34.5/115 kVA Solar Power Plant & Substation Senior Design Project

Senior Design Team 18 - May 2024

Siti Mohd Radzi, Baylor Clark, Eduardo Jimenez-Tzompaxtle, Chicheng Tang, Eli Schaffer, Liam Gossman

BLACK & VEATCH

Agenda

- Safety Moment
- Gantt Chart
- Substation Overview
  - Substation Design Steps
- Solar Array/Field Overview
  - PV Cells
  - Combiner Boxes
  - Inverters (Skids)

Safety Moment - Sleep

Why is it important?

- Maintain a healthy weight
- Reduces stress and improve your mood
- Get along better with teammates

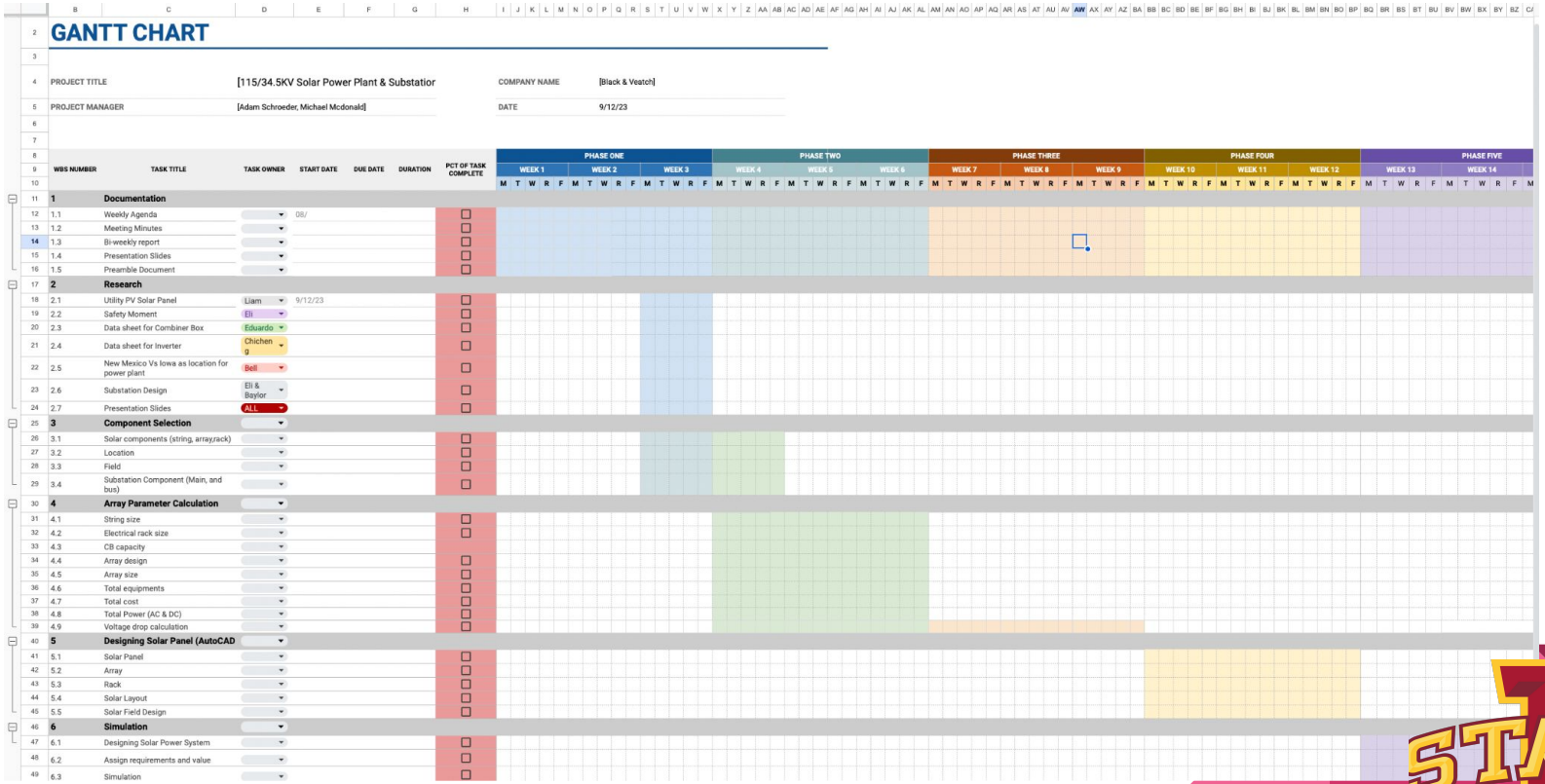
Signs of improper sleep:

