RatedPower
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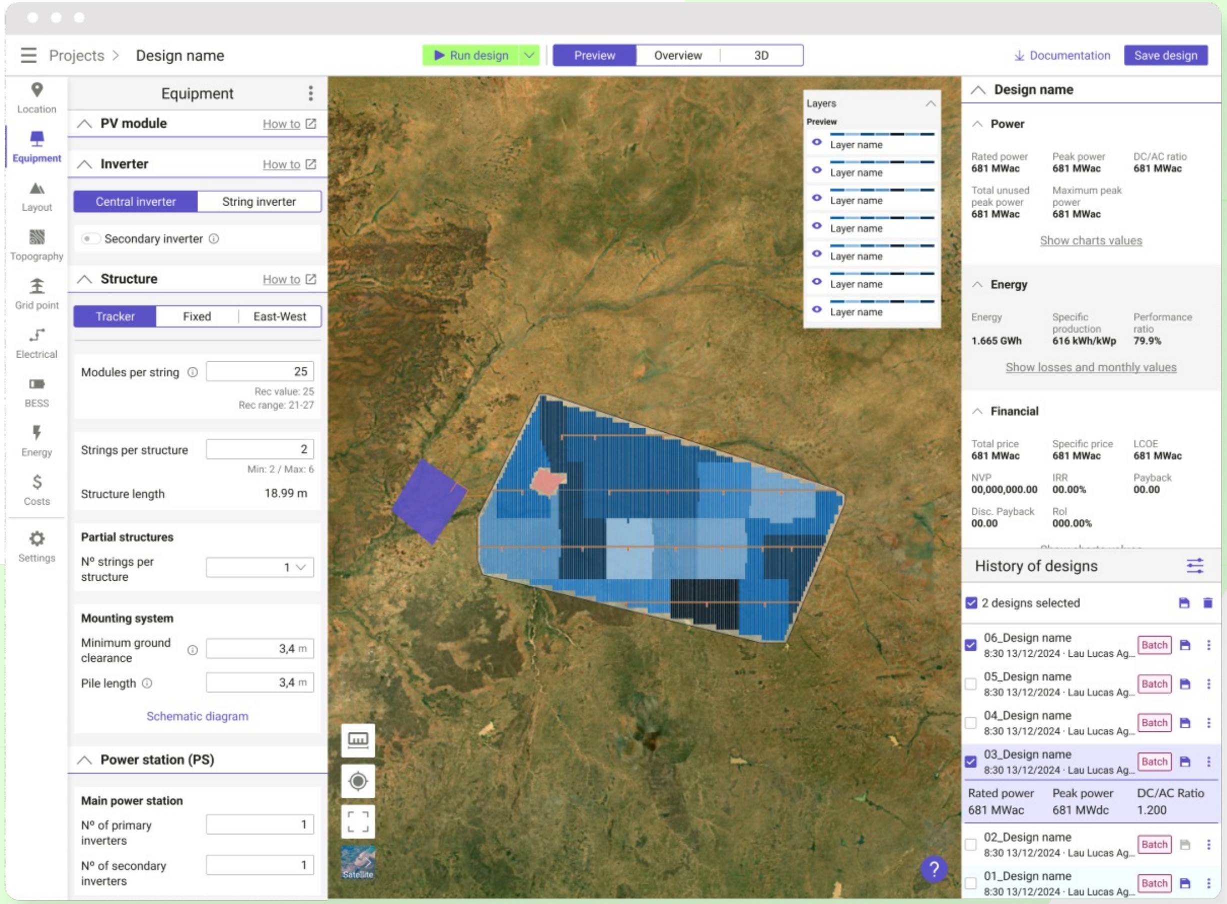
Smart energy *flow*

June 2025



Step-up Transformers

and the hidden-cost of poor substation design

Your speaker today

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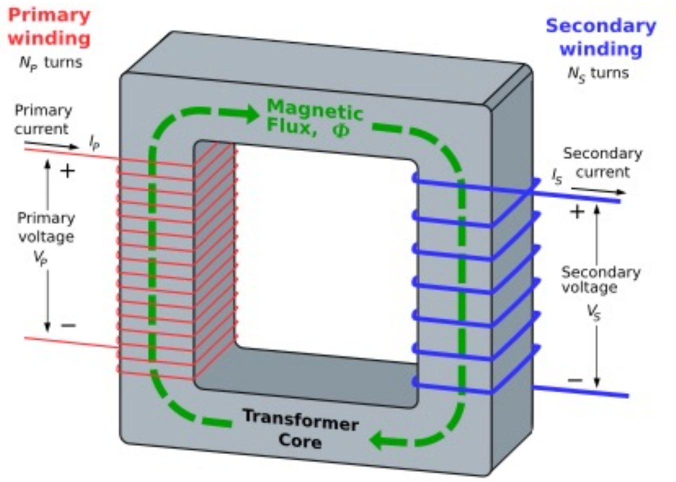
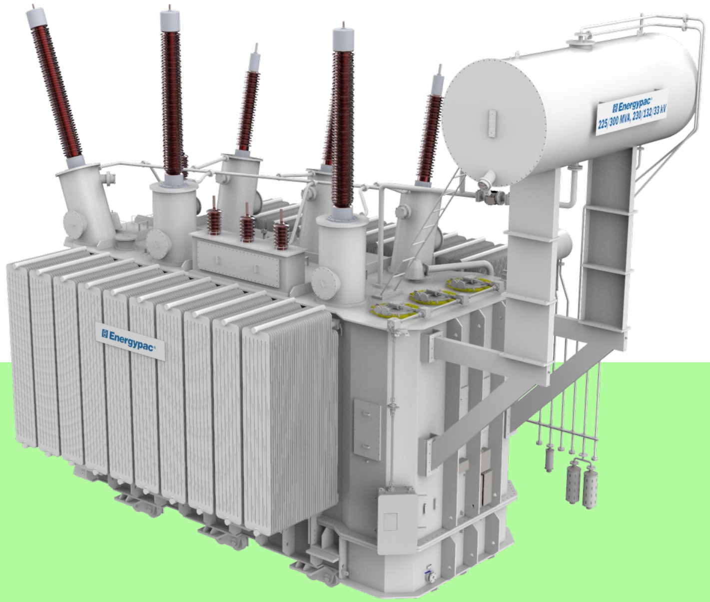
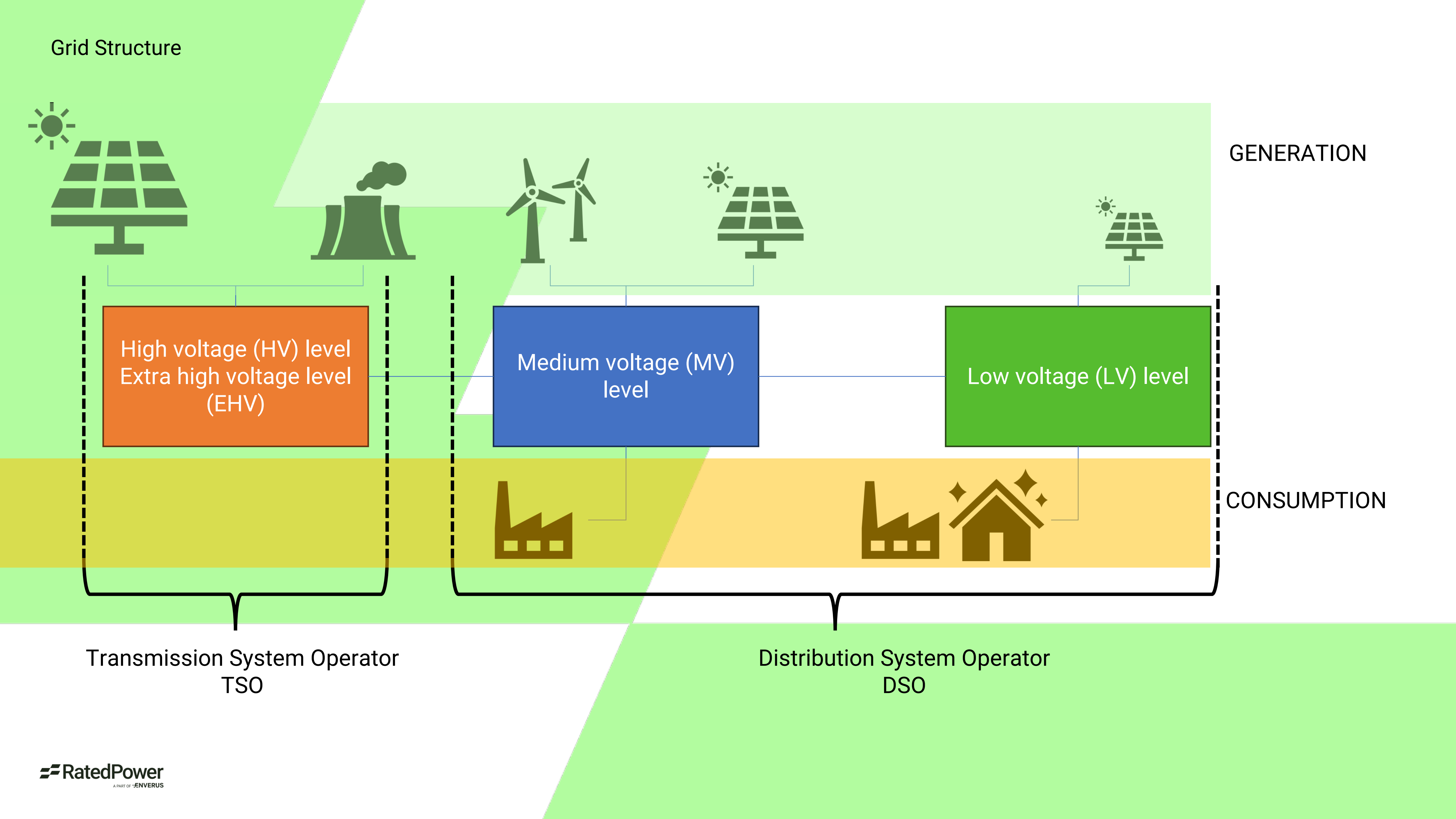
01. Transformers

