Pixii PowerShaper Services description

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Revision History

Revision	Date	Comment
0.1	2019-05-22	Initial
0.2	2020-04-30	Updates according to implementation per Q2 2020.
0.3	2020-11-27	Updates 04-2020
0.4	2022-04-08	Updates Q1-2022

1 Overview

Services provide the different functionality of a Pixii PowerShaper system using various algorithms and control strategies. They include peak shaving, demand response/supply, target state of charge and other functionalities. These core services can be used separately, or together with a scheduler to support different higher-level applications such as Demand charge reduction, PV self-consumption, Time of Use, and others.

The PowerHandler is the main task that controls the power of the converters, controls the loads and sources. It is run in the Pixii Gateway and interacts with the hardware such as converters, battery, and meter, and external actors providing control requests such as cloud applications and energy management systems.

This document explains the main parts of the system and how they are used to achieve the different services, and the limitations of these.

Chapter 2 describes the different components in the Pixii Power Shaper, and how external components such as meters can be accessed from the Pixii system, and how external components such as cloud applications and Energy management systems can access the Pixii system.

Chapter 3 explains some of the main services. These include the scheduler, demand response, target state of charge, and peak shaving.

Chapter 4 gives an overview of some applications and how the services in chapter 3 can be used to implement these applications.

Chapter 5 contains an example that illustrates the priority levels.

Note that the information in this document is subject to change without any previous notice.

1.1 Abbreviations

API	Application programming interface. A set of functions and procedures allowing the creation of applications that access the features or data of an operating system, application, or other service.
BMS	Battery management system
BSS	Battery storage system
CAN	Controller Area Network. Communication bus standard.
Converter	Pixii bidirectional converter which can act as inverter and rectifier
DR	Demand response
HAN-port	Home area network interface for accessing data from the electricity meter.
HTTPS	Hypertext Transfer Protocol Secure is an extension of the Hypertext Transfer Protocol (HTTP) used for communication over a computer network.
MQTT	A light-weight machine-to-machine (M2M)/"Internet of Things" connectivity protocol
PS	Peak shaving
SoC	State of charge, an estimated value of the remaining capacity of a battery.

2 System characteristics

2.1 Pixii control system

The main communication structure is depicted in Figure 1. The main Pixii components are the Converters and Gateway including IO. The Gateway communicates with the Converters, battery BMS (if available) and external components such as meters, energy management systems, smart phones / computers and cloud solutions on appropriate interfaces and over applicable protocols and data formats.

The rest of the chapter explains some of the parts in more detail.

