Design Report: 115/34.5 kV Solar Power Plant & Substation Design

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Eli

Project Information

Due to increasing Renewable Energy requirements for utilities, a 34.5/115 kV distribution substation and 60 MW Solar Plant will need to be designed by Iowa State University. We as the project team are responsible for the complete design of solar layout, electrical layout, and associated construction deliverables. Our project team will also perform various calculations required of a typical substation, including load-flow analysis, short-circuit studies, system protection design, and grounding calculations.

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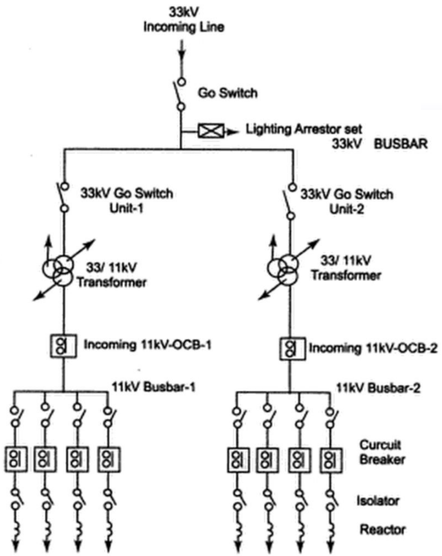
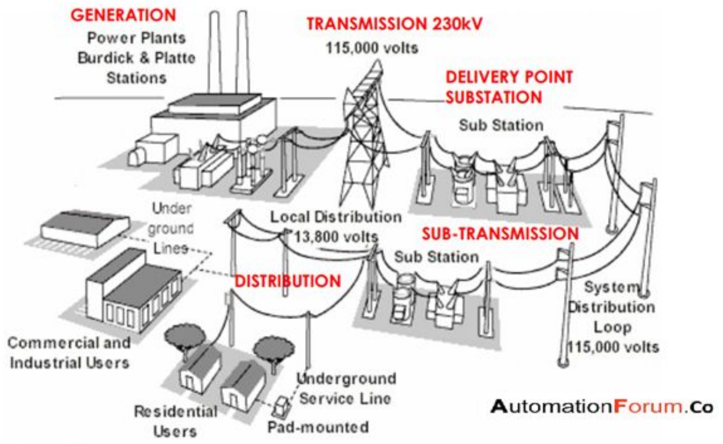
Substation Link   Solar Field Link

Substation Overview

Transmission lines come into substation at 115 kV. These lines then step down into transformers which take the voltage from 115 kV to 34.5 kV. The line then goes through a switchgear to help service in case of a disaster. After the switchgear, the lines go to bus bars 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 kV system and transformer, but similar principles apply to our project.

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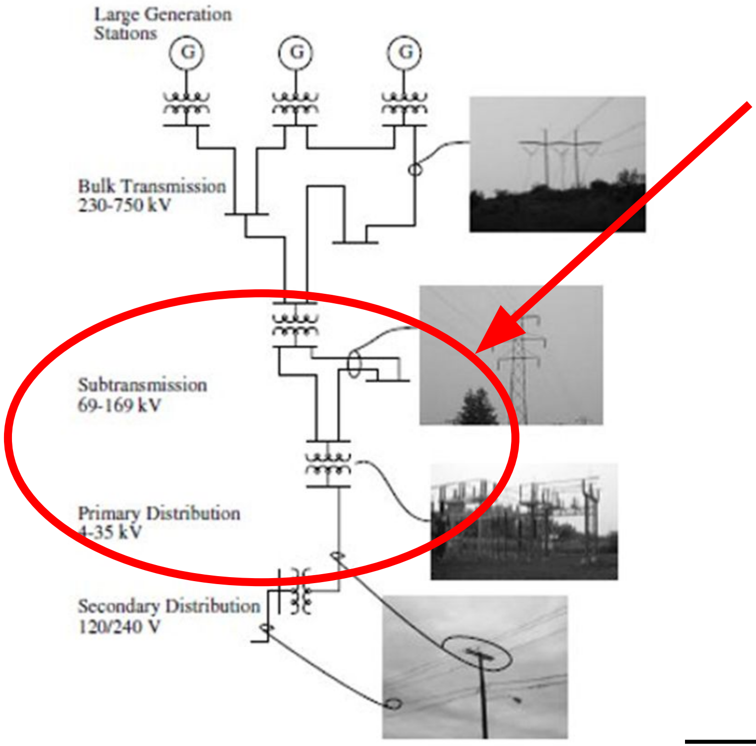
Substation One-Line Substation Picture

Electricity Infrastructure – Solar Farms (PV systems)



- Solar Farms (Photovoltaic systems) are usually interconnected to the grid at either the **sub-transmission voltage** or **primary distribution level**.
- Solar systems provide a DC output that must be inverted and stepped-up before making a network (grid) interconnection.