- They are used to **transform the voltage level** while transferring the power between primary and secondary circuit
- They exploit electromagnetic induction
- They are affected by two main losses
  - **Iron losses** → related to the iron core
  - **Copper losses** → related to the copper wiring







Grid Structure
GENERATION
High voltage (HV) level
Extra high voltage level
(EHV)
Medium voltage (MV)
level
Low voltage (LV) level
CONSUMPTION
Transmission System Operator
TSO
Distribution System Operator
DSO
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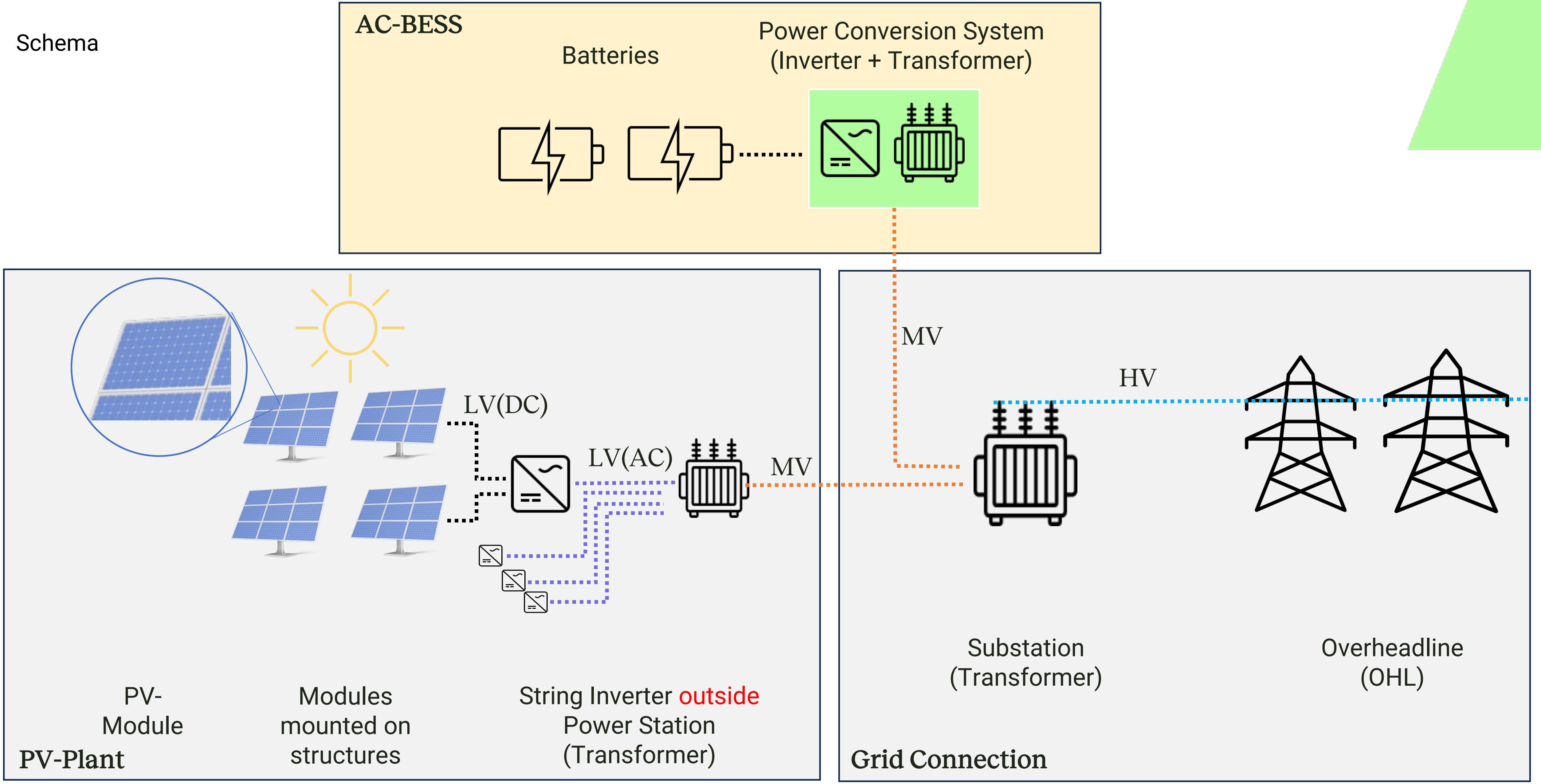
Schema


AC-BESS
Batteries
Power Conversion System
(Inverter + Transformer)
MV
HV
LV(DC)
LV(AC)
MV
PV-
Module
Modules
mounted on
structures
String Inverter outside
Power Station
(Transformer)
PV-Plant
Substation
(Transformer)
Overheadline
(OHL)
Grid Connection

What are the main objectives of the electric network?

