BESS Methodology

A methodology to design a battery energy storage system layout

September 15, 2023

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Abstract

This methodology describes the process to design the layout of a battery energy storage system in the software pvDesign. The authors of this methodology have proposed the following structure for the document.

- The circuit arrangement that a battery energy storage system can adopt.
- The design of an AC-Coupled BESS schema and how to consider the topography requirements, the layout generation, the medium voltage lines and the integration of the system in the interconnection facility.
- The design of a DC-Coupled BESS schema and how to generate an hybrid layout considering the photovoltaic plant constraints.

Note: All the calculations that are presented in this methodology are carried out in accordance with the latest electrical standards.

Contents

List of Figures

List of Tables

Chapter 1

Battery energy storage system arrangements

This chapter summarizes the possible electrical BESS arrangements that are available in the industry and the one that was prioritized for the development of pvDesign. [1]

1.1 Type of electrical arrangement

Solar panels can be coupled, or linked, to a battery either through alternating current (AC) coupling or direct current (DC) coupling. AC current flows rapidly on electricity grids both forward and backward. DC current, on the other hand, flows only in one direction.

In the past, AC-coupled BESSs were most often used with residential and commercial solar installations, and DC-coupled systems were used for remote and off-grid installations, but more options for DC-coupled systems have become available. Equipment manufacturers are developing streamlined and standardized power electronics equipment for DC-coupled BESSs. Over the past decade, inverter technology has advanced and resulted in the development of new AC-coupled and DC-coupled systems.

The possible layouts that can be obtained are the following ones:

1. AC Coupled BESS. In AC-coupled systems, there are separate inverters for the solar panels and the battery. Both the solar panels and the battery module can be discharged at full power and they can either be dispatched together or independently, creating flexibility in how the system operates. The solar panels and battery can either share an interconnection to the grid or run on separate interconnections.

   AC BESSs comprise a lithium-ion battery module, inverters/chargers, and a battery management system (BMS). These compact units are easy to install and a popular choice for upgrading energy systems and the systems are used for grid-connected sites as the inverters tend not to be powerful enough to run off-grid.

   It's worth noting that because both the solar panel and the battery are DC-current compatible, the current will need to be converted three times in an AC-coupled system. Figure 1.1 illustrates the AC-coupled BESS.

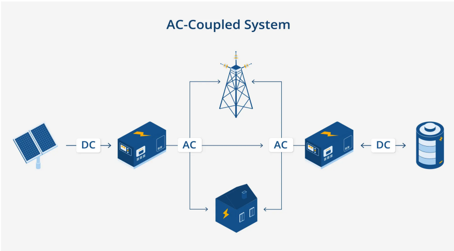

Figure 1.1: AC-coupled battery energy storage system diagram. Source: RatedPower

2. DC Coupled BESS. DC-coupled systems typically use solar charge controllers, or regulators, to charge the battery from the solar panels, along with a battery inverter to convert the electricity flow to AC.

   The solar panels and battery module use the same inverter and share the grid interconnection, reducing the cost of equipment. This also reduces power losses from inverting the current and running separate interconnection lines to the grid, as the solar array and battery are dispatched as a single facility. But this offers less flexibility than an AC system. Figure 1.1 illustrates the DC-coupled BESS.

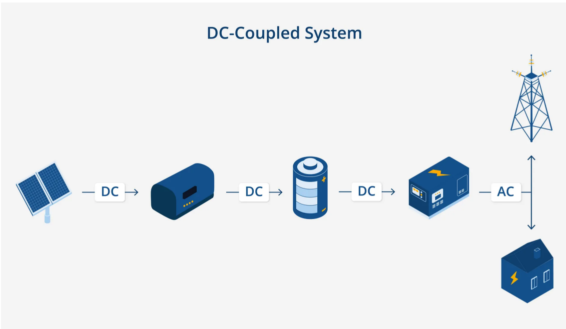

Figure 1.2: DC-coupled battery energy storage system diagram. Source: RatedPower

The software automatically generates a solution for an AC-coupled and DC-coupled BESS.

1.2 AC-Coupled BESS advantages and disadvantages

There are several benefits to using an AC-coupled BESS for your solar plant, including:

1. Retrofitting: AC-coupled batteries are easy to install on an existing solar panel system, and more can be added to expand capacity.
2. Flexibility: Installers are not restricted in where the inverters and batteries can be located. AC coupling works with any type of inverter.
3. Resiliency: The flexibility to install multiple inverters and batteries in different locations helps risk of an outage if an inverter fails. Having multiple inverters provides more combined power and battery faults do not have an impact on power generation.
4. Versatility: AC-coupled systems enable batteries to charge from the grid as well as the solar panels and the grid, so if the solar panels are not generating enough electricity, the battery can still charge from the grid.

On the other hand, the disadvantages can be listed as follows:

1. Cost: AC-coupled systems cost more than DC-coupled systems as they use multiple inverters.
2. Lower efficiency: The stored energy is converted three times, from the DC current to AC current to supply the building and then back to DC current to the battery and again back into AC. Each conversion results in a small amount of energy loss.
3. Supply limitations: AC BESSs are not designed to be used off-grid and as they are transformerless, they cannot manage the surge loads from multiple appliances.