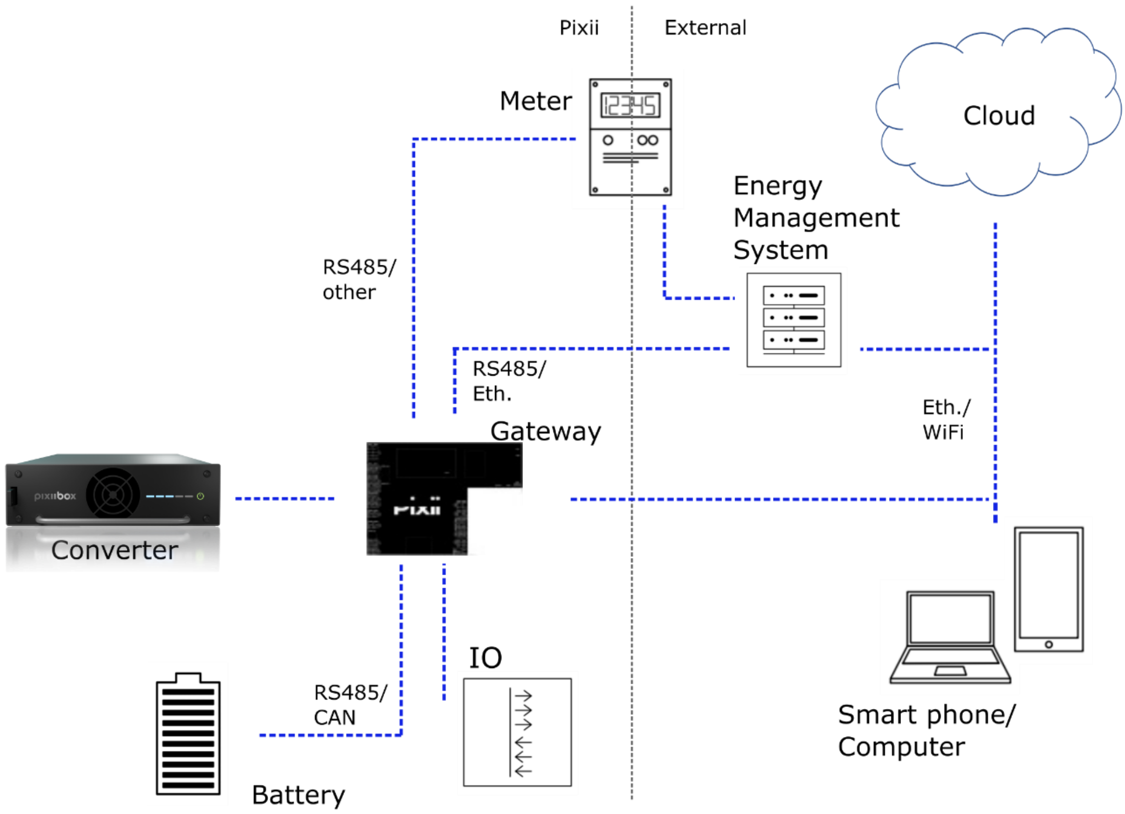


Figure 1. Pixii Control system overview

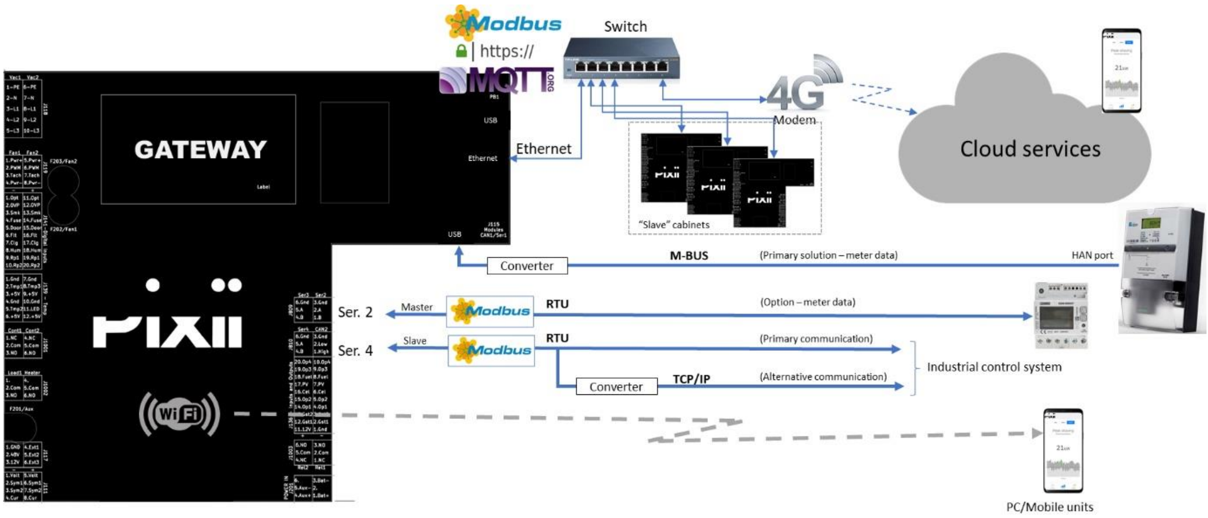


Figure 2. Multicabinet communication

2.2 Battery

The battery values and status will be made available to the Gateway via the battery BMS (if available such as for Li-ion chemistries). Currently, battery values directly via current/voltage measurements (such as for Lead-acid) is not supported.

The battery capacity is divided into different parts, see Figure 3. Using energy below the min or above max limits will not be possible. They can be adjustable within hard-coded min and max values depending on the battery manufacturers' recommendations for preserving optimum lifetime.

The reserved levels are between min and reserved lower; and between max and reserved upper. They are meant for critical functions such as demand response or other emergency needs in the system and should only be used for the contingency service level if this is a requirement for the operation of the system. They can also be adjusted according to the desired strategy.

The normal level is between the reserved upper and lower levels.

Note that the levels can be defined both as SoC (%) and voltage levels, and the most restrictive level will be used. State of charge calculations/estimations have relatively large uncertainties, in particular for lead-acid and LFP chemistries. This means that using SoC as basis for reserving capacity for services will be inaccurate. Using voltage measurements are more accurate in terms of safe operation of the battery. The SoC estimation is reported by the BMS (from the battery manufacturer), and the PowerShaper system relies on that.

If there is no BMS connected to the PowerShaper system, the PowerShaper will use the DC voltages and currents reported by the PixiiBoxes for upper and lower limits, and for derating.

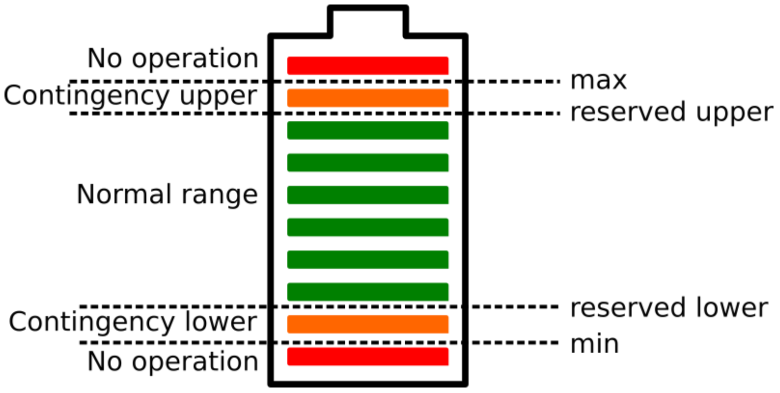


Figure 3. Battery strategy

The battery will also have restrictions on how much current and power can be drawn from and fed into it. This depends mainly on the state of charge and temperature. The PowerShaper system will use the information reported by the battery BMS. The battery BMS has safety features in place. The PowerShaper system has additional safety features in place based on temperature, smoke detector etc.