- To connect generation and consumption, transferring power where it's needed
- To keep it as cheap and efficient as possible
- To ensure a reliable and resilient power supply

Why different voltage levels?

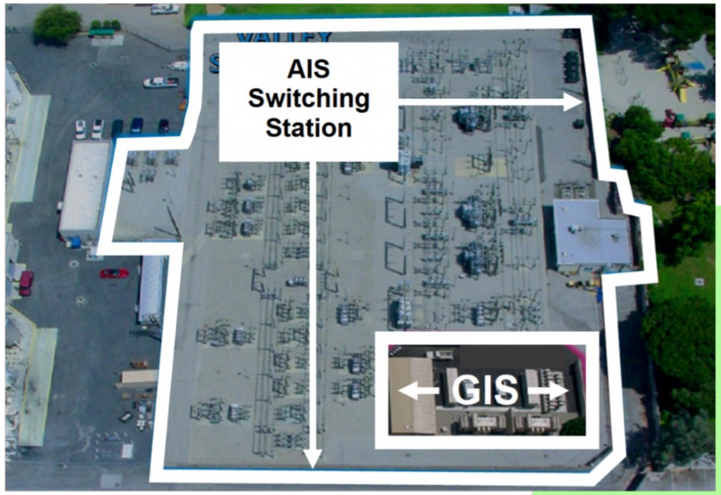
→ Power is generated at lower voltages

→ To transfer that power more efficiently along large distances, voltage is stepped up to MV/HV levels using **transformers** → higher voltage → lower current →lower transmission losses

→ Depending on the size of a PV plant, it could get interconnected to the public grid at MV or HV level. The rules varies from Country to Country and are determined by DSOs and TSOs.

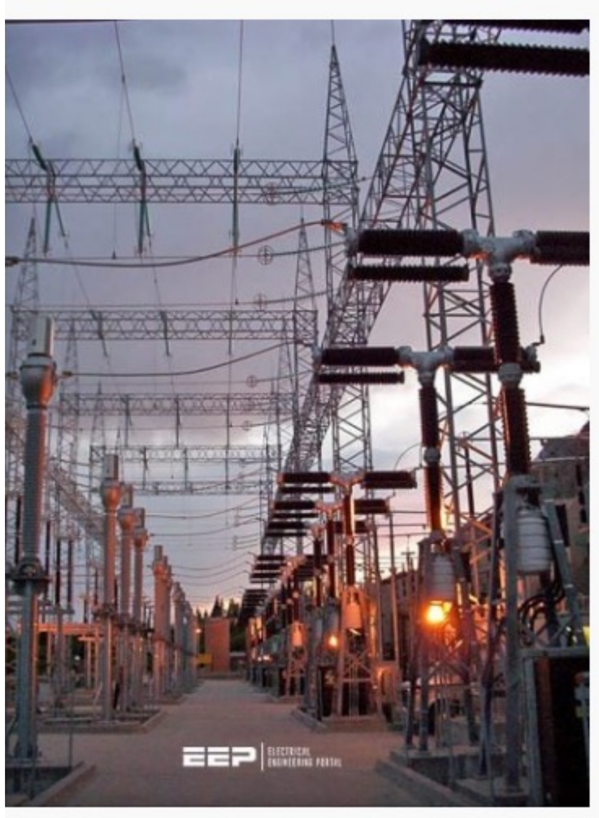
02. Substation Design

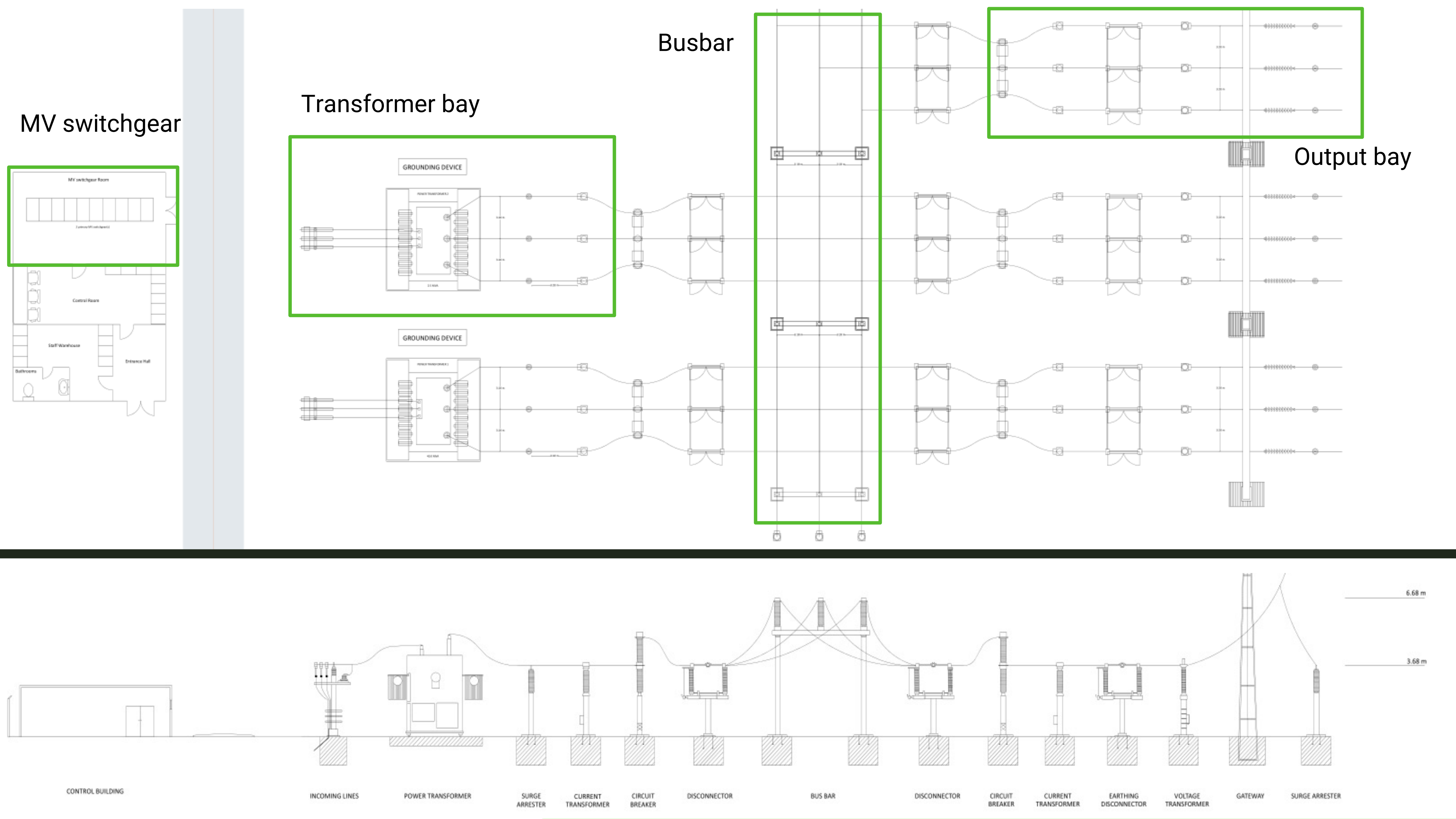
- They step up the voltage from MV to HV level with transformers
- There are three main types:
  - **Gas Insulated Substations (GIS)** → not available in RP
  - **Air Insulated Substations (AIS)** → available in RP
  - Mixed-technology switchgear (MTS) → not available in RP