1.3 DC-Coupled BESS advantages and disadvantages

Where AC-coupled systems suffer in terms of efficiency and cost, DC-coupled systems have the advantage:

1. Affordability: DC-coupled systems tend to be cheaper than AC-coupled systems as the solar panels and battery use a single inverter and less extra equipment such as voltage transformers and switchgear.
2. Higher efficiency: Unlike AC systems which convert the current multiple times, DC BESSs only convert the current once, reducing energy losses and making them more efficient.
3. Oversizing: DC-coupled systems allow solar panels to generate more electricity than the inverter rating. The excess energy can be used to charge the battery, an EV charger or a water heating system, whereas in an AC-coupled system the energy is lost.

On the other hand, the disadvantages can be listed as follows:

1. Limited flexibility: Installers have less flexibility than with an AC system, as the inverter needs to be located close to the battery.
2. Less resiliency: With a single inverter in a DC-coupled system, if the inverter fails, the solar power as well as the battery capacity is lost.

Chapter 2

AC-Coupled BESS

This chapter describes the process for designing the layout of an AC-Coupled BESS based on main electrical standards such as IEC and IEEE as well as practical guides. Therefore, the objective is to obtain the dimensions of the complete layout of the system, the information related to the battery containers, the power conversion system, the medium voltage cabling and the substation.

In the AC-Coupled schema, the batteries will be connected to the storage inverters to convert the current from dc to ac. The AC-Coupled BESS can be split into three levels: the battery container, the power conversion system, and the medium voltage cables. The principal elements that must be included in every level are presented below:

Battery container

- The battery racks.
- The low voltage protection equipment.

Power conversion system

- The storage inverters. At this moment, only central inverters can be selected.
- The power transformer.
- The electrical busbar.

Medium voltage cable

The medium voltage cables are used to connect the power conversion systems into an existing substation. The software will give all the information about the characteristics of the cables such as material, insulator, diameter, section, cores, circuits and bundles,while taking into account external conditions, current loads, trenching system, etc...

2.1 Battery area requirements

The criteria in pvDesign which have been set to choose an AC-coupled BESS are presented below.

1. The user has defined a battery area.
2. The user has chosen the AC-coupled schema as the BESS arrangement.

So, it is essential to define a battery polygon (BA) and an MV placemark within that polygon.

The size of the user-defined area will determine the space available to install the storage system. The MV point will be the interconnection point between the battery area and the substation.

Some requirements must be considered so that pvDesign can recognize that area as the battery area:

- The polygon defining the area of the batteries must be called BA.
- The area cannot exceed 40 ha.
- The MV placemark is mandatory, and is placed inside the BA.
- The battery polygon cannot be placed inside any AA polygon.
- The battery polygon has to be located outside the ST polygon.
- A restricted area (RA) cannot be placed inside the BA.

2.2 Topography requirements

For the AC-Coupled BESS, the surface has to be flat even if the user does not apply earthworks. For that, earthworks will be applied to the battery area. If there is no digital elevation model data, it will not be possible to flatten the surface. Detailed information regarding the model can be found in [2].

Figure 2.1 illustrates the earthworks performed for an AC-coupled BESS layout.

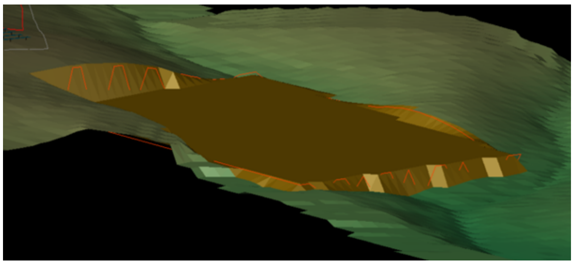

Figure 2.1: AC-coupled battery energy storage topography requirements. Source: RatedPower

2.3 AC-Coupled BESS power block

The layout of an AC-Coupled BESS schema is dependent on the electrical parameters of the power conversion system and the battery containers. The minimum unit or block of the BESS is the set of a PCS and the battery containers connected to it.

The inverter type and the number of inverters per PCS can be selected, thus establishing the power of the PCS or minimum unit of the system.

$$S_{\mathrm{PCS}} = \sum S_{\mathrm{inv}} \tag{2.1}$$

Where:

- S_{PCS} is the capacity of the power conversion system. [VA]

- S_{inv} is the capacity of the storage inverters. [VA]

In pvDesign, we assume that the storage solution is modular. The user has to set the energy of a battery container. Alternatively, the energy of a single battery rack and the number of racks to include per container can be set.

$$E_{\text{BatCont}} = E_{\text{rack}} \cdot N_{\text{rack}} \tag{2.2}$$

Where:

- E_{BatCont} is the energy of the battery container. [Wh]
- E_{rack} is the energy of the battery racks. [Wh]
- N_{rack} is the number of racks.

pvDesign will install the necessary number of containers according to the system requirements. The supply cycle duration is calculated using Equation 2.3.

$$h = \frac{E_{\text{BatCont}}}{P_{\text{PCS}}} \tag{2.3}$$

Where:

- h is the amount of time the batteries can be charging or discharging to the grid with the actual PCS.
- P_{PCS} is the capacity of the power conversion system. [W]
- E_{BatCont} is the energy of the battery container. [Wh]

For example, a 2000 kW PCS and a 3000 kWh container, the supply time (time taken for a complete charge or discharge cycle) will be 1.5 hours. If you connect two battery containers (6000 kWh) to the same PCS, you would have a system with 3 hours of supply.