2.3 Meter measurements

The power and other measurements from the grid connection may come from different sources. This includes:

No.	Source
1	Meters using e.g. RS485 Modbus interface. Several models are supported. Contact Pixii for the currently supported models.
2	Communication with the HAN-port (Norwegian specification based on Mbus and OBIS-codes). Please refer to https://www.nek.no/info-ams-han-utviklere/ for more details. Supported via a wired connection. A separate communication

Table 1. List of supported meter measurement sources

Other options exist but require engineering or development.

Update rates will be depending on which of these interfaces is used and the characteristics of these.

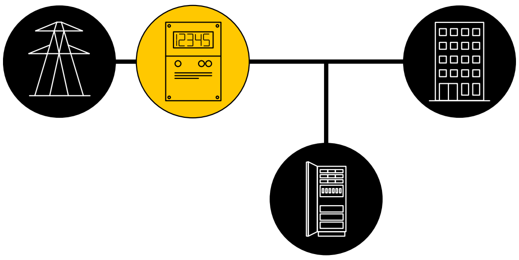


Figure 4. System behind meter

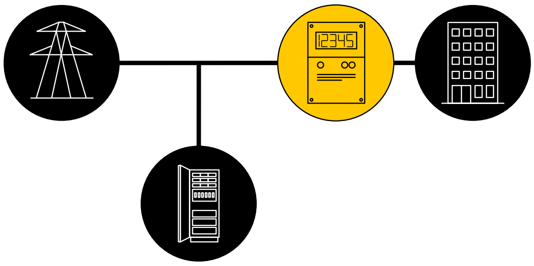


Figure 5. System in front of meter

To avoid instability and negative effects on the grid, a PI-regulator is applied to power control when basing on meter values (e.g. for peak shaving).

The placement of the meter relative to the connection point needs to be set to get the correct calculations. See Figure 4 and Figure 5.

2.4 External systems integration

The Pixii Gateway can support different interfaces and protocols depending on the system requirements and abilities.

The main communication interfaces are RS485 (for Modbus), and Ethernet.

There are two RS485 interfaces which are used for external systems: One acts as master and is used to retrieve values from power meters. The second acts as a slave/server aimed at supporting communication with energy management systems. It supports some relevant models as defined in the SunSpec protocol (www.sunspec.org), and some Pixii specific functions.

The Ethernet interface supports a web-interface for local configuration, and for communication with external systems such as cloud applications. The main protocols supported are MQTT and Modbus TCP.

Please refer to the document “Pixii PowerShaper Guidelines for External Communication and Control Integration” for more information and references to further documents.

2.5 Internal power handler

The main Gateway power handler loop is executed approximately once per second. The power handler in the converters is faster.

The measurements come from the converters, internal measurements, and measurements from external equipment such as a meter at the point of common coupling. These are used for inputs to the different parts of the Power handler functions.

2.5.1 Converters

The converters (PixiiBoxes) provide functionality which are software configurable.

The converters have two ports. The main configuration is to connect port 1 to the battery and port 2 to the AC grid, and in this case the converters can do bidirectional conversion of power.

The power rack will provide information about the phase each unit is connected to, and this information may be used by the PowerHandler to perform services.

The main limitations for the maximum charge/discharge current and power of the converters are:

- Hardware defined DC current and voltage operation range.
- Hardware defined AC current, voltage, and frequency operation range.
- Converter temperature.
- Grid code regulations defining the allowed operation within specified grid frequency and voltage ranges, and other parameters.

2.5.2 Services

The services need to be prioritized so that there is always one that has precedence. There are currently no restrictions to the number of levels, however Pixii cannot guarantee how combinations of services will perform. Example of levels are shown in Table 2.

Table 2. Example of service priority levels

Priority	Name	Description	Battery capacity level
1	Demand response	Demand response has the highest priority.	Contingency + Normal
2	Scheduler	Different services (currently Peak shaving, Target SoC and Demand response) with different parameters may be specified to run at different intervals.	Normal
3	Peak shaving	Static peak shaving service	Normal
-	Idle	If none of the other services are active, the system will be in idle, and keep the batteries at the idle SoC and voltage	Normal

The prioritization may be done via the user interface. Services can be enabled/disabled.

A service may be in different states. The highest priority (parent) service will be run unless it is in off or idle state. In those cases, the next priority (child) service can be run.

Table 3. Service states

State	Description
Off	The service is disabled
Idle/pause d	The service is enabled, but the conditions for it to be running are not met.
Pending	The service is enabled, the conditions for it to be running are met, but a higher priority service is running.
Running	The service is running. The service is enabled, the conditions for it to be running are met, and no higher priority service is running.

