Technical Information

SMA SMART HOME
Battery Charging Management with Time-of-Use Energy Tariffs

1 Basic Information

1.1 Time-of-Use Energy Tariffs and Battery Storage Systems

More and more electric utility companies are equipping households with smart meters. The underlying intention is to be able to offer electricity tariffs to customers based on usage and at the same time to keep the load on the utility grid to a minimum.

If electricity is more expensive at times of high demand (peak rate) than at times of low demand (off-peak rate), customers will automatically consume more when it is cheaper and save when it is expensive. Thus, utilization of the utility grid will automatically become more even and remain stable.

Are you the owner of a battery storage system, which may also be connected to a PV system? If so, you now have a very simple additional option for using even more cheap electricity and reducing your energy bills: with the battery charging window function in SMA Smart Home.

1.2 Necessary Components

If your electric utility company offers you a time-of-use electricity tariff in which there is a significant price difference between the peak- and off-peak rates, it is worth installing the following components in your household:

- A battery storage system from SMA Solar Technology AG, e.g., a Sunny Boy Storage or a Sunny Island with a suitable battery.
- The battery storage system is often already equipped with a Sunny Home Manager and the SMA Energy Meter.
- A natural extension to this is a PV system with an SMA inverter, e.g., a Sunny Boy SB5.0-1AV for a typical PV system with 5 to 6 kWp installed PV power on the roof of the house.

1.3 Cost Savings with Time-of-Use Electricity Tariffs

A battery storage system enables you to store electricity in the battery at a cheap off-peak rate, and then to use this stored electricity to supply the household appliances at times of the expensive peak rate.

By shifting the energy consumption, for each kWh of energy used, you save the difference between the peak rate and the off-peak rate (arbitrage). Depending on the time-of-use electricity tariff, this can amount to a difference of up to 30 cents. Thus, the cost of a battery system is amortized significantly more quickly than with fixed electricity prices.

2 Configuration

As of firmware version 1.13 (August 2016), the Sunny Home Manager can control the battery via the battery inverter in such a way that cost savings are made in conjunction with time-of-use electricity tariffs. Two steps are necessary to make the settings in the Sunny Home Manager system in Sunny Portal.

2.1 Entering the Electricity Tariff (Time-of-Use)

Depending on the provider's electricity tariff, different time periods with different electricity prices apply.

In Sunny Portal, call up the Sunny Home Manager system. On the page **Configuration > PV System Properties > Parameters** in the area **Electricity Tariff**, the information can be entered in the entry fields.

The following example shows all settings necessary for a typical time-of-use electricity tariff. The prices assumed for this example are:

- Peak rate: 29 ct/kWh
- Shoulder rate: 19 ct/kWh
- Off-peak rate: 9 ct/kWh

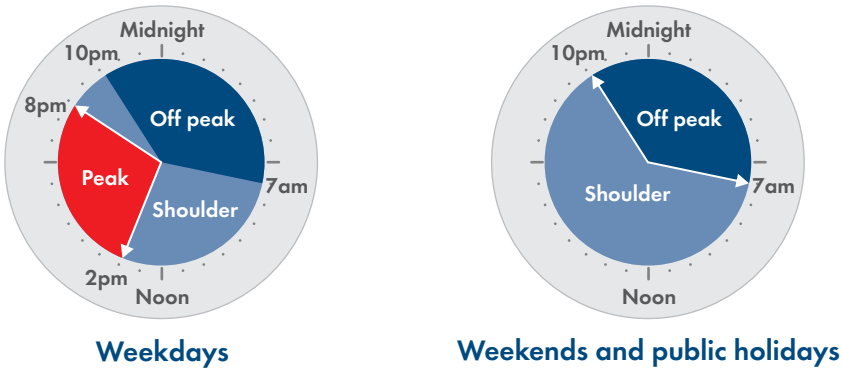

Figure 1: Example for time-of-use electricity tariff (source: Australian electric utility company)

Information

- A time period can not be set that crosses over the midnight point. In this case, such a time period is to be divided into two corresponding partial time periods (up to and after midnight).
- The following limitation applies in the implemented firmware version of Sunny Home Manager: Even if a public holiday falls on a weekday, the weekday rates continue to apply.