- Slowed thinking
- Worse memory
- Lack of attention span

TENTATIVE PLAN

SEMESTER	DESIGN (AUTOCAD)	ANALYSIS & CALCULATION	SIMULATION (ETAP)
FALL 2023	Array Rack Solar Panel Layout Solar Field Layout	Array parameter Power Calculation Economic Cost Analysis Voltage-drop calculation	Solar Power System
SPRING 2024	One-line diagram Yard equipment layout Bus Plan Grounding Layout	Sizing layout Grounding calculation DC and AC load Cost Lightning Protection Calculation	Substation simulation

Gantt Chart (FALL 2023)



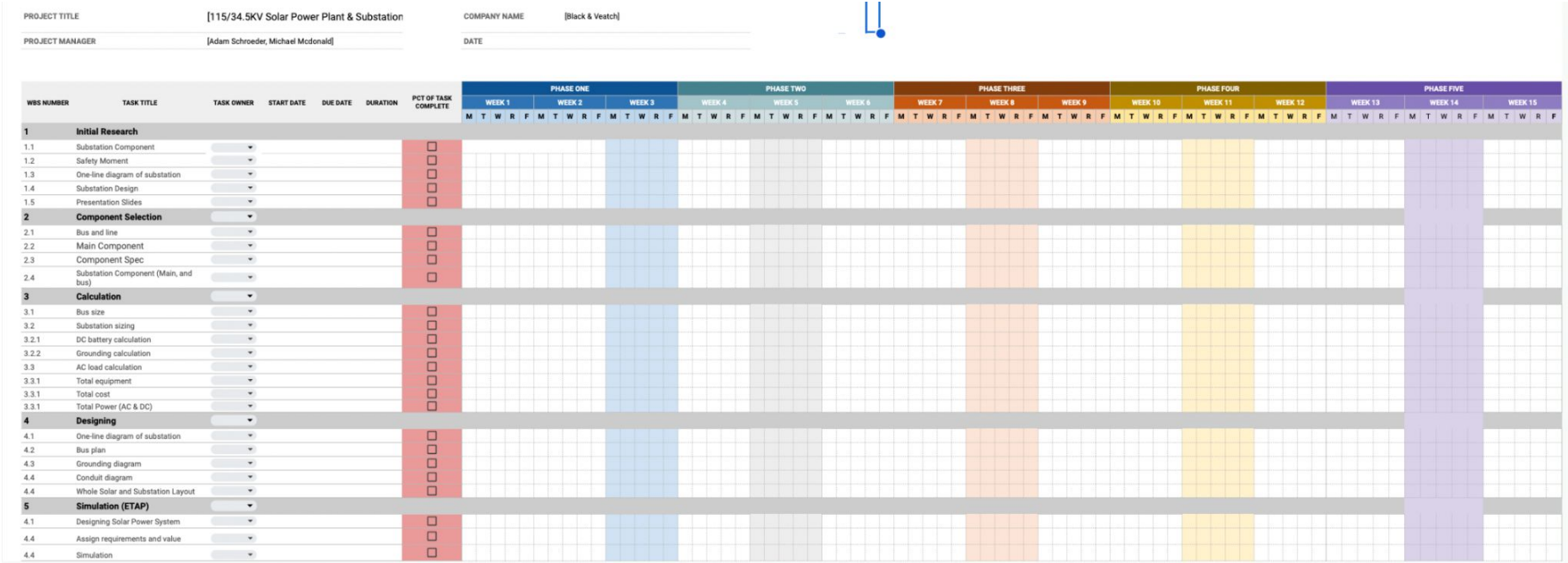
GANTT CHART

PROJECT TITLE	[115/34.5KV Solar Power Plant & Substatior
PROJECT MANAGER	[Adam Schroeder, Michael Mcdonald]
COMPANY NAME	[Black & Veatch]
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		08/			
1.2	Meeting Minutes					
1.3	Bi-weekly report					
1.4	Presentation Slides					
1.5	Preamble Document					
2	**Research**					
2.1	Utility PV Solar Panel	Liam	9/12/23			
2.2	Safety Moment	Eli				
2.3	Data sheet for Combiner Box	Eduardo				
2.4	Data sheet for Inverter	Chichen g				
2.5	New Mexico Vs Iowa as location for power plant	Bell				
2.6	Substation Design	Eli & Baylor				
2.7	Presentation Slides	ALL				
3	**Component Selection**					
3.1	Solar components (string, array,rack)					
3.2	Location					
3.3	Field					
3.4	Substation Component (Main, and bus)					
4	**Array Parameter Calculation**					
4.1	String size					
4.2	Electrical rack size					
4.3	CB capacity					
4.4	Array design					
4.5	Array size					
4.6	Total equipments					
4.7	Total cost					
4.8	Total Power (AC & DC)					