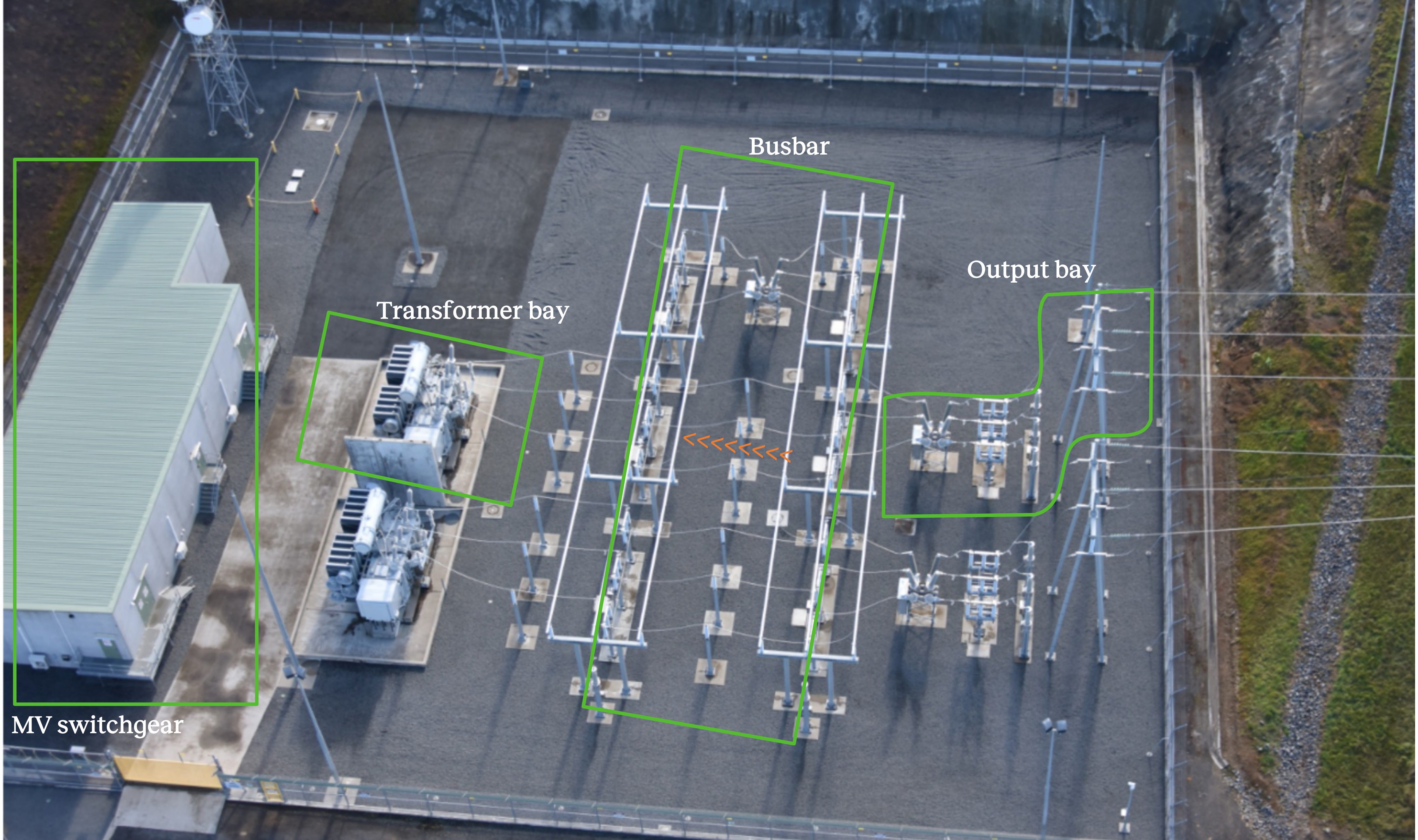
Gas Insulated Substation (GIS)

Air Insulated Substation (AIS)





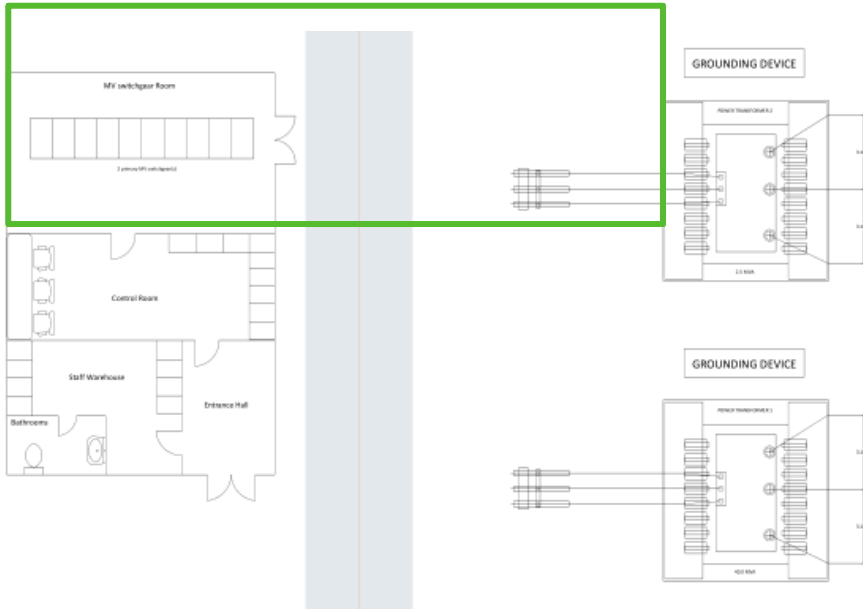
MV switchgear
Transformer bay
Busbar
Output bay
MV switchgear Room
Control Room
Staff Warehouse
Entrance Hall
Bathrooms
GROUNDING DEVICE
GROUNDING DEVICE
6.68 m
3.68 m
CONTROL BUILDING
INCOMING LINES
POWER TRANSFORMER
SURGE ARRESTER
CURRENT TRANSFORMER
CIRCUIT BREAKER
DISCONNECTOR
BUS BAR
DISCONNECTOR
CIRCUIT BREAKER
CURRENT TRANSFORMER
EARTHING DISCONNECTOR
VOLTAGE TRANSFORMER
GATEWAY
SURGE ARRESTER


Busbar
Output bay
Transformer bay
MV switchgear

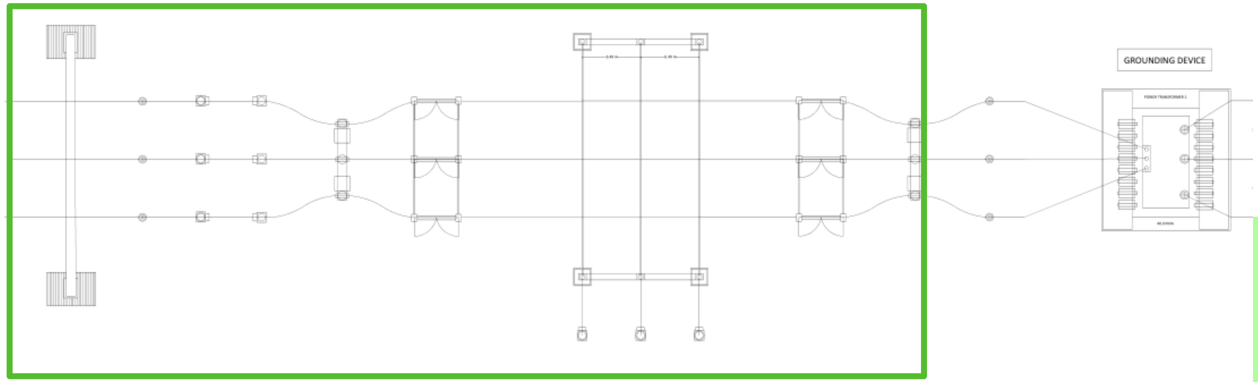
Pooling Substation

- It's similar to a substation
- It steps up the voltage from HV to EHV
- In RatedPower only the Air Insulated Substation (AIS) type is available
- The Input bays are overhead and not in a building as for substations