Transferring the settings in Sunny Portal appears as follows:

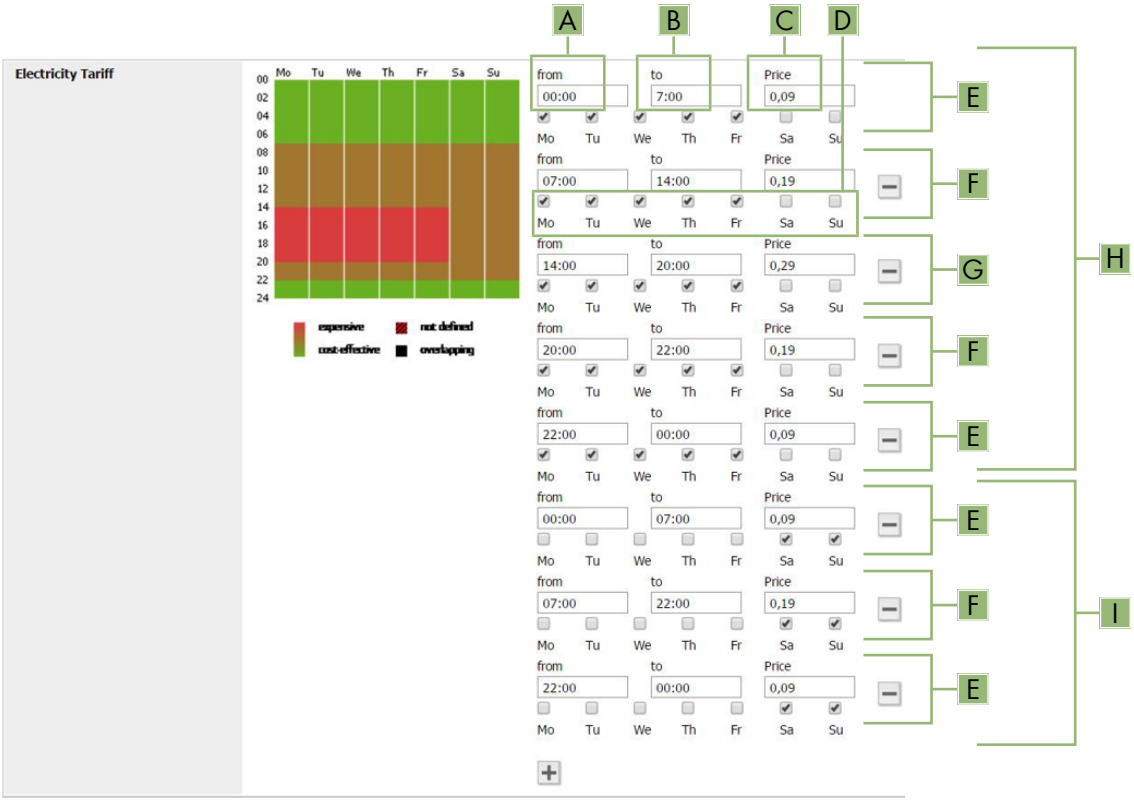

Figure 2: Settings for a time-of-use electricity tariff in Sunny Portal

Position	Explanation
A	Start time of the Time-of-use electricity rate
B	End time of the Time-of-use electricity rate
C	Price per kWh according to the time-of-use electricity tariff of the electric utility company
D	Selection of the weekday on which the respective rate applies in the specified time period.
E	Off-peak rate
F	Shoulder rate
G	Peak rate
H	Weekday
I	Weekend
	Adds an additional time period for the electricity tariff
	Removes a time period for the electricity tariff

The information is displayed graphically in the colored representation on the upper left-hand side. An option to make corrections is given in the event of overlapping or undefined time periods.