2.4 Layout generation

After having defined the power of the PCS and the capacity of a container, the BESS requirements can be defined.

- Maximum capacity: selecting this option, the maximum possible power will be installed in the area defined for the BESS.
- Specific capacity: The user is able to configure a specific size for the battery system by defining the number of PCS to install. The system power will be the multiple of the PCS power.

The following distances presented in Figure 2.2 can be found in the AC-Coupled BESS layout:

- Ds-s or the distance between adjacent blocks can be defined by the user.
- Df-f or the distance between opposing blocks can be defined by the user.

- According to [3], the safety distances between containers or Db-b is fixed to 0.9144 m (3 ft).
- According to [3], the safety distance between containers and PCSs or Db-p is fixed to 1.524 m (5 ft).

The dimensions of the battery containers and the power conversion system will be determined by the user. In order to keep the same pvDesign philosophy with the power station dimensions of the PV plant, the height, length and width of the container are inputs. All the battery containers and power conversion systems will have the same dimensions.

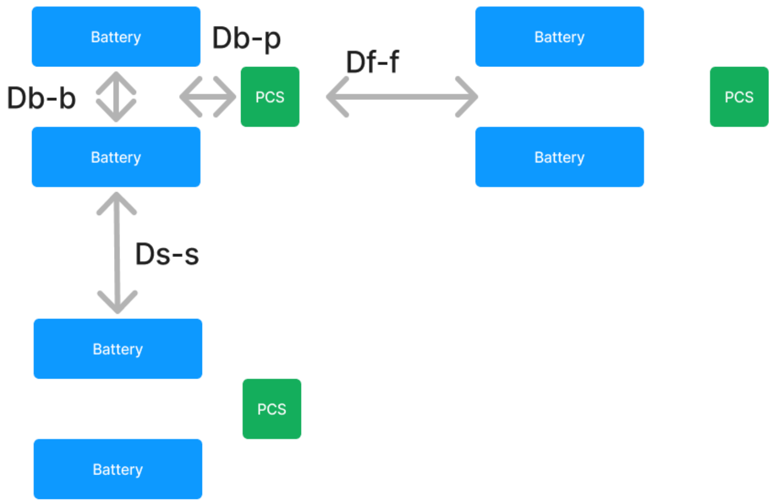

Figure 2.2: Safety distances between battery power blocks. Source: RatedPower

The next step when generating the layout is to calculate the optimal rotation angle of the layout for the battery placements. The idea behind this is the fact that a rectangular shape is usually the best when it comes to placing the maximum amount of batteries. For example, for the next polygon, the best direction to place the batteries is determined by the red arrow.

The grey dots of the Figure 2.3 represent the area specified by the user. The big blue rectangle is the smallest surrounding rectangle that contains the available area. The red line would be a good direction to follow when installing the layout and the small blue rectangles are the battery plus the PCS groups.

In addition, the user can edit the BESS placement by customizing the orientation angle. The orientation angle plays a role in determining the system's efficiency and space utilization. The users are provided with three distinct options to set the BESS orientation according to their specific requirements.

- Rotated (recommended/user input): For a more personalized approach, users have the flexibility to define a custom orientation angle that aligns with their specific project needs or site characteristics.
- Vertical alignment (90º): This option allows the user to choose a vertical BESS orientation, enabling efficient use of vertical space.

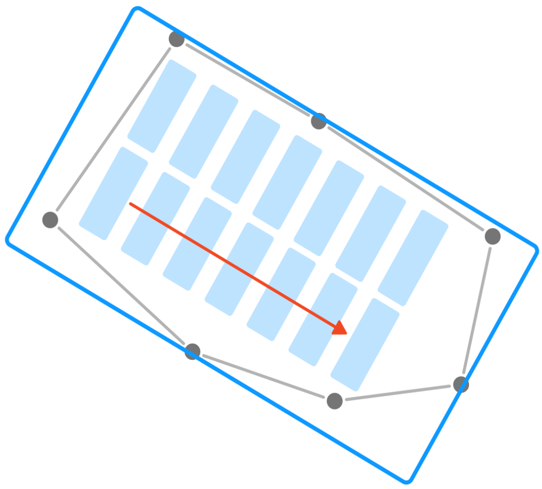

Figure 2.3: Optimized rotation angle of the BESS layout. Source: RatedPower

- Horizontal alignment (0º): By selecting this option, the BESS layout will be aligned horizontally, ensuring maximum efficiency in terms of horizontal space utilization.

After determining the number of containers per group and using the dimensions of the different components, the group's dimensions can be calculated individually. For this, two arrangements can be established. The first one would be the "PCS in front" arrangement. The second configuration is the "PCS in side" can be seen in Figure 3.2

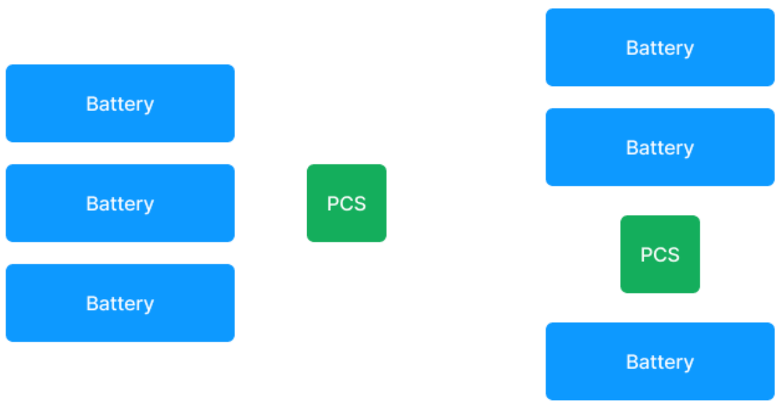

Figure 2.4: PCs in front at the left. PCS in side at the right. Source: RatedPower

As an initial approach, the PCS in front solution seems to be better in general and will be the arrangement adopted by default.