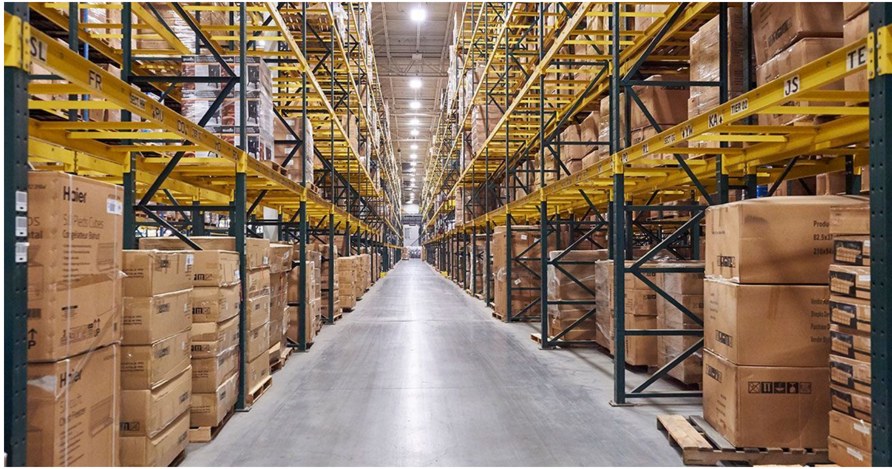
Safety Moment - Piling Stocking and Shelving Hazards

Hazards of improper stocking

- Back injury
- Stricken by equipment or accessories
- Damage to items or racking systems
- Improper securing items cause injury

Preventing hazards

- Correct form of lifting objects
- Heavier items on the lower or middle section
- Sack items on even flat surfaces
- Keep pathways and aisales clean



Source Link Link to Image

Design Overview

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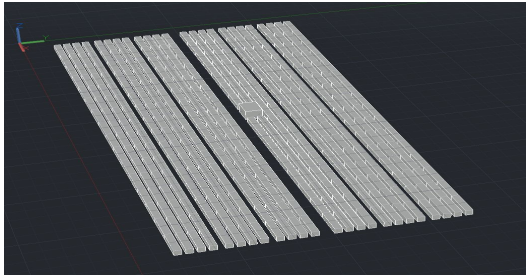
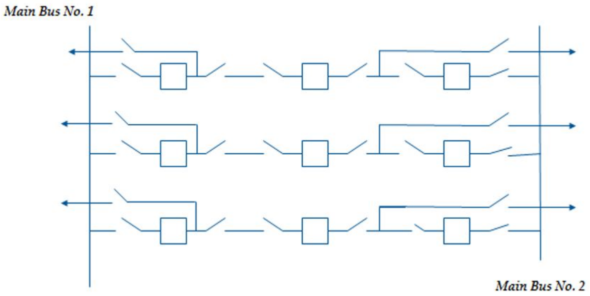
Design Content

- Choose solar farm equipment
- Set up solar farm equipment to meet desired parameters
- Calculate and design the wiring needed to connect each component



- Choose substation bus layout
- Design bus connections and choose proper protection equipment
- Design overall substation layout to maintain safety and avoid faults
- Calculate and design grounding grid for the substation

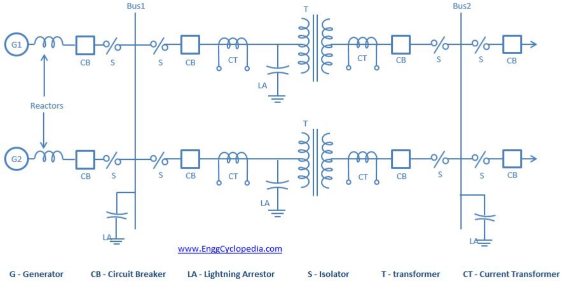


Design Complexity

- Choosing the solar array equipment relates to the principles of efficiency and iteration, as many different equipment combinations must be iterated through in order to select the most efficient setup

- Setting up the physical layout of the solar farm relates to the principle of simplicity, as the design must avoid needless complexities and unnecessary land/equipment expenses

- The design of the substation relates to the principles of reliability and quality, as the specific layout and equipment used in the substation must result in a low maintenance, highly reliable connection to the grid