2.2 Defining the Battery Charging Window

Once the electricity tariff has been defined, information regarding the battery charging window can be entered. According to the information entered for the electricity tariff (see Section 2.1 "Entering the Electricity Tariff (Time-of-Use)", page 3), it is expedient to set the battery charging window to a time period of between 02:00 hrs and 04:00 hrs. Because the time period for the off-peak rate is the same for all weekdays, the battery charging window can also be the same for all weekdays.

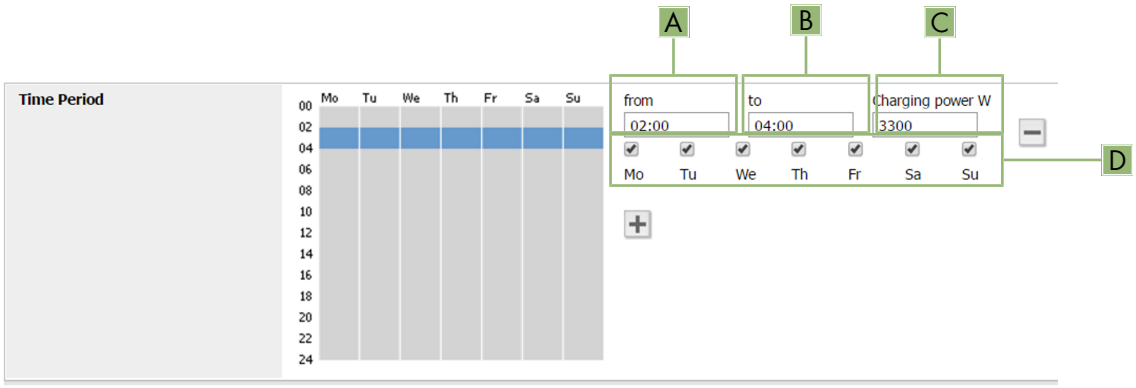

Figure 3: Settings for the battery charging window in Sunny Portal

Position	Explanation
A	Start time of battery charging (from the drop-down list or direct entry, accurate to the minute)
B	End time of battery charging (from the drop-down list or direct entry, accurate to the minute)
C	As a default value, the maximum charging power of the battery inverter that the Sunny Home Manager has detected in the system appears here automatically. In the figure is specified the example of 1 Sunny Island 4.4M with a maximum charge power of 3300 W. If a 3-phase system with 3 Sunny Island 4.4M battery inverters is taken into consideration, the input power corresponds to the power per phase, i.e. the maximum charging power is then 3 times 3300 W. If the battery charging window is sufficiently long and the battery capacity not too large, a lower charging power can be defined. If the charging power is set to too low a value, it can be that the battery is not fully charged. A value of 0 W can also be entered as the charging power (see Section 3.3 "Holding Cheap PV Energy in the Battery", page 10).
D	Selection of the weekday on which the battery charging window applies in the specified time period.
	Adds an additional battery charging window
	Removes a battery charging window

2.3 Battery Behavior during the Battery Charging Window

If a battery charging window has been specified, the following conditions apply for this battery charging window:

- The battery will be charged at the specified charging power. During the night, the power will be drawn directly from the utility grid. During the day, excess PV power will be used. If the excess PV power is not sufficient, the missing portion of the specified charging power will be drawn directly from the utility grid.
- Battery discharging is blocked for the duration of the window.
- All other battery controls are blocked for the duration of the window.

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  - If the battery is already fully charged (SOC = 100% or a different specified maximum value), it can not, of course, be charged. In this case the battery behaves passively until the end of the window. This means that it is neither charged nor discharged.
  - If the battery is already relatively full (SOC > 90%), it can be that it is not charged with the full charging power specified. This depends on how the battery functions – depending on the battery type, the charging behavior can differ towards the end of the charging procedure.
  - Lithium-ion batteries are controlled by their own battery management system (BMS). Even though the Sunny Home Manager issues the corresponding charging command to the battery, it can be that the BMS declines this and the battery is not charged. The BMS normally has the task of protecting the battery from damage or of preventing premature aging.