Input lines - Substation



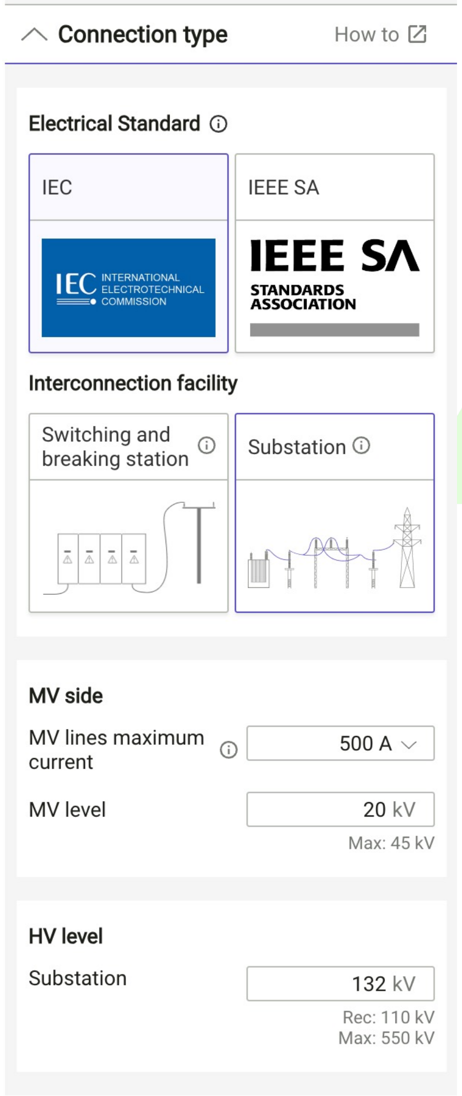
Input lines – Pooling Substation



Sub-tab 1: Connection type

At this moment, RatedPower will define an **air-insulated substation (AIS)**.
For each substation, RatedPower will automatically determine, be default, the following elements:
•**Substation arrangement**
•**Transformer type**
•**Transformer bay size**
•**Output bays** (only for highest voltage level facility)

•Each of them **can also be selected manually** by the user, let's look into details of each option.



We will also be given the option to customize the MV/HV voltage (in kV) and the MV Lines maximum current

- **Single busbar :**

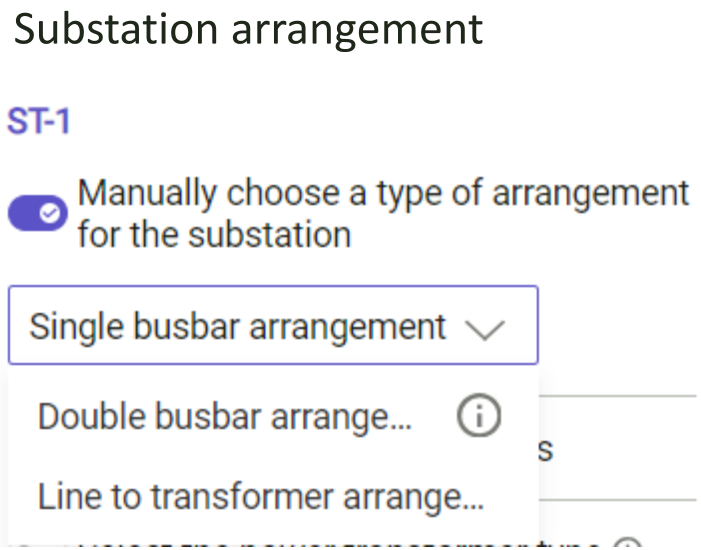
A single busbar is established to allow operational and flexible bay configurations.

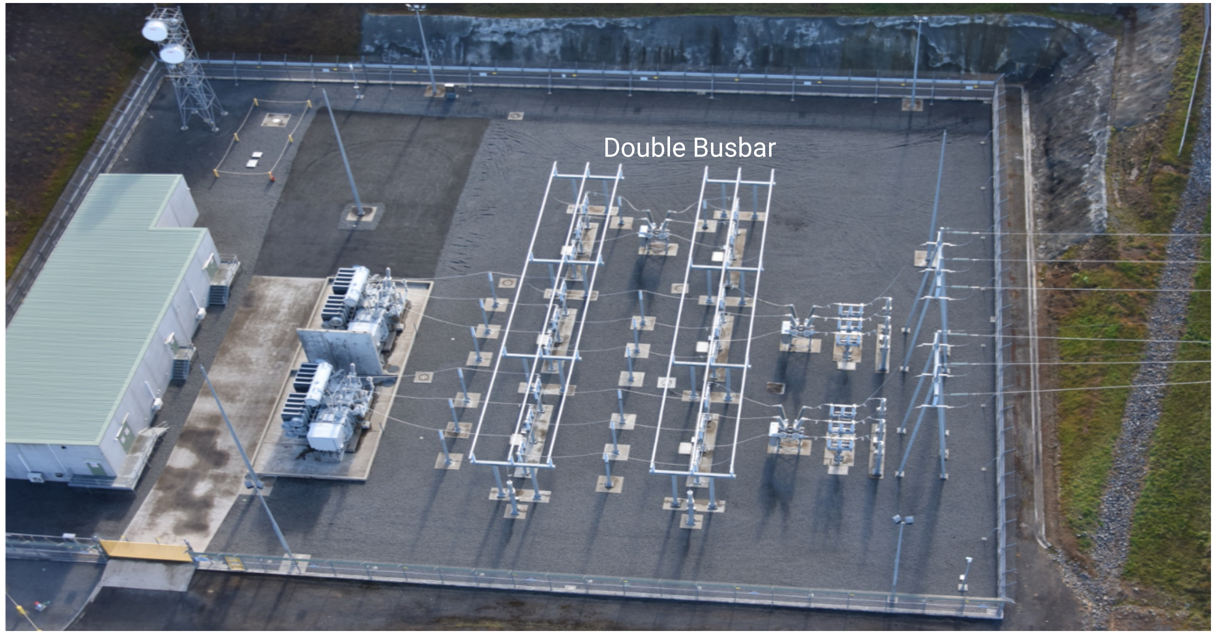
- **Double busbar :**

Two busbars are established to allow operational and flexible bay configurations, to increase the security of supply, and to improve availability during maintenance periods.

- **Line-to-transformer :**

The line-to-transformer substation connects the PV plant to the grid directly without the use of a busbar. It stands out for being the simplest substation layout.