Some services may have its' own configurable min/max SoC it can operate within. However, the min/max SoC from the battery BMS and main settings will override any SoC from the services.

Figure 6 shows the service priority levels as related to the battery capacity reserved levels, with an example.

In this case, the contingency service is Demand response. In this example, it is in idle state, which means no Demand response signal has been received.

Level 2 is a schedule service and will operate if the battery capacity is within the normal range. In this example, it is a Target SoC service which currently is in running state.

The next level, level 3, is an none-scheduled service. It can as with level 2 only be run if the battery capacity is within the normal battery capacity range. The service in this example is Peak Shaving and is in a pending state.

The next, and lowest level in this example, default, is not configured to any particular service. Conditions for it to be running is met, however, since a service level above this is running, it is put in a pending state.

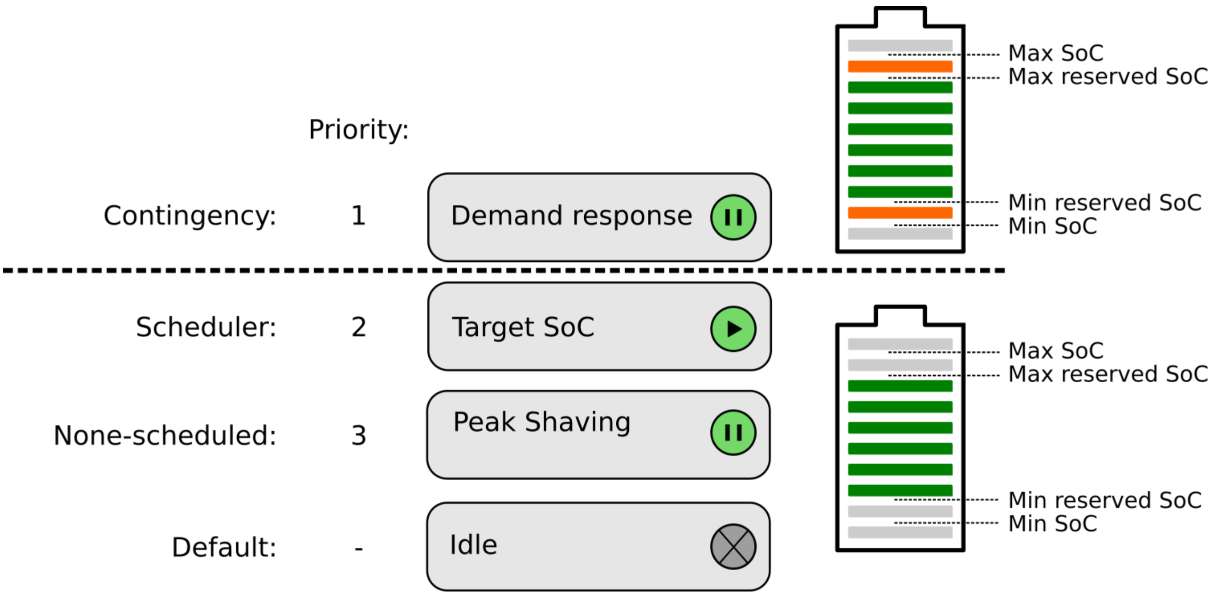


Figure 6. Priority levels related to reserved battery capacity

The different services will set one or more references. E.g. some will only set the total active power reference, others may set the end SoC etc.

The operation of the converters will be depending on the type of service and how the converters are connected electrically. In some cases, the converter will be controlled by the references sent from the gateway, in other cases it will operate autonomously and simply receive activation/deactivation signals from the gateway.

In addition to the battery capacity, the total power and power per phase may be a limiting factor when running a service. This applies to services relying on power between phases, such as Power phase balancing and Voltage phase balancing. If the imbalance between the phases exceeds the installed power per phase, the system will not be able to fully compensate for the imbalance.

Figure 7 illustrates how the converters on the different phases may have different power references. In this case, the converters on phase 1 draws 3 kW, while the converters on phase 2 and 3 feed 1.5 kW each. The power drawn from the battery is close to zero. Note that power phase control currently is not available as an external command for customer use but is available as a Voltage support service based on an internal algorithm.