4.9	Voltage drop calculation					
5	**Designing Solar Panel (AutoCAD**					
5.1	Solar Panel					
5.2	Array					
5.3	Rack					
5.4	Solar Layout					
5.5	Solar Field Design					
6	**Simulation**					
6.1	Designing Solar Power System					
6.2	Assign requirements and value					
6.3	Simulation					

PHASE ONE: WEEK 1, WEEK 2, WEEK 3
PHASE TWO: WEEK 4, WEEK 5, WEEK 6
PHASE THREE: WEEK 7, WEEK 8, WEEK 9
PHASE FOUR: WEEK 10, WEEK 11, WEEK 12
PHASE FIVE: WEEK 13, WEEK 14

Gantt Chart (SPRING 2023)



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PROJECT MANAGER	[Adam Schroeder, Michael Mcdonald]	DATE	

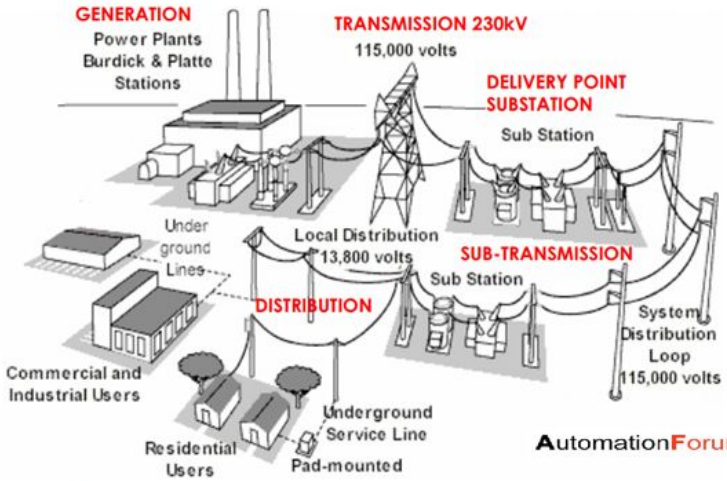
WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Initial Research**					
1.1	Substation Component					
1.2	Safety Moment					
1.3	One-line diagram of substation					
1.4	Substation Design					
1.5	Presentation Slides					
2	**Component Selection**					
2.1	Bus and line					
2.2	Main Component					
2.3	Component Spec					
2.4	Substation Component (Main, and bus)					
3	**Calculation**					
3.1	Bus size					
3.2	Substation sizing					
3.2.1	DC battery calculation					
3.2.2	Grounding calculation					
3.3	AC load calculation					
3.3.1	Total equipment					
3.3.1	Total cost					
3.3.1	Total Power (AC & DC)					
4	**Designing**					
4.1	One-line diagram of substation					
4.2	Bus plan					
4.3	Grounding diagram					
4.4	Conduit diagram					
4.4	Whole Solar and Substation Layout					
5	**Simulation (ETAP)**					
4.1	Designing Solar Power System					
4.4	Assign requirements and value					
4.4	Simulation					