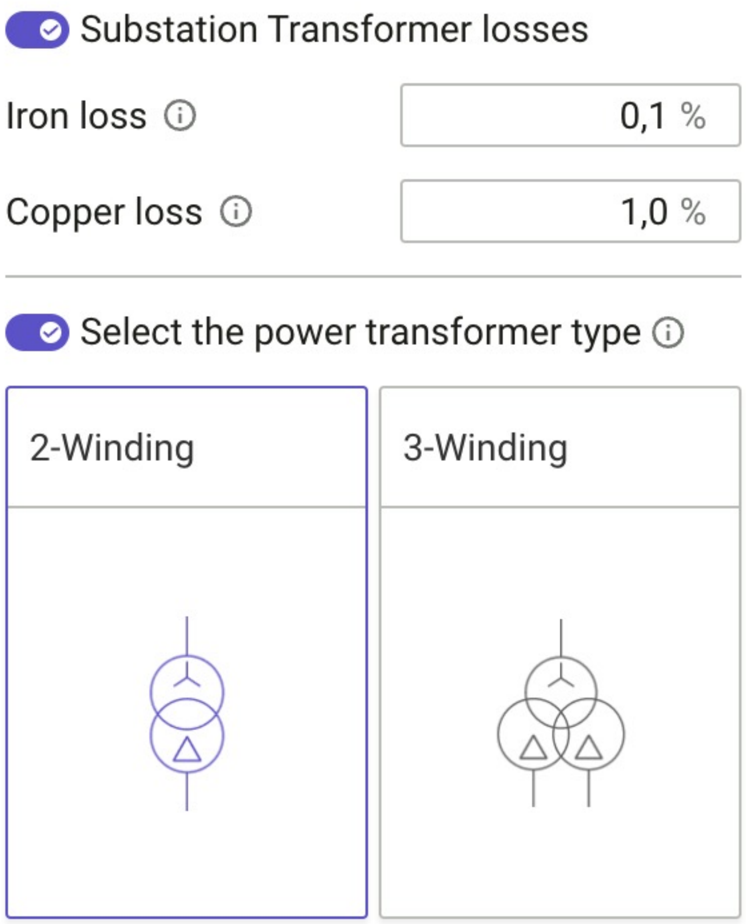




- It’s possible to customize the substation **Iron Losses and Copper Losses**

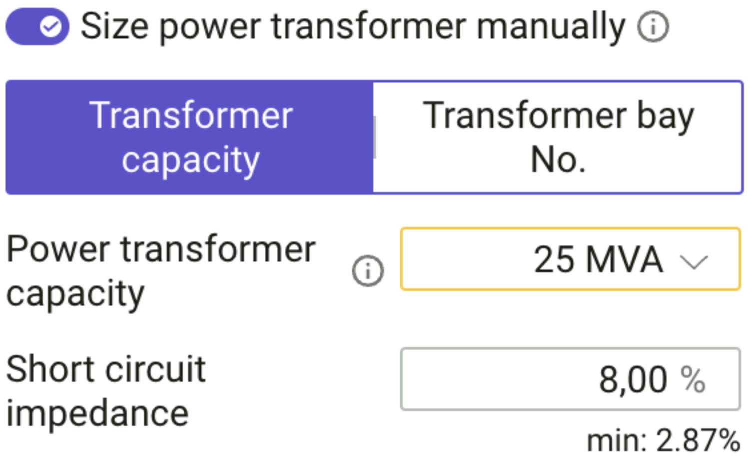
- It’s also possible to choose between a 2-windings and a 3-windings transformer. RatedPower will recommend you the best choice based on the plant's capacity.

Power transformer type and transformer losses

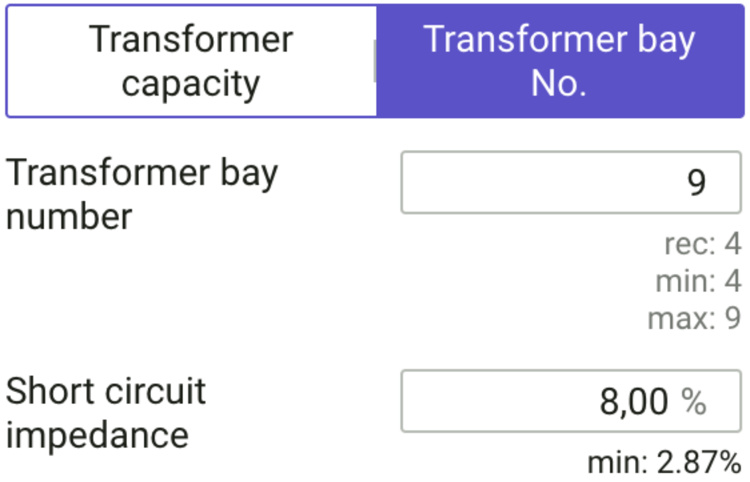


You can either specify the transformer capacity or the number of transformer bays.

Power transformer size*:



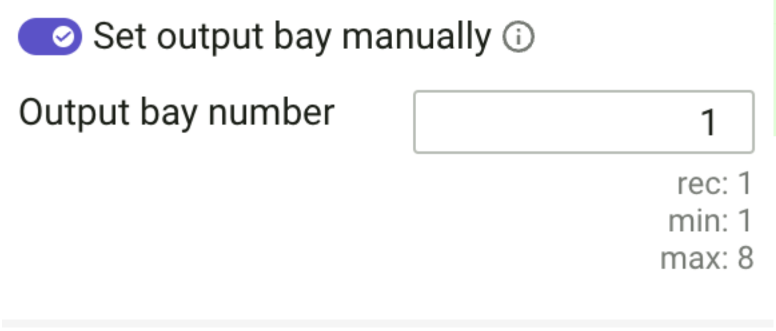
If you **input the transformer capacity**, RatedPower will calculate the number of transformers required to evacuate the power through the ST.



If we **input the number of bays**, RatedPower will determine the power transformer capacity, while providing with a recommended value as well as a minimum and maximum value to input for protective equipment to be able to withstand the flowing current.

In both cases, you can also specify the short-circuit impedance of the power transformer.

- Finally, this option concerns the number of outgoing bays from the substation to either a pooling substation or the grid.
- RatedPower will also provide with a recommended value as well as a minimum and maximum value for protective equipment to be able to withstand the flowing current



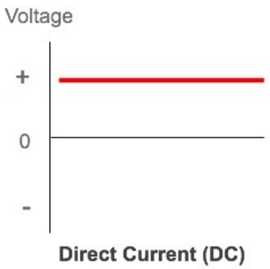
Output Bays

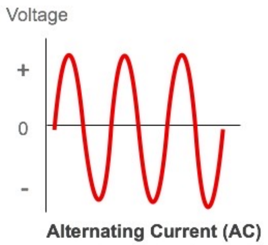
03. Power Station Design

Power station
Inverter + Transformer

LV DC

MV AC

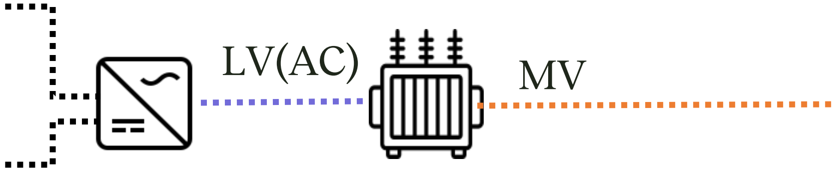




What is a Power Station?

- **Power station = Transformer station/Skid**
- **Purpose:** Increase/Decrease the incoming Voltage
- **Reason:** A higher Voltage can be distributed in smaller cables with less losses

Source: https://www.solarserver.de/2022/04/04/huawei-neue-photovoltaik-trafostation-in-deutschland-ausgeliefert/



Power Station = Transformer Stations

MV level 20 kV
Max: 45 kV

Main Power Station

N° of primary inverters: 4

Secondary Power Stations

Select the types of PS to install in your plant.