Liam

Modern Engineering Tools

AUTODESK
AutoCAD

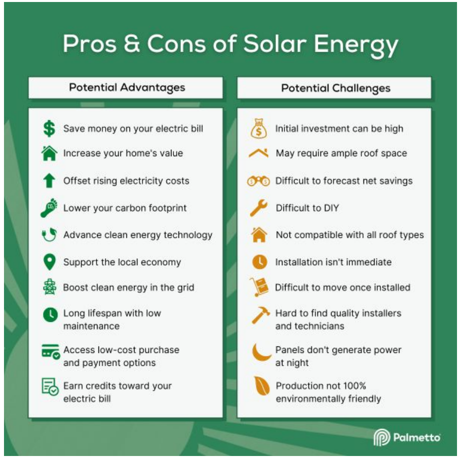
BLUEBEAM®
REVU® 20
STANDARD

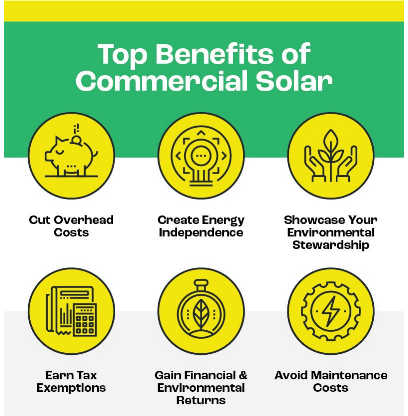
etap®
Thinking Power

Design Context

- Solar energy holds a significant and multifaceted position concerning the general public, its global ramifications, environmental effects, and economic implications.

1. Public Health:
    a. Commercial solar energy reduces the the need for fossil fuels in electricity production. In turn, reduces air pollution that contributes to respiratory illnesses. As air quality improves due to reduced pollution, there can be a decrease in healthcare costs associated with respiratory diseases and other health issues related to air pollution.
2. Global Impact
    a. The use of commercial solar energy reduces the amount of greenhouse gases being released into the atmosphere. Little to no emissions produced through solar energy. Increases cooperation among international markets for solar energy.
3. Environmental Impact:
    a. Commercial solar farms do require the use of large areas of land and can affect biodiversity. Production of panels uses natural resources including silicon.
4. Economical Impact:
    a. Increasing commercial solar use will increase job need to construction and operating costs. Adoption of renewable energy reduces energy costs and companies can receive tax exemptions. Growth of solar stimulates the economy while reducing climate change.



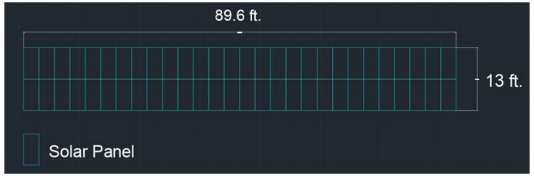


Citation 1
Citation 2

Prior Work/Solutions

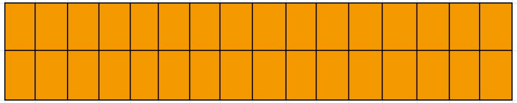
Project 1 - 2020

String Size		
Min Temp	-6.6	C
Voc	48.81	V
Ref temp	25	C
Temp Coeff of Voc	-0.003	/C
Temp delta	-31.6	
temp correction	1.09	
V0c corrected	53.43718	
string voltage	1500	V
String size	28.07033	
string size	28	
Actual String Voltage	1496.2	



Project 2 - 2024

		String Size		
	Location Dependent	Min Temp	-40	C
	Datasheet (STC)	Voc	50.2	V
	Datasheet (STC)	Ref temp	25	C
	Datasheet	Temp Coeff of Voc	-0.0029	/C
		Temp delta	-65	
		temp correction	1.19	
		V0c corrected	59.6627	
Confirm possible with Panel type chosen	Designer Choice: 600, 1000, 1500, 2000V	string voltage	1500	V
		String size	25.14133	
		string size	25	
		Actual String Voltage	1491.6	



89.68 in x 44.64 in (panel)

15 ft x 60 ft (rack)

Design Decisions

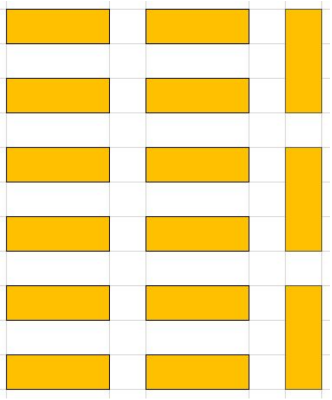
Solar panel
- 550 W
- 41.10 V

Combiner box
- 16 Inputs
- 1 Output
- 1500 VDC

Skids
- Each supports 1500 V
- Has inverter from AC to DC with a Transformer

Array Design (15 in total)
- Combiner box
- Skid
- 2 columns 6 rows
- 1 column 3 rows
- 78 MW DC and 60 MW AC