Regarding the location of the power blocks within the battery area boundaries, the power conversion system would be facing the MV point placed in the battery area by the user. The PCSs will be oriented so the distance to the MV point of the battery area is reduced. Also, the battery groups will be installed to be closer to this MV point.

2.5 Medium voltage cables

The cables that connect the power conversion systems to the primary cubicles of the interconnection facility are calculated based on [4], [5] and other electrical standards. The cables will be sized following three criteria:

- The maximum current-carrying capacity. The maximum operating current is corrected based on the different characteristics of the installation and the site. This corrected value must then be lower than the maximum current-carrying capacity that the cable can withstand.
- The voltage drop.
- The short-circuit temperature rise. When a short-circuit occurs, the amount of current flowing through the conductor might surpass nominal current during short periods of time, heating up the insulator. It is necessary to verify that the proposed cross-section can withstand the maximum short-circuit current.

The most significant criterion that affects the high power cables is the maximum current-carrying capacity. For more details about how to size the cables, it is recommended to read the electrical methodology which is available in pvDesign. In this document, only the most important parameters to size the cables are mentioned:

- Type of installation: The cables are directly buried.
- System: AC three-phase medium voltage system.
- Number of cores: Single.
- Conductor material: Aluminium.
- Insulation: XLPE.
- Soil temperature: 25°C. To define the soil temperature correction factor.
- Soil resistivity: 1 K·m/W. To compute the soil resistivity correction factor.
- Cables' laying depth: 0.9 m. This is an input to obtain the depth of burial correction factor.
- Number of circuits per trench. This will be taken into account to calculate the cable grouping correction factor.
- Number of three-phase conductor per system. This will be taken into account to calculate the cable grouping correction factor.

The maximum number of power conversion systems connected to the same MV circuit comply with Equation 2.4.

$$I_{\text{circuit}} \leq I_{\max} \tag{2.4}$$

Where:

- I_{circuit} is the current that flows through the MV circuit. [A]
- $I_{\max}$ is the maximum circuit current selected by the user. [A]. By default 500 A

The length of the MV cables are calculated based on the layout generated by pvDesign.

2.6 Interconnection facility integration

The interconnection facility will take into account the capacity of the BESS output MV lines. The output capacity of the interconnection facility is calculated using Equation 2.5 and can be translated as the sum of the PV plant and BESS MV lines capacities.

$$S_{\mathrm{ST}} = S_{\mathrm{PV}} + S_{\mathrm{BESS}} \tag{2.5}$$

Where:

- S_{ST} is the capacity of the interconnection facility. [VA]
- S_{PV} is the capacity of the PV MV lines. [VA]
- S_{BESS} is the capacity of the BESS MV lines. [VA]

The distribution of the PV and BESS MV lines to the substation complies with the following objectives:

- The number of MV primary cubicles that are shared by PV and BESS MV lines will be at most 1.
- The capacities of all MV primary cubicles of the substation are as balanced as possible.

2.7 Energy Output

The proposal is to provide the user with an estimation of the energy which would be available to charge the BESS. The estimation will be a summation of two losses which are already implemented in the energy yield calculation model:

- The overpower losses at the inverter. This loss is equivalent to energy available to charge a DC coupled battery.
- The clipping losses, calculated at the substation bars. This loss is equivalent to energy available to charge an AC coupled battery.

Detailed information regarding the model can be found in [6]. Users can use these estimates to feed other calculation models, such as internal tools, or other software. It is not possible to compensate reactive power using the current AC-Coupled battery system presented in pvDesign.

Chapter 3

DC-Coupled BESS

This chapter describes the process for designing the layout of a DC-Coupled BESS based on main electrical standards as well as practical guides. Therefore, the objective is to obtain the dimensions of the complete layout of the system, considering the PV plant constraints.

In the DC-Coupled schema, the batteries will be connected to the PV plant inverters to convert the current from dc to ac. The DC-Coupled BESS can be split into the battery containers that are located within the PV plant boundaries and the power stations of the PV plant. The principal elements that must be included in every level are presented below:

Battery container

- The battery racks.
- The DC/DC converters.
- The low voltage protection equipment.

Power station (Power conversion system)

- The PV inverters.
- The power transformer.
- The electrical busbar.

3.1 DC-Coupled BESS power block

The criteria in pvDesign which have been set to choose a DC-coupled BESS is presented below.

1. The user has chosen the DC-coupled schema as the BESS arrangement.
2. The users has selected central inverters as the ones for the photovoltaic plant. DC-Coupled BESS schema will not be available for PV plants with string inverters.

In addition, only primary inverters and main default power stations, those with the highest inverter capacity, will have storage (DC/DC converters). Non-default power stations will not have DC/DC converters and battery containers.

