial, Ethernet) |
| 21 (P, G) | Distance (Phase Mho, Ground Mho, Ground Quad) |
| 25 | Synchronism Check |
| 27 | Undervoltage |
| 50 (P, G, Q) | Overcurrent (Phase, Ground, Neg. Seq.) |
| 50BF | Breaker Failure Overcurrent |
| 51 (P, G, Q ) | Time-Overcurrent (Phase, Ground, Neg. Seq.) |
| 52PB | Trip/Close Pushbuttons |
| 59 | Overvoltage |
| 67 (P, G, Q) | Directional Overcurrent (Phase, Ground, Neg. Seq.) |
| 68 | Out-of-Step Block/Trip |
| 79 | Autoreclosing |
| 81 (O, U) | Over-/Underfrequency |
| 85 RIO | SEL Mirrored Bits* Communications |
| DFR | Event Reports |
| HMI | Operator Interface |
| LGC | Expanded SELogic* Control Equations |
| MET | High-Accuracy Metering |
| PMU | Synchrophasors |
| SER | Sequential Events Recorder |

| ADDITIONAL FUNCTIONS | |
|---|---|
| BRM | Breaker Wear Monitor |
| LDE | Load Encroachment |
| LOC | Fault Locator |
| SBM | Station Battery Monitor |

[1] Copper or Fiber-Optic
* Optional Feature

**Figure 1 Functional Diagram**




| ANSI NUMBERS/ACRONYMS AND FUNCTIONS | |
|---|---|
| 21 | Phase and Ground Distance |
| 25 | Synchronism Check |
| 27/59 | Under- and Overvoltage |
| 50 | Overcurrent |
| 51 | Time-Overcurrent |
| 67 | Directional Overcurrent |
| 68 | Out-of-Step Block/Trip |
| 79 | Single-and Three-Pole Reclosing |
| 81 (O, U) | Over- and Underfrequency |
| 85 RIO | SEL Mirrored Bits Communications |
| DFR | Event Reports |
| HMI | Operator Interface |
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| BRM | Breaker Wear Monitor |
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[1] Copper or Fiber Optic * Optional Feature

**Figure 1 Functional Diagram**

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# Transformer Relaying

- **Primary Transformer Relaying – SEL 487E**
  - Provides distance protection and multiwinding protection for the transformer
- **Secondary Line Relaying – SEL 587**
  - Provides current differential protection for the transformer

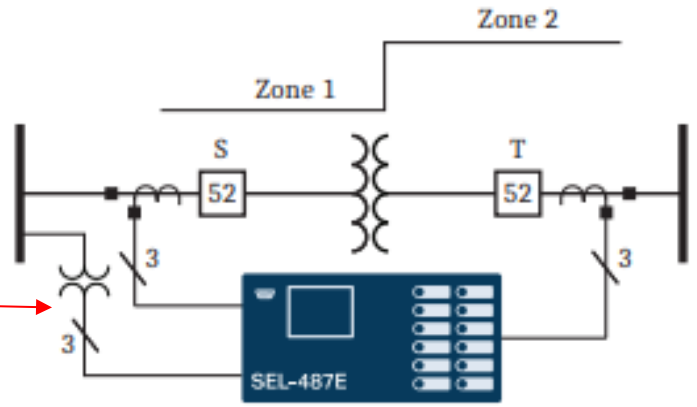
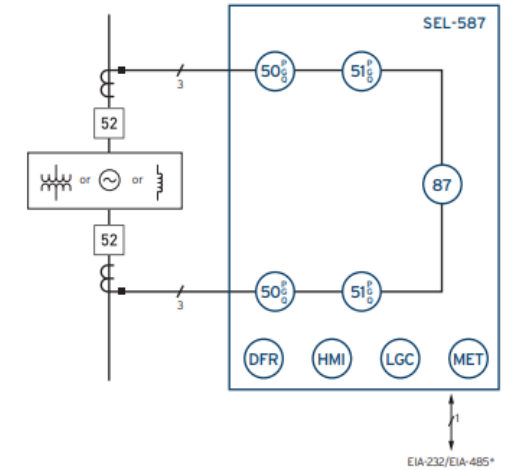