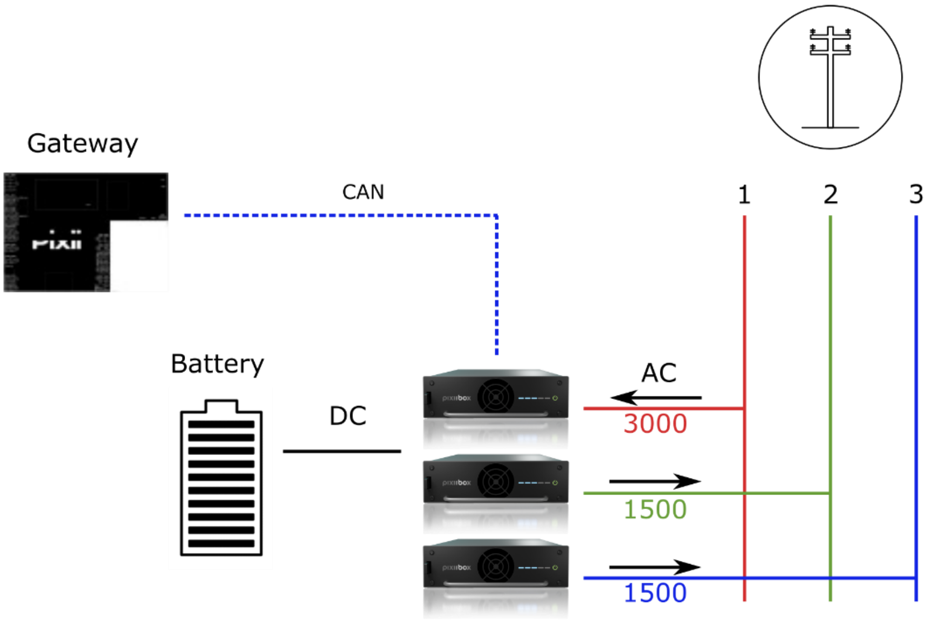


Figure 7. Converter phase control

Figure 8 shows a timeseries illustration of how the actual power output from the converters is related to the battery and power capacity.

The blue dotted line is the desired power output from some imagined algorithm. The maximum charge and discharge power are the two horizontal black dotted lines. The green solid line is the SoC, and the black solid line is the actual power output. Below the graph are illustrations of the battery capacity and power capacity respectively at selected points in time. When reaching a battery or power capacity limit, the icons are highlighted with a red circle.