The power block of a DC-Coupled BESS schema is dependent on the electrical parameters of the PV plant primary inverters, the DC/DC converter characteristics and the battery containers. The minimum unit or block of the BESS is the set of a power station and the DC/DC converter and battery containers connected to it.

The DC/DC converter power per inverter is calculated by Equation 3.1 and the BESS/PV power ratio is given in Equation 3.2.

$$P_{\text{DC/DC-inv}} = N_{\text{DC/DC}} \cdot P_{\text{DC/DC}} \tag{3.1}$$

$$R_{\text{BESS/PV}} = \frac{N_{\text{DC/DC}} \cdot P_{\text{DC/DC}}}{P_{\text{inv}}} \tag{3.2}$$

Where:

- $P_{\text{DC/DC-inv}}$ is the DC/DC converter power per inverter. [W]
- $N_{\text{DC/DC}}$ is the number of DC/DC converters per inverter.
- $P_{\text{DC/DC}}$ is the DC/DC converter power. [W]
- $R_{\text{BESS/PV}}$ is the BESS/PV power ratio.
- P_{inv} is the primary inverter active power. [W]

The DC/DC converters (buck/boost converter) change (step up/down) the battery voltage to the inverter input voltage (equivalent to the string voltage of the PV plant). A generic converter power can be defined as a program input. That is, the maximum continuous power (included in the DC/DC databases).

The recommended converter power value is given in Equation 3.3.

$$P_{\text{DC/DC recommended}} = \frac{R_{\text{BESS/PV recommended}} \cdot P_{\text{inv}}}{N_{\text{DC/DC recommended}}} \tag{3.3}$$

Where:

- $P_{\text{DC/DC recommended}}$ is the recommended DC/DC converter power. [W]
- $R_{\text{BESS/PV recommended}}$ is equal to 0.5.
- P_{inv} is the active power of the PV inverters. [W]
- $N_{\text{DC/DC recommended}}$ is the recommended number of DC/DC converter per inverter and equals to 2.

The maximum DC/DC converter power is derived from Equation 3.4.

$$P_{\text{DC/DC max}} = \frac{1.5 \cdot P_{\text{inv}}}{N_{\text{DC/DC}}} \tag{3.4}$$

Where:

- $P_{\text{DC/DC max}}$ is the maximum DC/DC converter power. [W]
- P_{inv} is the active power of the PV inverters. [W]
- $N_{\text{DC/DC max}}$ is the number of DC/DC converter per inverter.

The minimum DC/DC converter power is derived from Equation 3.5.

$$P_{\text{DC/DC min}} = \frac{0.1 \cdot P_{\text{inv}}}{N_{\text{DC/DC}}} \tag{3.5}$$

Where:

- $P_{\text{DC/DC min}}$ is the minimum DC/DC converter power. [W]
- P_{inv} is the active power of the PV inverters. [W]
- $N_{\text{DC/DC max}}$ is the number of DC/DC converter per inverter.

Once the maximum continuous power per converter have been set, the number of converters for central inverter can be defined. The maximum number of converters per inverter is given in Equation 3.6.

$$N_{\text{DC/DC max}} = \frac{P_{\text{DC/DC}}}{P_{\text{inv}}} \leq 1.5 \tag{3.6}$$

Where:

- $N_{\text{DC/DC max}}$ is the maximum number of DC/DC converter per inverter.
- $P_{\text{DC/DC}}$ is the total converter power. [W]
- P_{inv} is the active power of the PV inverters. [W]

And the power conversion system discharge power is given in Equation 3.7.

$$P_{\text{PCS}} = min(1, R_{\text{BESS/PV}}) \cdot P_{\text{inv}} \cdot N_{\text{inv}} \tag{3.7}$$

Where:

- P_{PCS} is the discharge power of the system. [W]
- $R_{\text{BESS/PV}}$ is the BESS/PV power ratio.
- P_{inv} is the active power of the primary inverter. [W]
- N_{inv} is the number of primary inverters in the power station.

In pvDesign, we assume that the storage solution is modular. The user has to set the energy of a battery container. Alternatively, the energy of a single battery rack and the number of racks to include per container can be set.

$$E_{\text{BatCont}} = E_{\text{rack}} \cdot N_{\text{rack}} \tag{3.8}$$

Where:

- E_{BatCont} is the energy of the battery container. [Wh]
- E_{rack} is the energy of the battery racks. [Wh]
- N_{rack} is the number of racks.

pvDesign will install the necessary number of containers according to the system requirements. The supply cycle duration is calculated in Equation 3.9.

$$h = \frac{E_{\text{BatCont}}}{P_{\text{PCS}}} \tag{3.9}$$

Where:

- h is the amount of time the batteries can be discharging from the grid. The charging hours might be higher than supply hours defined. The maximum hours of supply are 24 hours.
- P_{PCS} is the discharge power of the system. [W]
- E_{BatCont} is the energy of the battery container. [Wh]

The maximum number of battery containers that can be connected to the power station will be 6. By default, 1 container per PS will be recommended.

3.2 Layout generation

After having defined the power block, the BESS requirements can be defined.