**Figure 8 Transformer Distance Application**




**gure 1 Functional Diagram**

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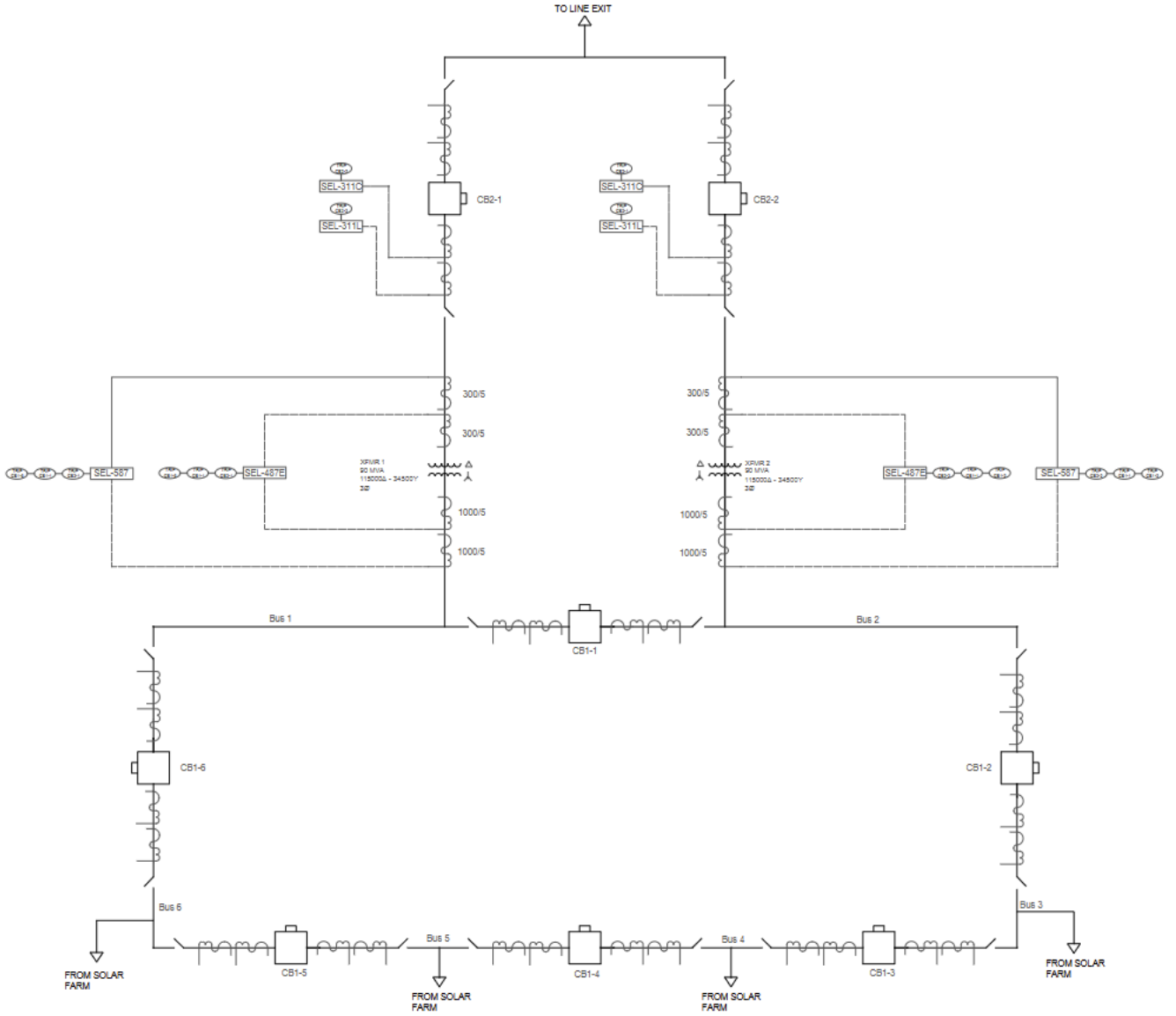
# One-Line Drawing