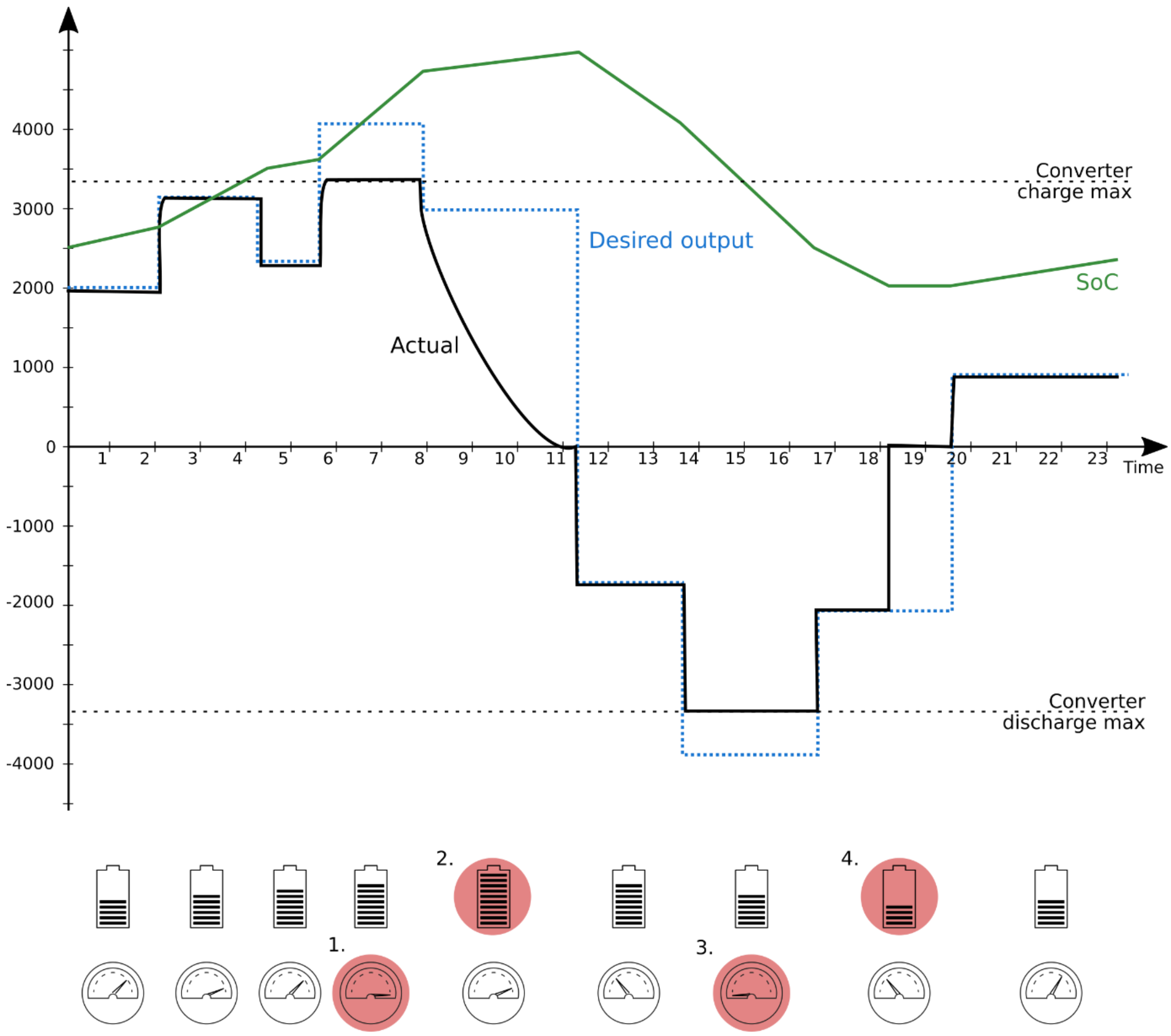


Figure 8. Actual output vs battery and power capacity

Table 4. Description of events

Event	Description
1	The charge reference is higher than what the converter can provide. The battery can still be charged.
2	The battery is reaching its maximum capacity, and the converter will not be able to charge at the maximum desired capacity.
3	The converter is discharging. The discharge reference is higher than the converter maximum discharge power capabilities.
4	The minimum allowed SoC level is reached, and the converter stops discharging.

A more involved example over several schedule intervals will be shown in chapter 5.

3 Services

This chapter explains some of the main services. These include the scheduler, demand response, target state of charge, and peak shaving.

3.1 Scheduler

3.1.1 Purpose

Start and stop a specific service at a defined time. It supports single-shot and recurring events. The Gateway handles this service. Schedules may be configured locally via the Web-interface or received from an external source via an API. Externally received schedules will be stored locally in the Gateway.

The main difference of an externally received and an internally configured schedule is the purpose or intent. An internal schedule is mainly used for having default operation for longer periods of times, e.g. on weekly or seasonal basis and not intended to be changed often. The intention of an external schedule is to be used by an external application such as an aggregator or cloud application that calculates an optimum set of parameters for a duration of around 24 hours based on different measurements and sources such as weather forecasts.

3.1.2 Implementation

The scheduler monitors the date and time and starts and stops services that are configured to use the scheduler. A production plan may be made of several schedule entries with different services to achieve a specific outcome of the system over time. An example is shown in Figure 9. The first and fourth items are State of charge services (explained in chapter 3.3), while the second and third items are peak shaving (explained in chapter 3.4).

In case two or more events overlap partly or fully in time, the one that was configured/received last will have priority. This is based on the assumption that a newer schedule is supposed to replace an older. Further, if a new production plan is received that partly or fully overlaps the previously received production plan, the new production plan will overwrite the existing from after the end of the current time interval (if ongoing).

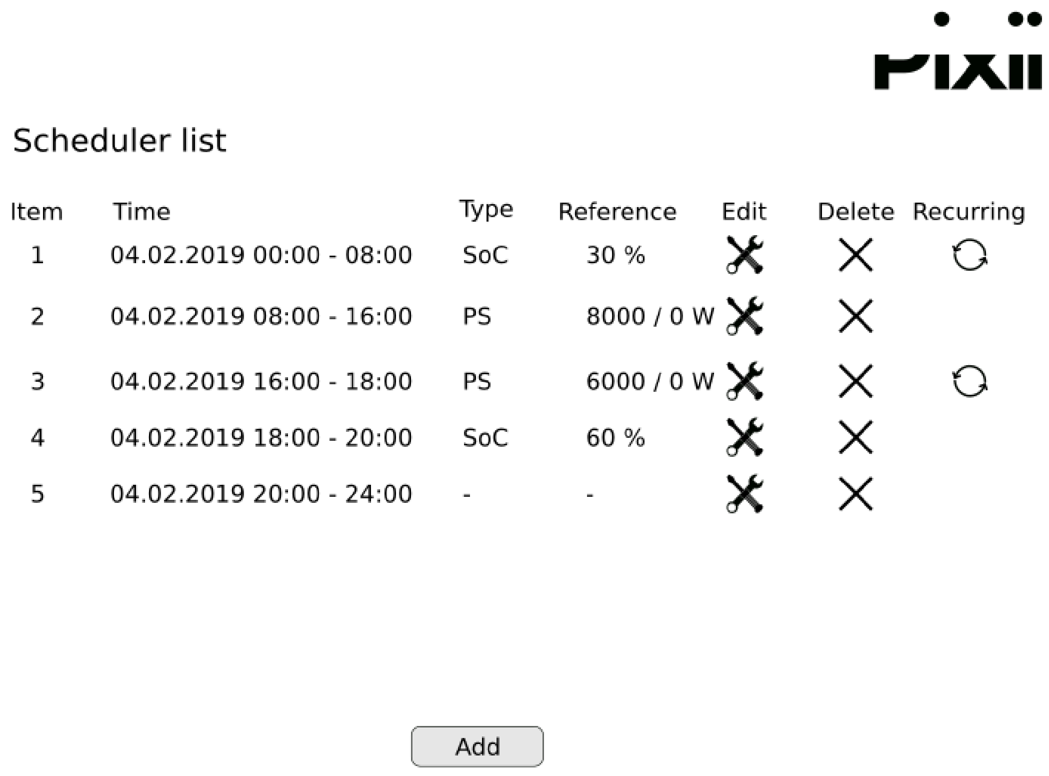


Figure 9. Example schedule list making up a production plan

A schedule event may be recurring, i.e. it can be repeated at defined intervals.