- Maximum capacity: selecting this option, the maximum possible power will be installed. All default power stations will have battery containers, only the primary central inverters of those power stations. It is not possible for a non-default power station to have storage.
- Specific capacity: The user defines the amount of desired power stations with battery containers to install. Default power stations will have battery containers, only the primary central inverters of those power stations. It is not possible for a non-default power station to have storage. The desired rated power is calculated using Equation 3.10.

  $$BESS = N_{\text{desired ps}} \cdot P_{\text{PCS}} \tag{3.10}$$

  Where:

  - $BESS$ is the desired BESS total rated power. [W]
  - P_{PCS} is the discharge power of the system. [W]
  - $N_{\text{desired ps}}$ is number of desired power stations with battery containers to install.

  However, the real amount of power stations will be calculated after running the design since it depends on how many main power stations are going to be installed.

3.2.1 PV plant maximum/specific capacity and BESS maximum capacity

In this case, all the primary inverters in the default power stations will be connected to battery containers.

Figure 3.1: The battery containers are connected to all the power stations. Source: RatedPower

3.2.2 PV plant maximum/specific capacity and BESS specific capacity

In this case, the closest default power stations to the MV point of the available area will be connected to battery containers.

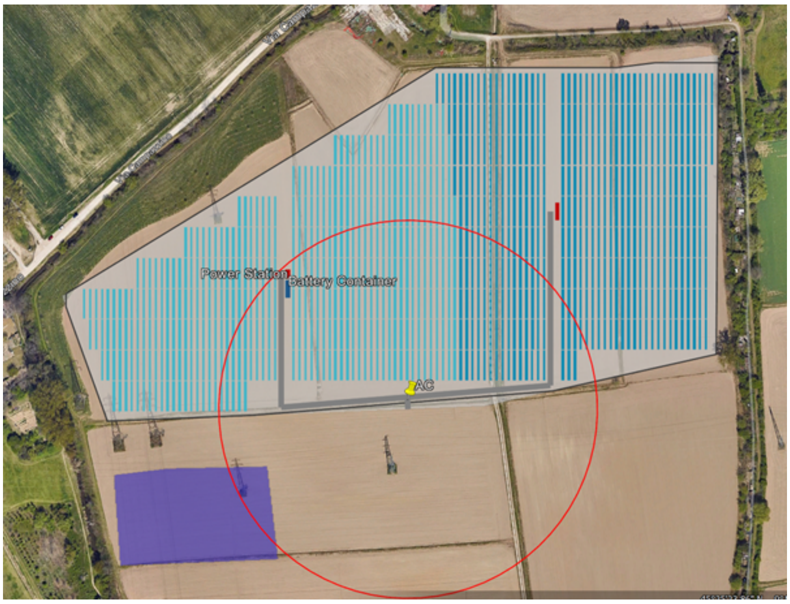

Figure 3.2: The battery containers are connected to the power station closest to the MV point. Source: RatedPower

3.2.3 Power block outside the solar field

When the power stations of the PV plant are out of the solar field, the batteries will be aligned to the road, as can be seen in Figure 3.3.