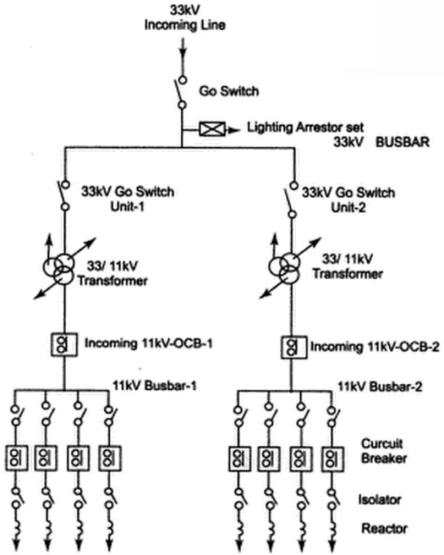
PHASE ONE			PHASE TWO			PHASE THREE			PHASE FOUR			PHASE FIVE		
WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15
M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F	M T W R F

Gantt Chart :
https://docs.google.com/spreadsheets/d/1JJT6Xag0IAaLGq4L6f2jQizj2VnZf0
QUrBNOHkiYRI/edit?usp=sharing

Substation Overview

Transmission lines come into substation at 115 kVA. These lines then step down into transformers which take the voltage from 115 kVA to 34.5 kVA. The line then goes through switchgear to help service in case of a disaster. After the switchgear, the lines go to busbars which help distribute the voltage to different lines to be distributed.



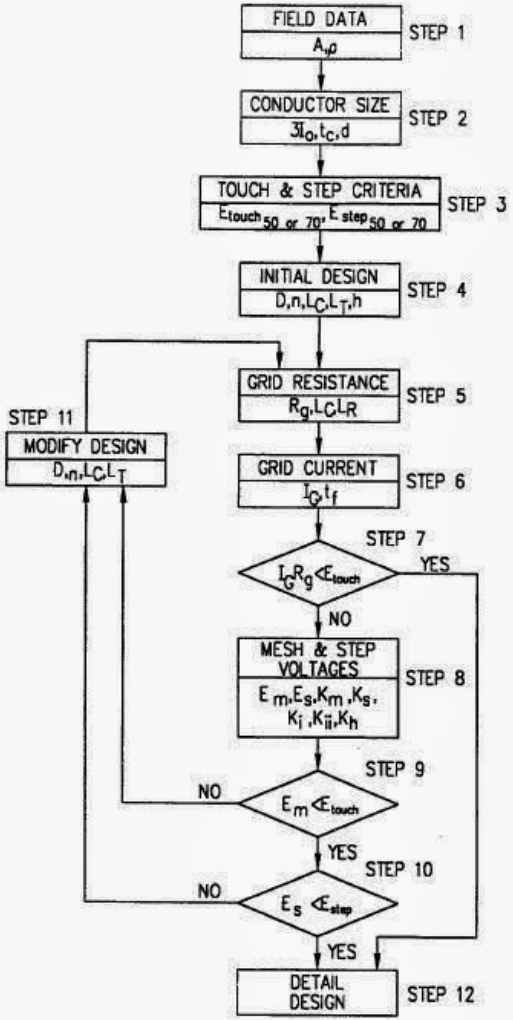


Feeders -> SG -> XFMR -> SG -> Circuit Breaker -> Busbar -> Outgoing Feeders

The circuit diagram to the left shows an overview of a typical substation circuit. This shows a 33/11 kVA system and transformer, but similar principles apply to our project.

https://www.watelectrical.com/electrical-substation-definition-layout-uses-of-substations/