The regulation will continue until either explicitly stopped, the last interval in a schedule is finished, or a service with a higher priority is activated.

Please refer to document “Pixii PowerShaper Service Priorities and Scheduler” for more details.

3.2 Demand response – power reference

3.2.1 Purpose

In this mode, a power reference is sent to the PowerShaper containing the desired charge/discharge power of the battery for a specified duration (either pre-configured or as a part of the payload).

3.2.2 Implementation

The service has one signed reference. If it is positive, it means charging the battery, and negative means discharging the battery and feeding to the grid. It is referred to the grid but will be limited by the battery charge/discharge capabilities.

The regulation will continue until either explicitly stopped or new reference is received, the duration times out, or a service with higher priority is activated.

Please refer to the document “Pixii Power Shaper Demand Response” for more details.

3.3 Target State of charge

3.3.1 Purpose

Charge or discharge a specified amount of energy during a specified time range. “Target” refers to the algorithm attempting to reach a State of Charge target within the specified time.

3.3.2 Implementation

In this mode, a reference is sent to the PowerShaper containing the desired SoC of the battery at the end of the interval. The interval may be hourly, every 15 minutes down to 1 minute. If the target SoC at the end of an interval is lower than the actual SoC at the start of the interval, it means that the battery should be discharged. If the target SoC at the end of the interval is higher than the actual SoC at the start of the interval, it means that the battery should be charged.

The service will calculate the charge/discharge power needed to achieve the SoC target at the end of the interval. This value will be re-calculated once every minute for as long as the interval lasts. There will be an upper power limit based on the number of active converters, and the battery limits. This is due to the battery might give current limitation resulting in the desired power reference not being followed.

The regulation will continue until either explicitly stopped, the interval is finished, or a service with higher priority is activated.

Figure 10. SoC scheduled shows the use of Target SoC in a schedule for a production plan. Note that at higher SoC, the power that is possible to feed into the battery will be reduced due to the characteristics of the battery.

Please refer to document “Pixii PowerShaper Target SoC” for more details.

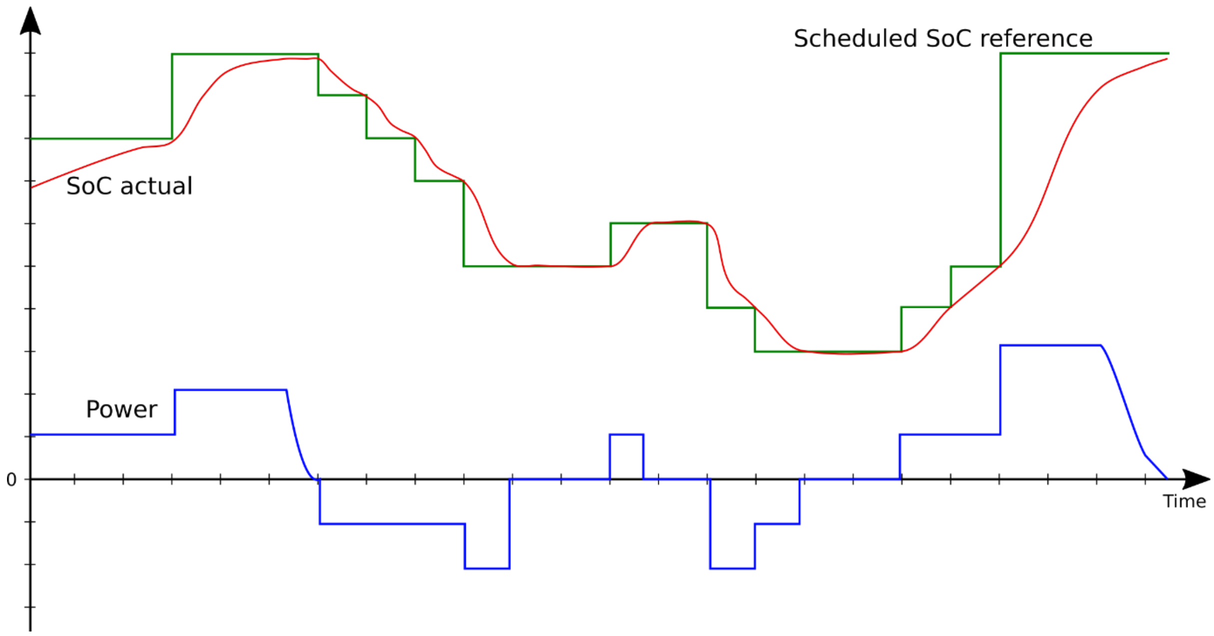


Figure 10. SoC scheduled

3.4 Peak shaving

3.4.1 Purpose

Limit the power peaks based on references and measurements and may also be used for PV self-consumption. This can work both when drawing power from the grid and feeding to the grid.