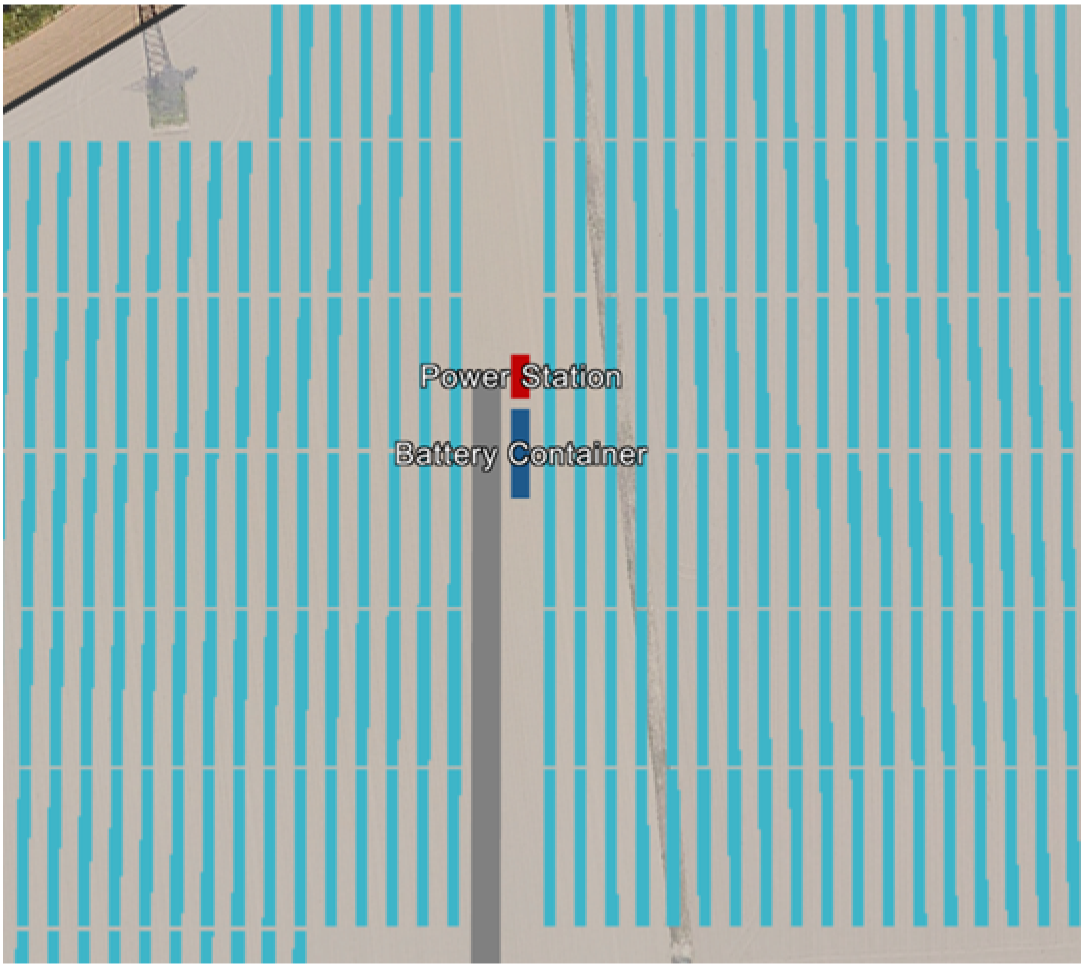

Figure 3.3: Power station and battery container located outside the DC solar field. Source: RatedPower

The dimensions of the battery containers will be determined by the user. In order to keep the same pvDesign philosophy with the power station dimensions of the PV plant, the height, length and width of the container would be the inputs. All the battery containers will have the same dimensions.

The following distances are taken into account in order to locate the battery containers close to the power stations:

- The battery container to road distance can be defined as a setback. The same value limits will be considered for setbacks as those currently considered for the power stations to road distances. The minimum value will be 1.5 m and the maximum value lower than 100 m.
- According to the NFPA 855 standard, the safety distance between containers and structures must be greater than 1.524 m (5 ft) and less than 4.572 m (15 ft).
- According to the NFPA 855 standard, the safety distance between containers must be greater than 0.9144 m (3 ft) and less than 4.572 m (15 ft).
- According to the NFPA 855 standard, the safety distance between containers and the power station must be greater than 1.524 m (5 ft) and less than 4.572 m (15 ft).

So, the distances presented in Figure 3.4 from the axis of the battery container - power station block to the roads will be:

$$D_{\text{axis-road}} = Max(d_{\text{PS-road}} + 0.5 \cdot w_{\text{PS}}, d_{\text{BESS-road}} + 0.5 \cdot w_{\text{BESS}}) \quad (3.11)$$

Where:

- $D_{\text{axis-road}}$ is the distance of the axis of the block to the road. [m]
- $d_{\text{PS-road}}$ is the distance from the power stations to the road [m]. The minimum $d_{\text{PS-road}}$ is equal to 1.5 m.
- w_{PS} is width of the power station. [m]
- $d_{\text{BESS-road}}$ is the distance from the battery container to the road. [m]
- w_{BESS} is width of the battery container. [m]

$$D_{\text{axis-structure}} = Max(d_{\text{PS-structure}} + 0.5 \cdot w_{\text{PS}}, d_{\text{BESS-structure}} + 0.5 \cdot w_{\text{BESS}}) \quad (3.12)$$

Where:

- $D_{\text{axis-structure}}$ is the distance of the axis of the block to the structures. [m]
- $d_{\text{PS-structure}}$ is the distance from the power stations to the structures. [m]
- w_{PS} is width of the power station. [m]
- $d_{\text{BESS-structure}}$ is the distance from the battery container to the structures. [m]
- w_{BESS} is width of the battery container. [m]

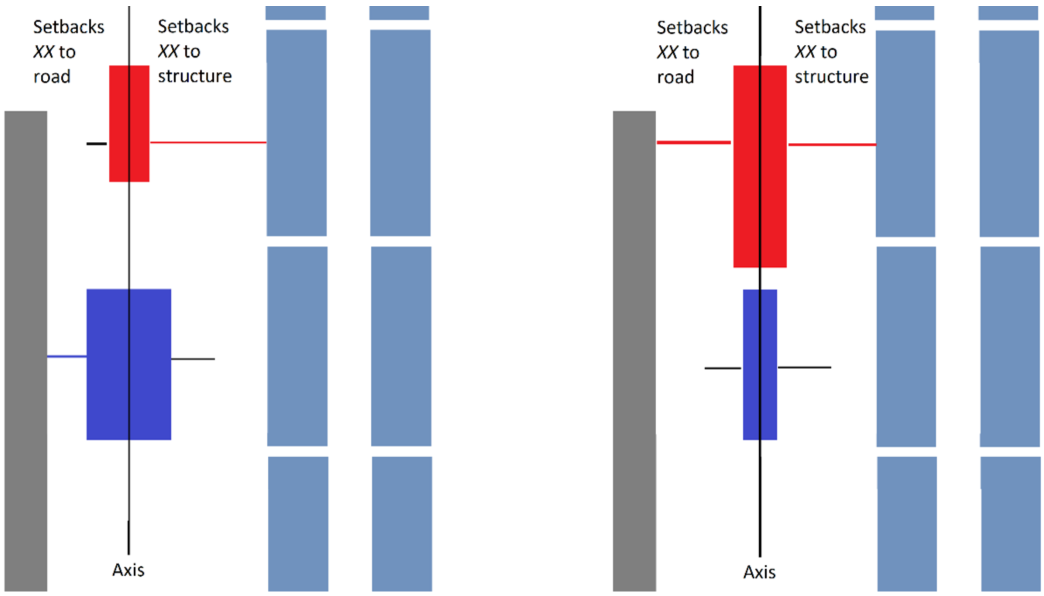

Figure 3.4: Distances between containers and roads or structures. Source: RatedPower

3.2.4 Power block inside the solar field

When the power stations of the PV plant are out of the solar field, the batteries will also be installed within the solar field, as can be seen in Figure 3.5.