https://automationforum.co/introduction-to-electrical-substation/



Design procedure block diagram

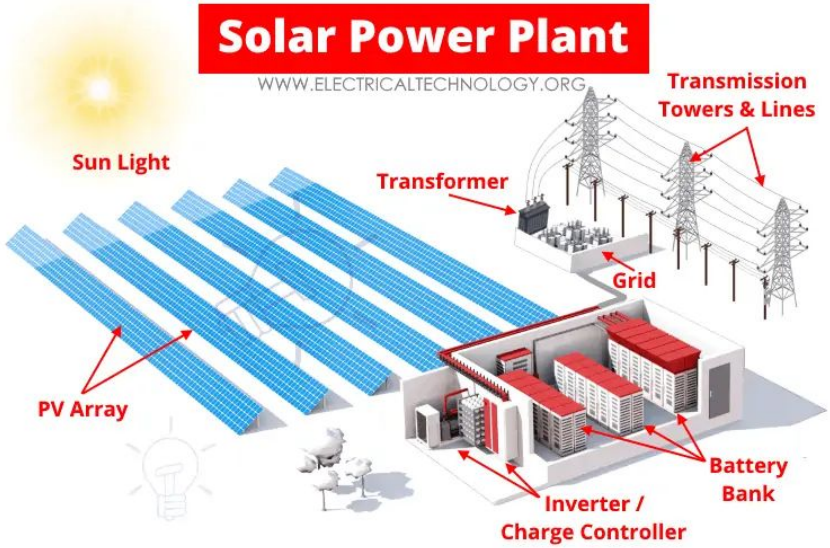
Substation Design Steps

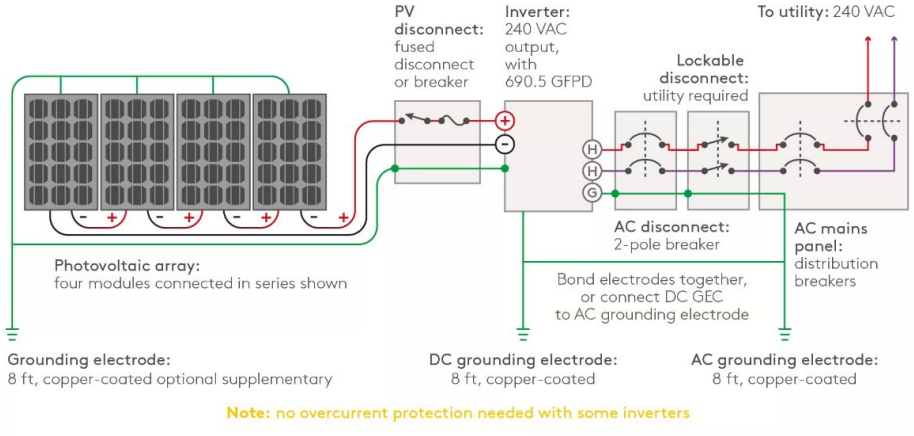
The flowchart to the left shows different steps that go into designing a substation. These steps are outlined in the IEEE Standard 80-2000 which was then superseded by the IEEE Standard 80-2013. They focus mostly on the grounding aspect of the substation.

http://www.electrical-knowhow.com/2014/01/Final-Design-for-AC-Substations-Grounding-System.html

Solar Field Overview

- PV Array connected in series
  - String or Rack
- Produces DC current
- Inverter converts DC to AC for use in the power grid
- Disconnects are used throughout solar plant for safety purposes
- Some substations contain battery banks
- Power is then sent to substation to be distributed to the grid
- Sent through to utility service



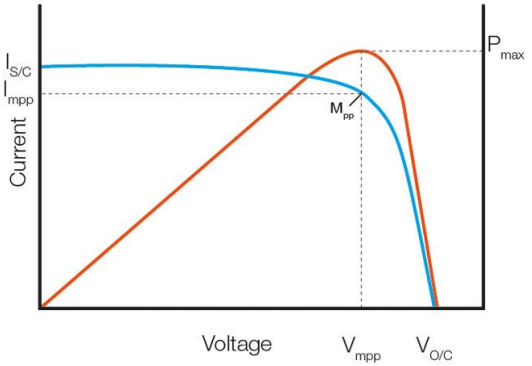


https://www.electricaltechnology.org/2021/07/solar-power-plant.html
https://www.essentracomponents.com/en-us/news/industries/renewable-energy/how-to-wire-solar-panels

PV Cells

Relationship between irradiance and temperature

- In general, as solar radiance increases, surface/air temperature also increases
- Output current of PV devices is directly proportional to incident solar radiation, while output voltage decreases logarithmically. Power increases overall.
- Output voltage of PV devices is inversely proportional to cell temperature. Current increases slightly with temperature. Power decreases overall.



MPPT

- Tracking and controlling output voltage and current caused by changes in temperature and solar irradiance. Achieved by sampling outputs and applying the correct load to draw maximum power.