Cable
- #10 AWG for solar cells to combiner boxes
- 400 MCM cable from combiner box to inverter

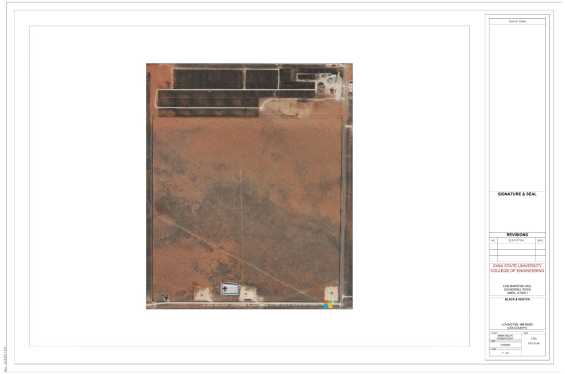


How it will be connected

Solar panel to combiner box which will connect to inverter and finally to a transformer into the grid/substation.

Location

Lovington New Mexico



Eduardo

Proposed Design

Solar Power Plant & Substation Design

60MW Solar Power Plant

Location: Lovington, New Mexico (High Solar Irradiation, Lower Land Cost)
Solar Plant Parameters: Array Parameter Tools
Components : Solar panels, combiner box, inverter
Solar Plant Layout: AutoCAD
Voltage-Drop Calculation: less than 5% (based on National Electric Code(NEC))
Power Flow Analysis: ETAP

115/34.5KV Substation

The substation step-up the voltage from 34.5kV to 115kV for transmission at the grid (high voltage for less power loss)

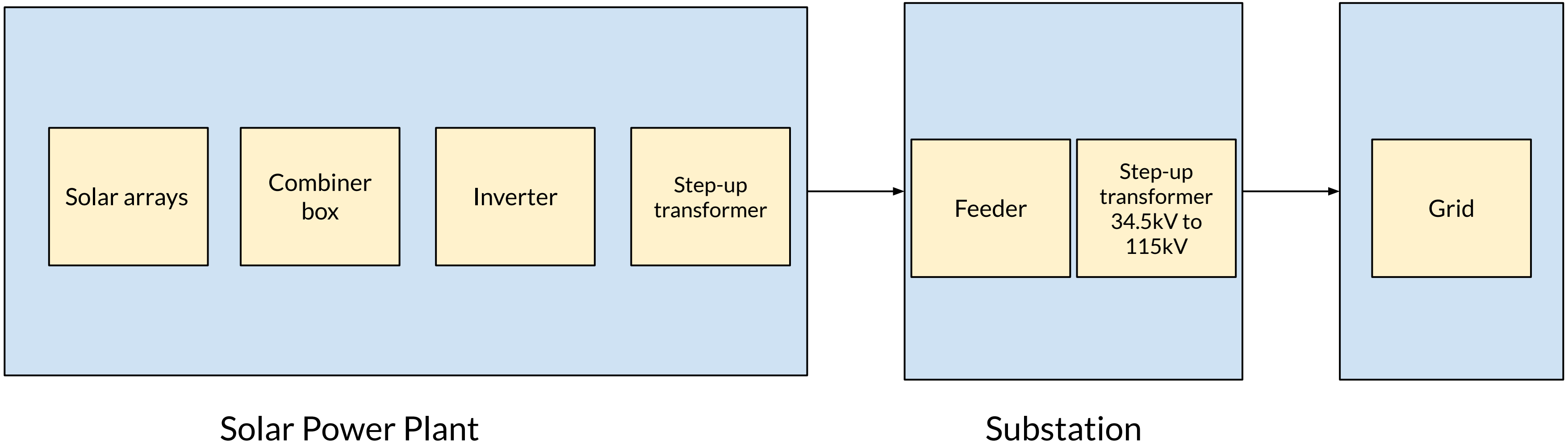
System one-line diagram
System three-line diagram
Protection and control analysis

Grid Connection

The grid delivers to the high electricity demand;