| Andrew


| 02/24/2025

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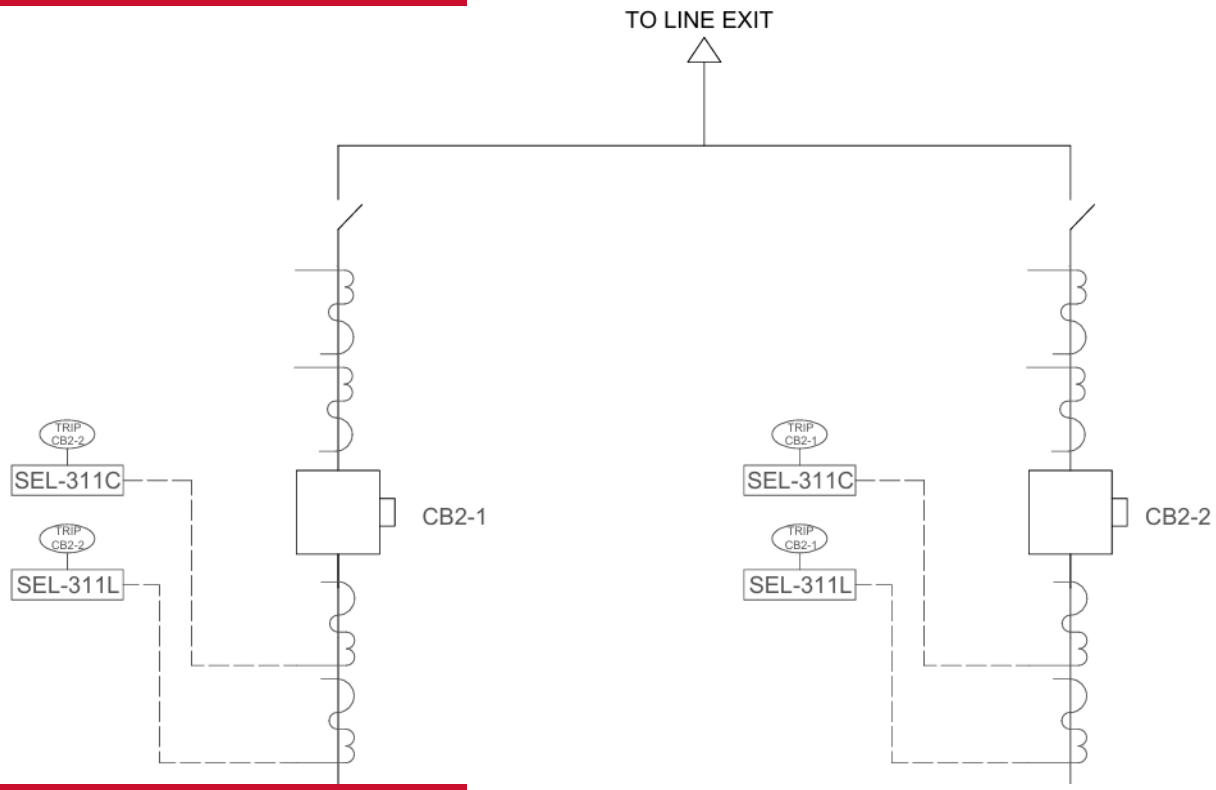
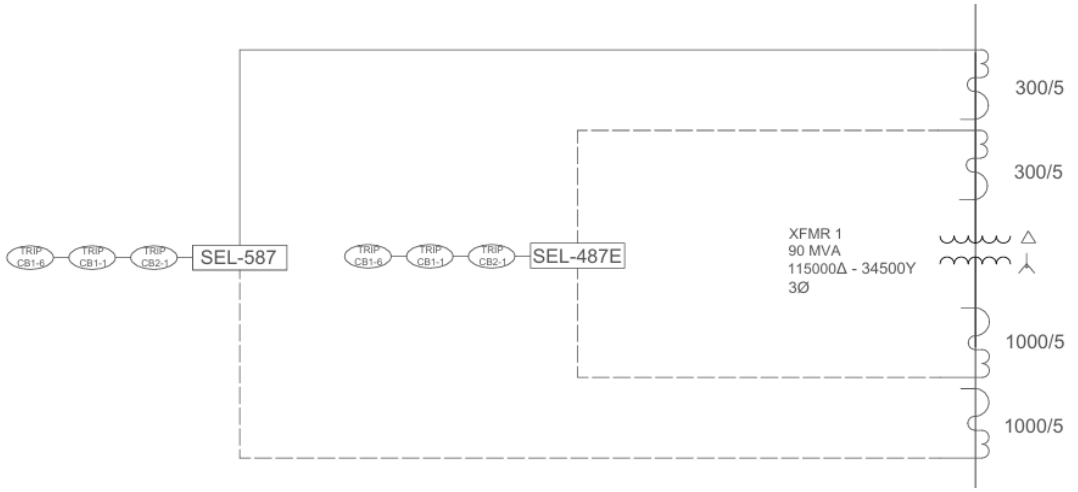
# One-Line Drawing