2.4 Battery Behavior outside of the Battery Charging Window

Outside of the battery charging window, the battery behaves in accordance with its normal function:

- If power is drawn at the grid-connection point, the battery inverter attempts to compensate for the purchased electricity by discharging the battery.
- If excess PV power is being fed in at the grid-connection point, the battery inverter attempts to balance the grid feed-in by charging the battery.
- If the maximum charging power of the battery storage system is exceeded in this mode, electricity is fed into the utility grid.
- If the maximum discharge power of the battery storage system is exceeded in this mode, electricity is drawn from the utility grid.

Additionally, the following applies outside of the battery charging window:

- If special battery controls are activated via the Sunny Home Manager, these will be performed (e.g., forecast-based battery charging for the utilization of dynamic active power limitation or zero export).

2.5 Limitations to the Battery Charging Function

No calculation/display of the self-consumption and self-sufficiency quotas

The specified charging power will be used within a battery charging window. Because it is not assured that this power can always be drawn from a PV excess, the battery will also use power from the utility grid for charging. The formulae currently used to calculate the self-consumption and self-sufficiency quotas, however, assume that the energy drawn from the battery is exclusively intermediately stored PV energy.

To avoid displaying incorrect values here, the following values are no longer displayed from the time period in which a battery charging window has been defined:

- Self-consumption quota
- Self-sufficiency quota

The different time periods can be called up on the page **Energy Balance** in the Sunny Portal system. If all battery charging windows are deleted, the above listed values will be displayed again from the following period.

Information

If a battery charging window has been defined in the system at any time, the applicable self-consumption / self-sufficiency quotas will never again be displayed in the overall view (all years since commissioning). It is not possible to restore or gray out partial information retroactively.

No battery discharging during a battery charging window

The battery can only be charged during a battery charging window. Even if electricity is drawn from the utility grid, the battery will not switch over to discharging mode.

Tip: If a charging power of 0 W is specified in the battery charging window, the battery will be set to inactive during the defined window that means it will neither charge nor discharge. This can be a useful mode for drawing stored energy for consumption at a specific point in time.

No mode for suppressing battery discharging

In the Sunny Home Manager, there is not yet a mode provided for suppressing battery discharging when the possibility of charging the battery with PV excess exists.

3 Application

3.1 Consuming Cheap Electricity at Expensive Times (Arbitrage)

Situation:

According to the time-of-use electricity tariff offered by the electric utility company, electricity is particularly cheap during the night. In the afternoon, the electricity is significantly more expensive, and there are appliances in the household that must be operated during this time period. The power generated by the local PV system is not sufficient to cover the electricity demand of these appliances.

Action:

Specify a battery charging window in the night over a time period during which the set charging power charges the battery as much as possible (see Section 3.2 "Optimizing Cost Savings", page 8).

Information

A PV system is not essential for using the battery charging window function. Even without self-generated PV energy, the original costs of the battery system can be amortized by using cheap electricity during expensive periods.

3.2 Optimizing Cost Savings

Power consumption during the battery charging window

Set the battery charging window to a time period when very little or no electricity is consumed in the household.

Reason: If the battery charging window is active, appliances in the household can not be supplied with electricity from the battery. The battery can only be charged during the active battery charging window.

Example: If an off-peak rate is available in the night, set the window to a time in which typically no electricity is consumed.

Do not discharge the battery during cheap periods.

If you charge the battery during the off-peak rate, set the end of the battery charging window to at least the time at which the off-peak rate ends.

Reason: It would not be sensible to store electricity in the battery at an off-peak rate and then to supply appliances by discharging the battery within the same off-peak period. It is naturally more expedient to draw the energy for the appliances directly from the utility grid at the off-peak rate.