Residential area
Industrial area
Public institutions
Commercial

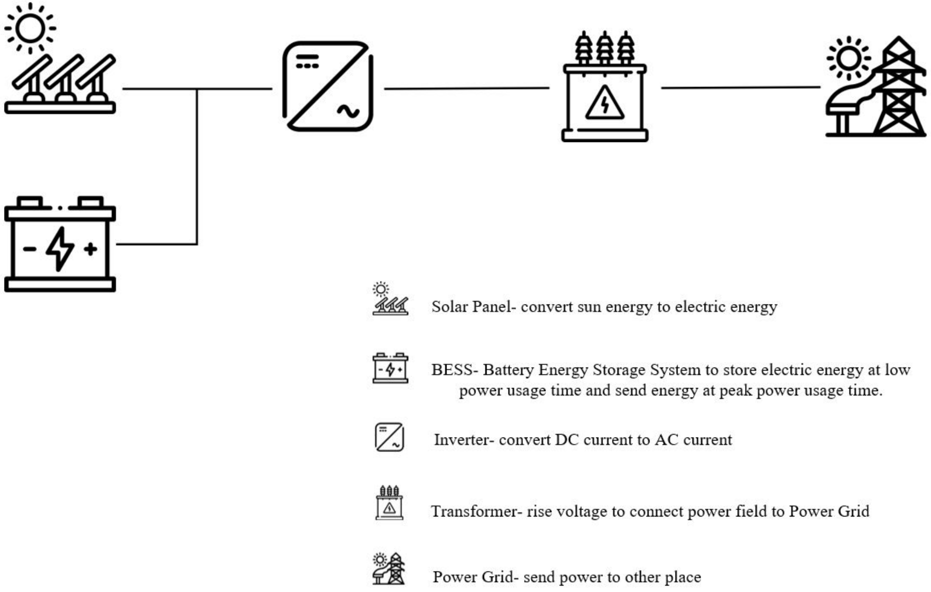
Components of the design



Power Storage - Design 0

After DC electric power generated by the solar panel, it will be transfer to inverter to convert it into AC electric power. Than, the step up transformer rise the voltage to power grid level, so the power can transfer into power grid.

At the same time, if the power generated more than use, it can store in Battery before transfer it to inverter and release at time that usage get bigger.

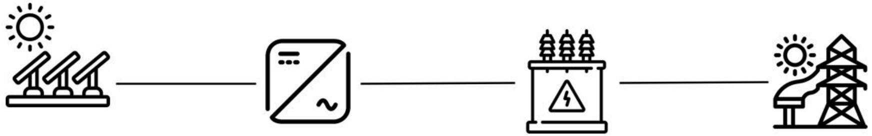


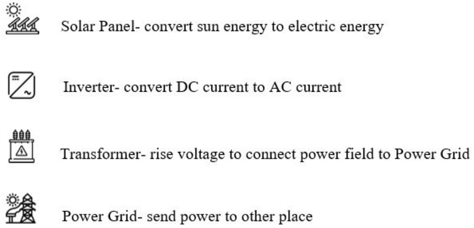
Power Storage - Design 1

After DC electric power generated by the solar panel, it will be transfer to inverter to convert it into AC electric power. Than, the step up transformer rise the voltage to power grid level, so the power can transfer into power grid.

Why not BESS?

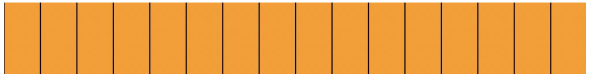
- Connect directly to the power grid
- Cost
- Environment



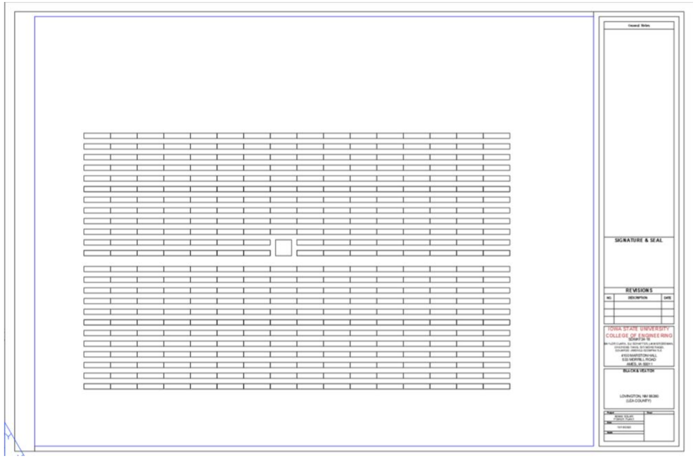


Solar Panel Layout - Design 1

-1 string per rack



-16 racks per row



-24 combiner boxes
(1 per row)
-1 inverter per array

1 string per rack (550W panels)
16 racks per 1 row
1 16-input DC combiner box per row
24 rows per 1 array
1 inverter per array
15 array in total

Estimated DC Power Output: 78.79MW
Estimated AC Power Output: 60MW