Applications

- Solar power is not a full controllable source of energy and is often inconsistent. In order to properly connect a solar array to the grid, special constraints must be made in order to ensure power is generated/connected safely and efficiently to the grid as a whole.

https://www.fsec.ucf.edu/en/education/k-12/curricula/use/documents/USE_17_IrradianceTemperaturePV.pdf

https://www.tycorun.com/blogs/news/the-ultimate-guide-to-maximum-power-point-tracking-principles-faqs-and-calculations

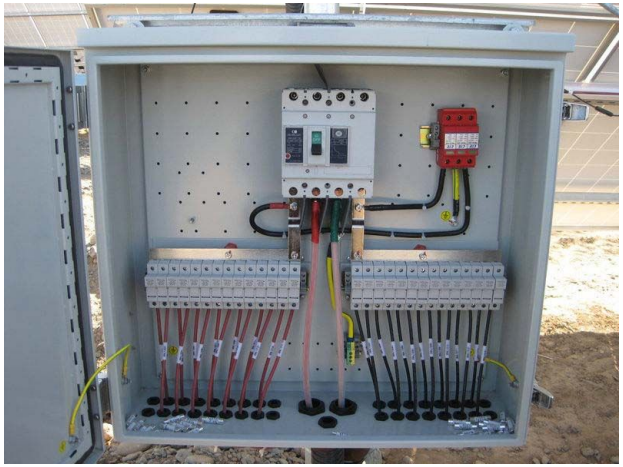
https://www.seaward.com/gb/support/solar/faqs/84179-what-is-solar-pv-i-v-curve-tracing/

Utility Grade Solar Panels Data Sheet

Link for Solar Panels Data sheets:
https://www.solarrun.com.au/solar-product-data-sheets/

https://www.amerescosolar.com/solar-panel-datasheet-library

Combiner Boxes



https://www.bhgsip-mediakit.com/r5/what-you-need-to-know-about-a-solar-combiner-box/

Main Purpose

- Merge multiple DC inputs
- Single DC output

Why use them?

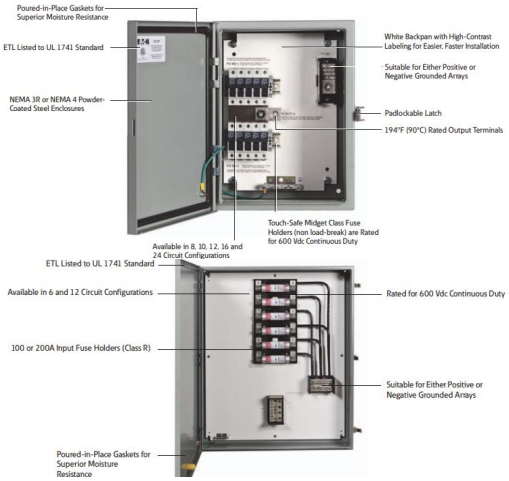
- Overcurrent and overvoltage to improve dependability
- Materials, labor, wiring cost reduced

In between solar panels and inverter/charge controller

Combiner Boxes

Characteristics

- Prevent moisture by adding gaskets to each panel door
- High Contrast Labeling to read easier
- 8-24 circuit inputs with 310A-400A continuous max current
- 6-12 circuit output with 720A-1520 continuous max current
- 100A or 200A fuse holders



https://www.eaton.com/us/en-us.html

Utility Grade Combiner Box Data Sheet

Link for Combiner Data sheets:

https://us.solarpanelsnetwork.com/blog/best-solar-combiner-boxes/

https://www.datasheetarchive.com/COMBINER%20BOX-datasheet.html

Utility-grade Solar Inverters

Main Purpose

- Make the electricity generate by the solar panels able to transmit into the grid.

Why use them?

- Convert DC to AC
- Allows output to be synchronized with the grid
- The Maximum Power Point Tracking(MPPT) allow Solar panels work more efficiently
- Stop sending power to grid in case there is failure, to protect workers

Where is Inverters?

- Between Solar Panels and Transformer

TMEIC's Solar Ware Ninja modular string inverter skid.

Utility Grade Inverter Data Sheet

Link for Inverter data sheets:

Commercial and UtilityEatonhttps://www.eaton.com › ecm › idcplg

Updates

1. Intellectual Property and Non-Disclosure Agreements
2. Software updates (AUTOCAD, BlueBeam, ETAP)