Example: The off-peak rate begins at 22:00 hrs and ends at 07:00 hrs. After 02:00 hrs, all electrical appliances are off and very little electricity is consumed. Set the battery charging window for a time period of 02:00 hrs to 07:00 hrs. From 07:00 hrs, the battery will be reset automatically to enable the appliances to be supplied through battery discharging in the event of electricity being drawn from the utility grid. The cost saving per kWh is the difference between the off-peak rate and the shoulder- or peak rate applicable after 07:00 hrs.

Do not set the battery charging window for too long a period

Only set the battery charging window to be long enough that at the selected charging power, no more energy than necessary is stored in the battery. Avoid setting the battery charging window to extend beyond the off-peak rate.

Reason: If the battery is fully charged before the end of the defined battery charging window, discharging in order to supply any household appliances that may be used is blocked for the remainder of the window. Furthermore, if a battery has a state of charge greater than 90%, it will no longer charge at the maximum possible charging power. The last 10% necessary to fully charge the battery may take a long time and block the supply of appliances with electricity from the battery. Certain batteries should not for functional reasons be charged to 100%.

Example: Normally, a battery state of charge (SOC) of 90% is sufficient for supplying household appliances during the expensive period. If, in the evening before you go to bed, the battery state of charge is typically 30%, the battery should be charged by 60%. The battery system that you have is, for example, a Sunny Island 4.4M with a 10 kWh lithium-ion battery.

A simple calculation determines the correct length of the battery charging window:

- Maximal charging power of a Sunny Island 4.4M = 3.3 kW
  - Set the charging power to 3.3 kW.
- Battery capacity = 10 kWh

  Battery state of charge at the end of the day = 30% (3 kWh)

  Desired amount of energy for charging from the off-peak rate = 60% (6 kWh)
  - This equates to a desired battery state of charge of 90% (9 kWh)
- At the set charging power of 3.3 kW, 6 kW will be charged within 1.8 hrs (1 hrs 48 min).
  - Set a battery charging window, for example, of 02:00 hrs to 03:48 hrs.
- If a lower charging power has been set, charging can take correspondingly longer.

Do not overload the household connection through charging power

Ensure that, within a battery charging window, the sum total of charging power and the remaining electricity consumption in the household does not exceed the drawing limit of the household connection.

Reason: This can result in extra costs being incurred due to peak-load rates. Furthermore, you run the risk of the main breaker triggering and the electricity supply to the entire household being cut off.

Example: The drawing limit of the household connection is specified at 15 kW. A typical load that can arise during the night (during the off-peak rate) is, for example, 10 kW (for a heater). The charging power in the battery charging window should therefore not be set higher than 5 kW. If necessary, an even lower value should be set in order to take other appliances that may connect simultaneously into consideration.

Select the optimum battery charging power

Ensure that a sensible charging power is set in the battery charging window.

- Charging at the maximum charging power may not run at the maximum charging efficiency.
- Too low a charging power in too short a battery charging window may result in the battery not being fully charged.

Reason: Depending on the battery inverter used, the charging power has a different value at maximum efficiency.

Example: With the Sunny Island 4.4M, the ideal charging power is approximately 20% of the nominal charging power (3300 W x 0.2 = 660). Here, the efficiency is 95.3%.