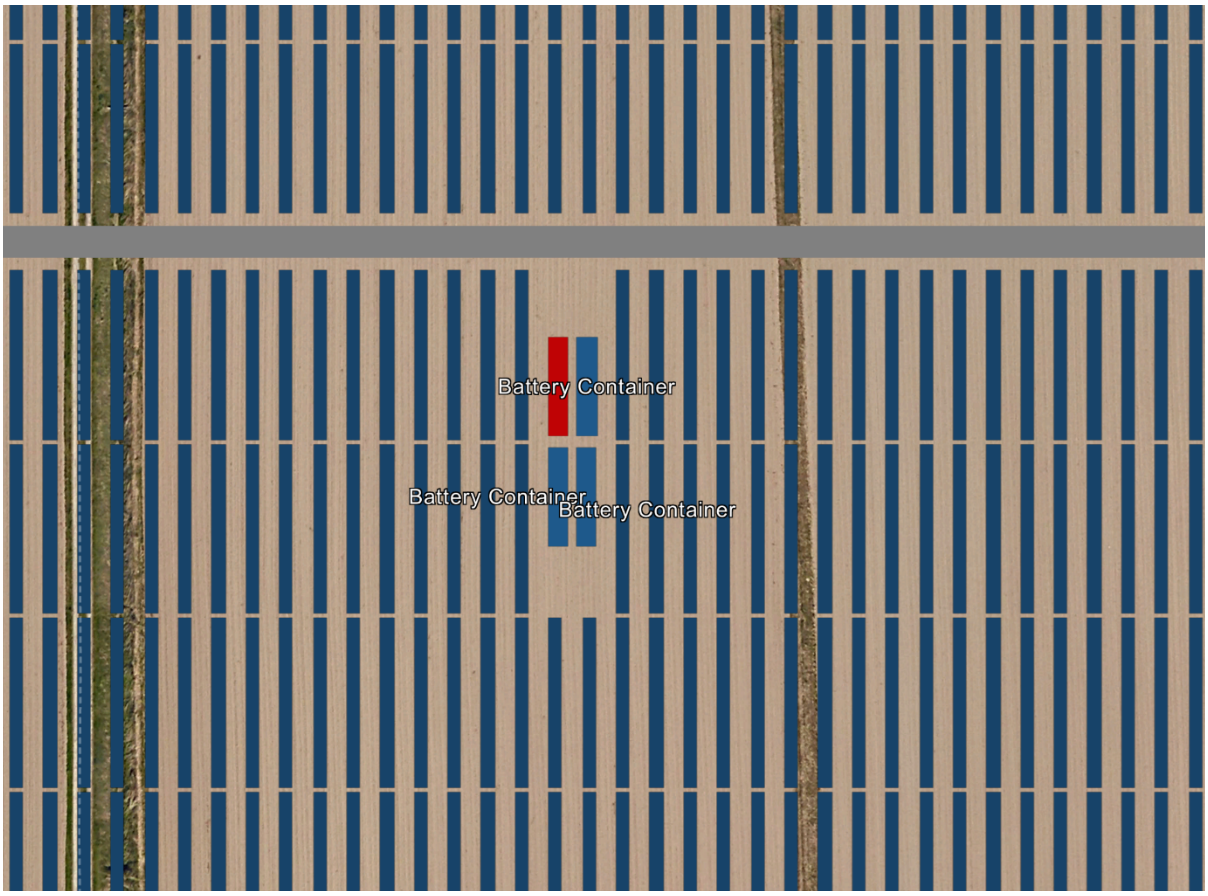

Figure 3.5: Power station and battery container located inside the DC solar field. Source: RatedPower

The arrangement of the power station and the battery containers must meet the following conditions:

- The PS must have direct access to the road (i.e. one of its sides must be in contact with the road, without containers or structures in between).
- The PS should be placed parallel or perpendicular to the structures.
- The battery containers can be placed parallel or perpendicular to the structures.
- The selected arrangement should be the one that deletes the fewest structures. If aligning the containers in the same row deletes the same amount of structures as having more than one row of containers, the case where all the containers are aligned is prioritized.

The dimensions of the battery containers will be determined by the user. In order to keep the same pvDesign philosophy with the power station dimensions of the PV plant, the height, length and width of the container are inputs. All the battery containers will have the same dimensions.

The following distances are taken into account in order to locate the battery containers:

- According to [3], the safety distance between containers must be greater than 0.9144 m (3 ft) and less than 4.572 m (15 ft).
- According to [3], the safety distance between containers and the power station must be greater than 1.524 m (5 ft) and less than 4.572 m (15 ft).

3.3 Energy Output

The proposal is to provide the user with an estimation of the energy which would be available to charge the BESS. The estimation will be a summation of two losses which are already implemented in the energy yield calculation model:

- The summatory of the overpower losses at the inverters with storage. This loss is equivalent to the energy available to charge a DC coupled battery.
- The summatory of the overpower losses at the inverters without storage. This loss cannot be recovered because these inverters do not have DC/DC converters or batteries to store these losses.

Detailed information regarding the model can be found in [6]. Users can use these estimates to feed other calculation models, such as internal tools, or other software.

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