- [x] Select all
- [x] PS 1: 3 primary inverters
- [x] PS 2: 2 primary inverters
- [x] PS 3: 1 primary inverters

Transformers

Select the power station to customize

Main PS | PS 1 | PS 2 | PS 3

Selected PS: PS Main: 4 primary inverters

Number of transformers: 1

Transformer n° 1

2-Winding

3-Winding

The selected transformer contains: 4 primary inverters

Capacity: 9.24 MVA
Min: 9.24 / Max: 12.01

Short-circuit impedance of selected PS: 8.0 %
Min: 5.0% / Max: 12.5%

Transformer Losses

Power Station

Iron loss: 0.1 %

Copper loss: 1.0 %

Enclosure: Indoor / Outdoor

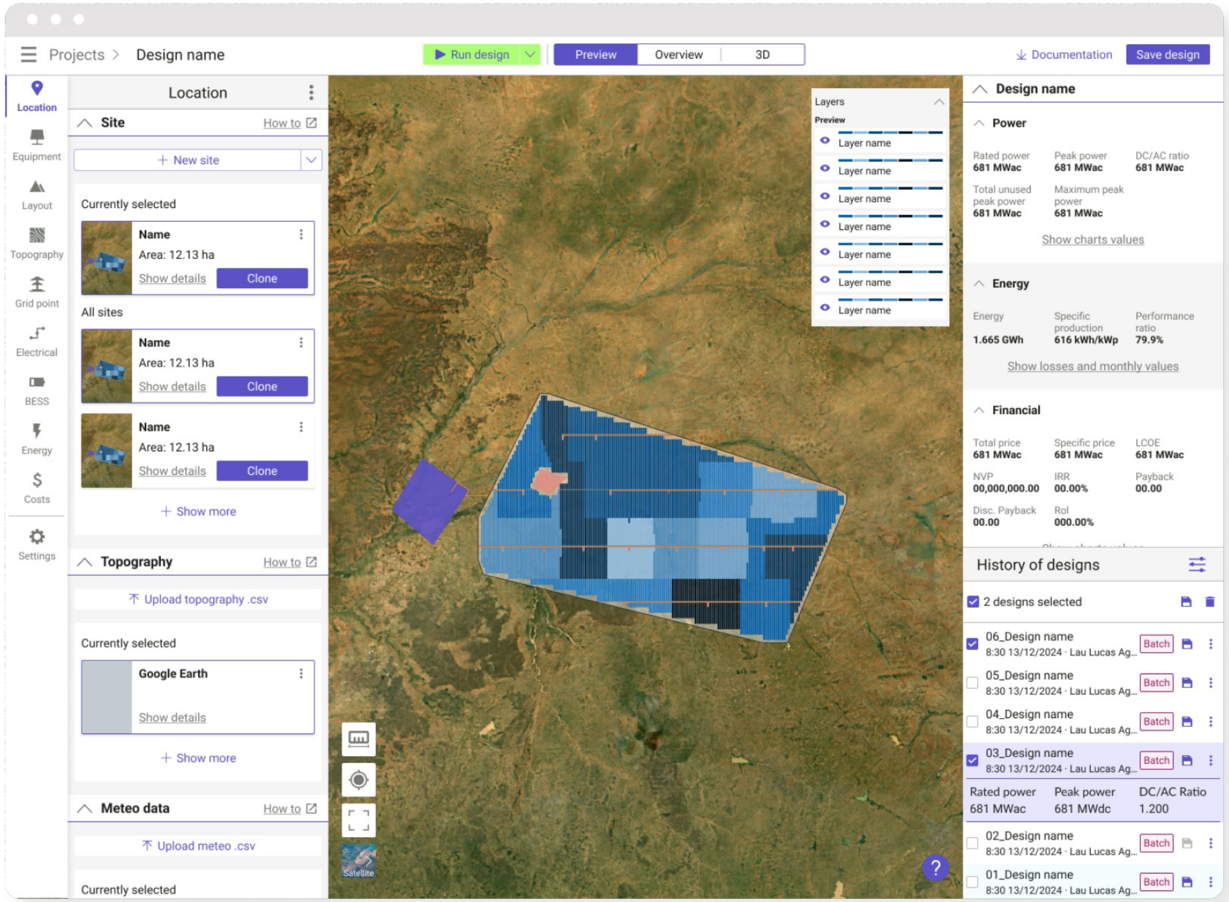
Types of Power Stations inside RatedPower

- Default Power Stations (Main Power Stations):
  These are prioritized in the plant, with the algorithm installing as many as possible.
- Non-Default Power Stations (Secondary Power Stations):
  These are installed when the remaining strings in an area are insufficient to form a default power station. Users can specify which secondary power stations to include, with priority determined by their AC power, starting with the largest and moving to the smallest allowed.

04. How to optimize your project

In RatedPower, the smallest unit of AC power is the power station.

- → RatedPower connects structures only when the size of a power station (PS) is achieved.
- → The total AC power of a design is the sum of all installed power stations.
- → In small areas, red structures or failed simulations may occur if there are not enough structures to meet the minimum requirements for the smallest PS defined by the user.
- → Addressing this often involves modifying equipment or layout constraints—such as pitch, setbacks, or structure configurations—to fit more DC power into the area.



- Enabling several non-default PS options gives the algorithm more flexibility to allocate smaller clusters of structures that do not meet the requirements of a bigger power station.

- “Install Maximum Peak Power” option optimizes DC/AC ratio to connect red structures

- LV grouping for multiple areas

- Small areas – more sensitive to layout parameters – minimize setbacks; custom PS size; PS location inside DC field.

This trick only works for

- Central Inverters
- Specific Capacity Designs
- Combination of 2 sizes

Enable Secondary (Central) Inverters

and select the same model as the primary inverter.

Size the design with Specific Capacity

We will bypass the prioritization of bigger PS by introducing the exact number of secondary inverters in our design as the way of telling RP how many of the secondary PS we want.

Step-by-step guide

Example

Two power stations with 8 inverters and two power stations with 7 inverters

Total number of inverters = 2*8 + 2*7 = 30

Let us define our main PS with 7 primary and 1 secondary inverter; and our secondary PS with 7 primary and 0 secondary inverters.

In specific capacity, we size the design with:

- Primary inverters: 7 * (2 + 2) = 28
- Secondary inverters: (8 - 7) * 2 = 2

05. Energy Model

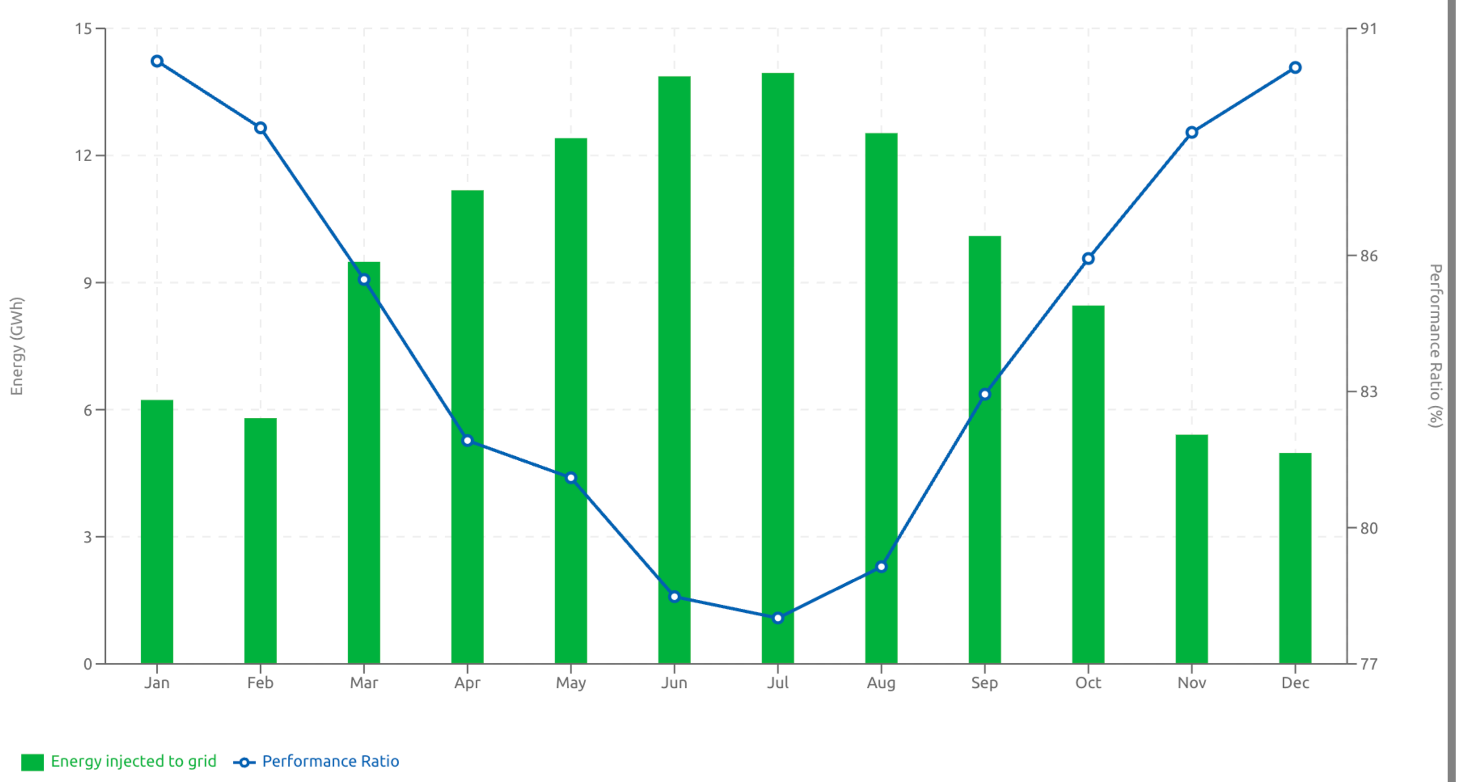
Transformer Losses

System losses

Module mismatch	-1.00%
Array shading	0.00%
DC Wiring loss	-1.19%
Inverter voltage threshold	0.00%
Inverter over voltage	0.00%
Inverter power threshold	0.00%
Inverter power limit	-1.75%
Inverter auxiliary loss	0.00%
Inverter efficiency	-1.49%
AC Wiring loss (inverter to transformer)	-3.59%
PS transformer Iron loss	-0.16%
PS transformer Copper loss	-0.77%
MV Wiring loss	-0.35%
Plant auxiliary loss	0.00%
Substation transformer Iron loss	-0.26%
Substation transformer Copper loss	-0.48%
Delivery limit loss	0.00%
Wiring plant to grid loss	-0.08%
Plant availability	0.00%
Grid availability	0.00%

Gains Losses 0% gains and losses

Monthly breakdown



06. Documents

Main related docs

Reports: Design, Energy, Substation

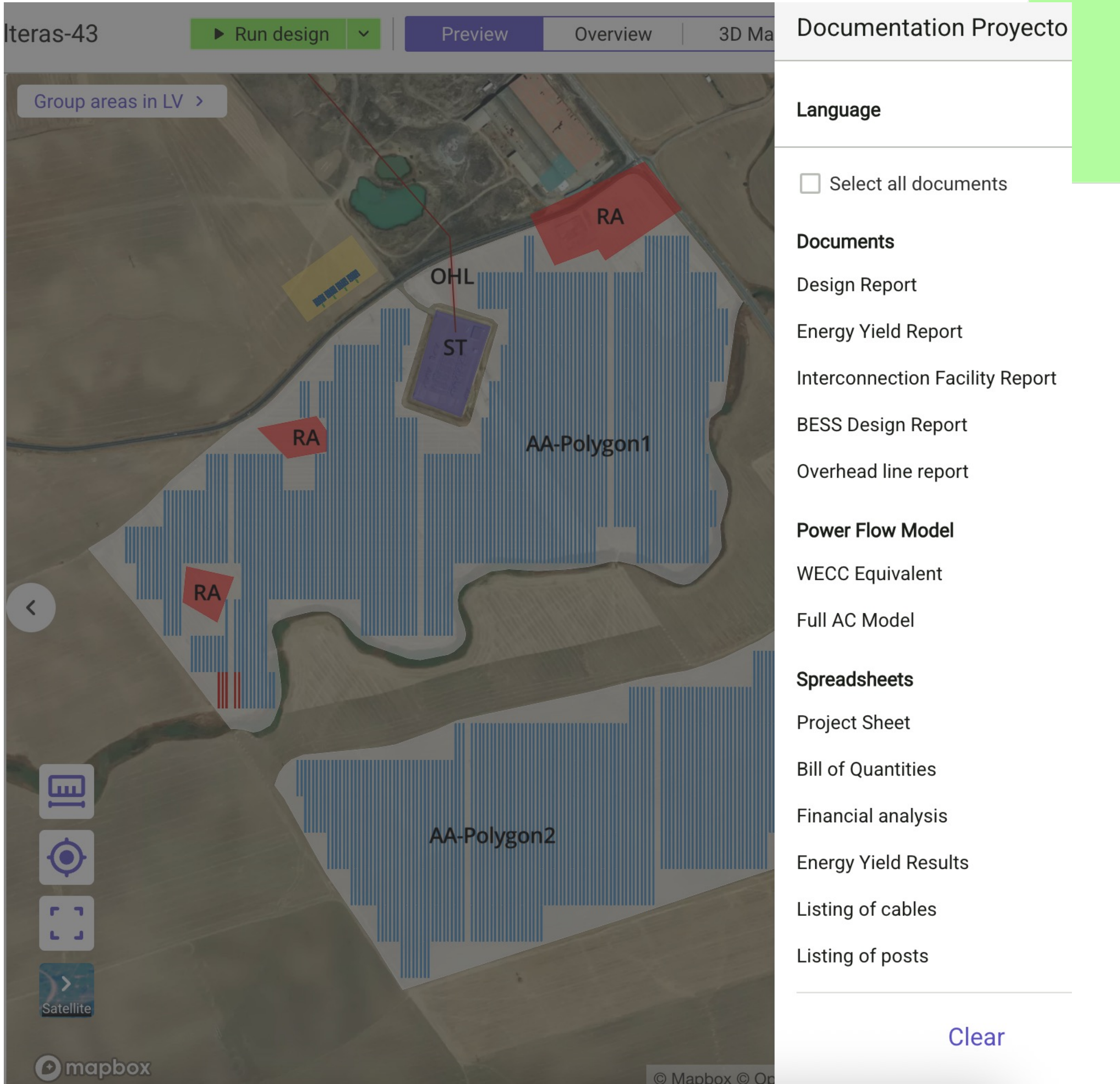
BoQ

SLDs

Substation Layout

Energy Yield Results

Power Flow Model



Thank you!

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Questions?

We're all ears! Drop yours in the question box!

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