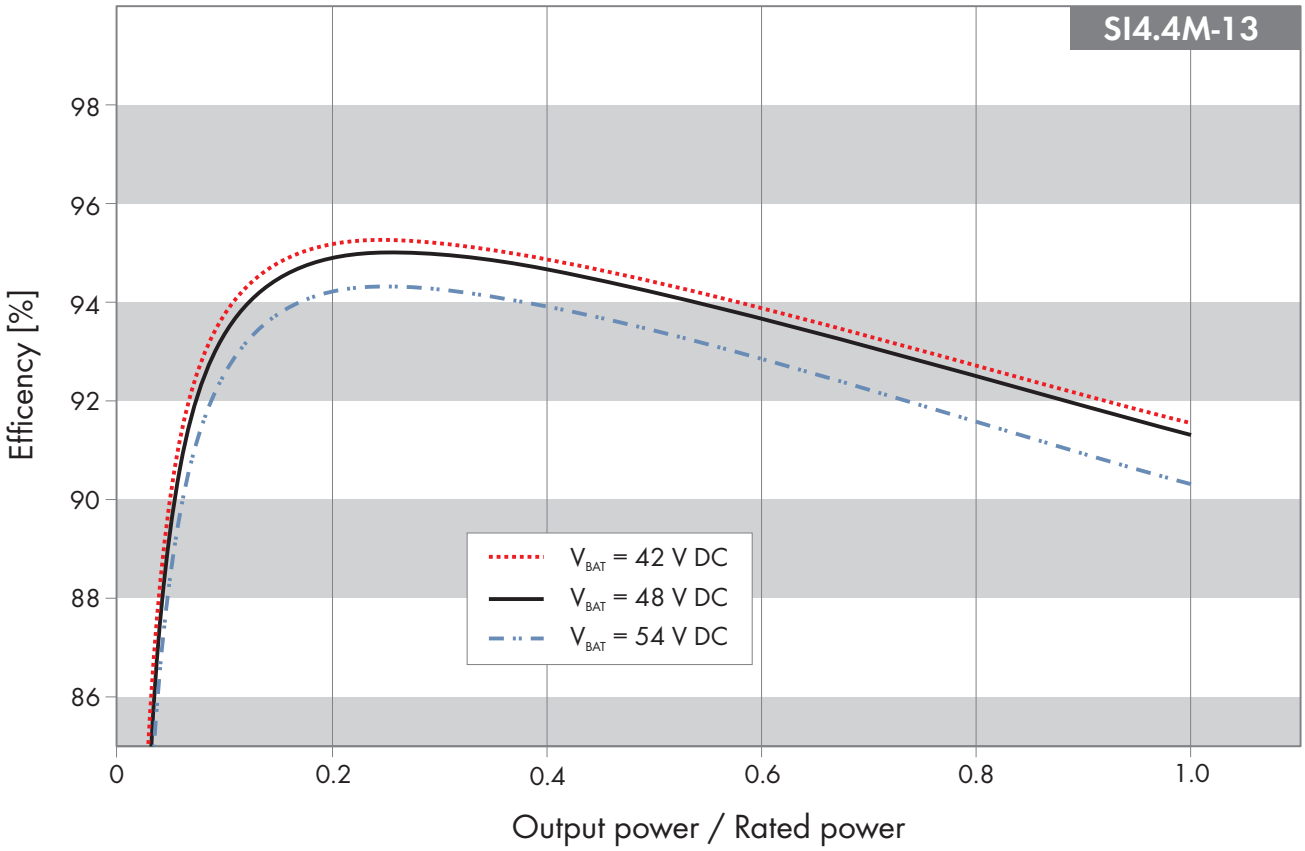

Figure 4: Efficiency curve Sunny Island 4.4M

If the off-peak rate permits, with a Sunny Island 4.4M, a charging power of 660 W should be selected to take advantage of the best efficiency. If, however, the entire time period of the off-peak rate is too short to charge the required energy (in kWh) at a charging power of 660 W, it can be more cost-effective to charge at a correspondingly higher power. The possible loss in power in this case would be approximately 3.5% (efficiency at nominal charging power 3300 W = 91.8%).

3.3 Holding Cheap PV Energy in the Battery

In the following situations, it can be more cost-effective to only make the energy stored in the battery available for a certain time for consumption by the household appliances.

Situation 1:

The battery contains energy from a low-cost electricity tariff or from the local PV system. Instead of consuming this energy at times of off-peak- or shoulder rates, the PV system operator would like to wait until the start of the peak rate before using the stored PV energy. This results in the greatest cost saving.