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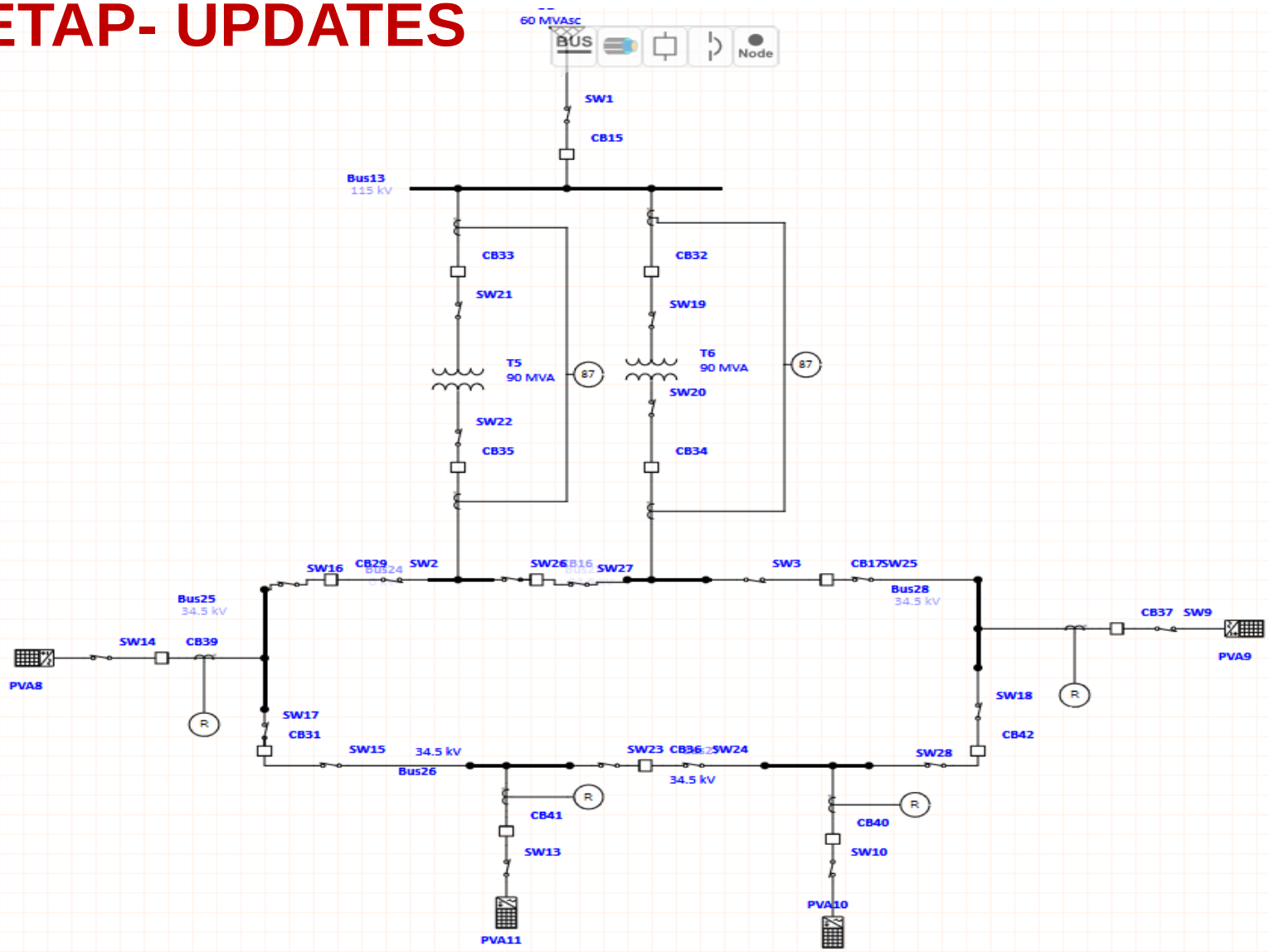
# ETAP- UPDATES