Situation 2:

The battery can be charged within two hours at ideal charging power during the off-peak rate. The time period in which the electric utility company guarantees the off-peak rate is, however, longer than two hours. To avoid stored energy being consumed from the battery during the off-peak rate, the PV system operator would like to block the battery for the remainder of the off-peak rate period.

Action:

- Specify a battery charging window with a sensible charging power (see Section 3.2 "Optimizing Cost Savings", page 8) for the time period necessary to charge the required kWh (see Section 2.2 "Defining the Battery Charging Window", page 5).

- Specify a battery charging window with a charging power of 0 W that bridges the end of the previous charging window to the following point in time:
  - The starting point of the peak rate window (for situation 1)
  - The end point of the off-peak rate window (for situation 2)

  In this way, you block the charging and discharging of the battery until it becomes sensible depending on the situation to use the energy from the battery again for the appliances.
- If the off-peak rate begins before the active battery charging window with the charging power set to > 0 W, it is recommended to block the starting point of the off-peak rate period in the same way.

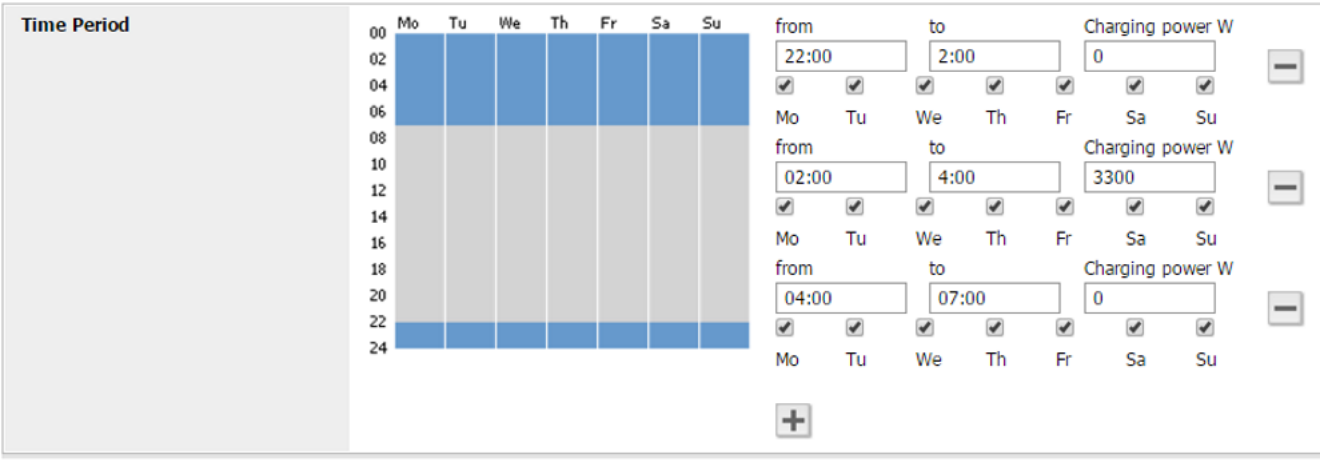

Figure 5: Blocking the battery charging window during the off-peak rate

4 Troubleshooting

If the following explanations do not provide you with a solution to your problem, please contact the SMA Service Line.

Problem	Explanation
The battery does not charge even though a battery charging window is active.	Depending on the internal battery functions, the battery management system (BMS) may refuse to allow charging or discharging at any given time. The battery will protect itself against any influences that could result in internal battery damage.
If a battery charging window is enabled, the self consumption and self sufficiency quotas are no longer displayed in Sunny Portal.	This is correct. Because the battery can also draw electricity from the utility grid for charging, it is no longer possible to calculate these quotas. After deleting all battery charging window settings, these quotas will again be displayed for the next cumulative period (day, month, year).
A high charging power can not be set in the battery charging window settings.	The system automatically only accepts the nominal power of the connected battery inverter (e.g., Sunny Island 4.4M: max. charge power = 3300 W).

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