Mohamed

02/24/2025

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# GANTT Chart

- Updated Gantt Chart based on comments
  - Added deliverables – 10%, 40%, etc.
  - Combined cables, relays, panels, & batteries to control building
  - Changed dates
  - Updated DC calculation section

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Project: | 115/34.5 kV Solar Power Plant & Substation | Company Name | Black & Veatch | | | |
| 2 | Project manager | Adam Schroeder, Eli Schaffer, Utsavee Desai | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | TASK TITLE | TASK OWNER | START DATE | DUE DATE | DURATION | TASK COMPLETE |
| 6 | | | | | | | |
| 7 | | SUBSTATION | | | | | |
| 8 | 1 | Documentation | | | | | |
| 9 | | Weekly Agenda | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 10 | | Meeting Minutes | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 11 | | Weekly Report | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 12 | | Presentation Slides | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 13 | | Project Design Document | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 14 | | Final Report | All | 1/27/2025 | 5/16/2025 | 109 | ☐ |
| 15 | | Revamp Gantt Chart | All | 2/10/2025 | 2/23/2025 | 13 | ☐ |
| 16 | | 10% Deliverable - Bus Config., Prelim Component Selection, One-Line | All | 1/27/2025 | 2/16/2025 | 20 | ☐ |
| 17 | | 40% Deliverable - Physical & Relaying Plans, AC & DC Calc. | All | 2/17/2025 | 3/23/2025 | 34 | ☐ |
| 18 | | 70% Deliverable - Three-Line, Grnd & Conduit Plans & Calc Revised | All | 3/24/2025 | 4/20/2025 | 27 | ☐ |
| 19 | | 90% Deliverable - Equip. Section Views, Control House Plans, ETAP Sim | All | 4/21/2025 | 5/4/2025 | 13 | ☐ |
| 20 | | 100% Deliverable - All Calculations, Sheets, Documents Sent to VC | All | 5/5/2025 | 5/16/2025 | 11 | ☐ |
| 21 | 2 | Research | | | | | |
| 22 | | Substation Components - Transformers | David & Ben | 1/27/2025 | 2/9/2025 | 13 | ☑ |
| 23 | | Substation Components - Disconnect Switches | David | 1/27/2025 | 2/9/2025 | 13 | ☑ |
| 24 | | Substation Components - Circuit Breakers | Mohamed & Ben | 1/27/2025 | 2/9/2025 | 13 | ☑ |
| 25 | | Substation Components - CCVTs | Sergio & Andrew | 1/27/2025 | 2/9/2025 | 13 | ☑ |
| 26 | | Bus Configuration | All | 2/3/2025 | 2/16/2025 | 13 | ☑ |
| 27 | | One-Line Plan | Ben | 2/3/2025 | 2/16/2025 | 13 | ☑ |
| 28 | 3 | Component Selection | | | | | |
| 29 | | Circuit Breakers | Mohamed & Ben | 2/3/2025 | 2/16/2025 | 13 | ☑ |
| 30 | | Transformer | David & Ben | 2/3/2025 | 2/16/2025 | 13 | ☑ |
| 31 | | Switches | David | 2/3/2025 | 2/16/2025 | 13 | ☑ |
| 32 | | Control Building - Cables, Relays, Panels, Backup Batteries | Andrew & Dallas | 2/3/2025 | 2/23/2025 | 20 | ☐ |
| 33 | 4 | Calculation & Design | | | | | |

# THANK YOU