3.4.2 Implementation

The service has two separate limits: one for charge and one for discharge. Charge/discharge may be at the same level. These settings are fixed/static (i.e. not adaptive based on changing consumption/production).

The value is the instantaneously measured power, normally at the installation connection point.

The charge and discharge power maximum values are normally the difference between the threshold and the measured power but limited to what the current the battery may receive or supply. In addition, it is also possible to specify the upper charge and discharge power. A PI-regulator is applied to the calculation of the output reference values to avoid step-responses which may be undesirable to the grid.

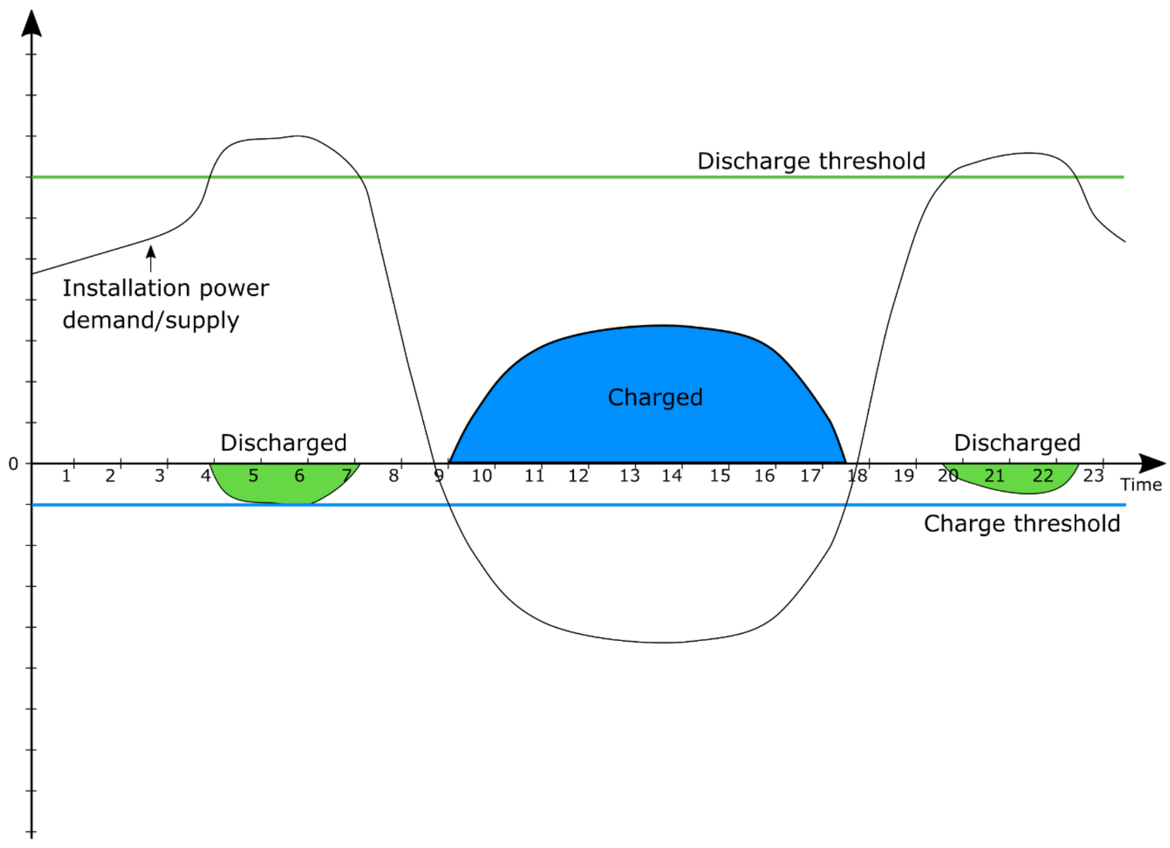


Figure 11. Peak shaving illustration.

The regulation will continue until either explicitly stopped, or a service with higher priority is activated.

Please refer to document “Pixii PowerShaper Peak Shaving” for more details.

3.5 Voltage phase balancing

3.5.1 Purpose

Support grid to maintain the grid voltage within set limits. This is mainly intended for use by DSOs.

3.5.2 Implementation

The algorithm is handled in the grid connected converters. The Gateway will set the min and max voltage limits and other parameters needed for the proper operation. This will be sent as configuration parameters to the converters.

The Gateway will send activation signals to the converters when the service shall be run.

The regulation will continue until either explicitly stopped, or a service with higher priority is activated.

Contact Pixii for more details about this functionality.

4 Applications

Different higher-level applications may be implemented using a combination of one or more services and the scheduler (for production planning) described in chapter 3. Some of the main applications and how they can be achieved are described in the following.

4.1 Demand charge cost reduction – Peak shaving

4.1.1 Purpose

Limit the power peaks based on references and measurements to reduce (monthly) demand charges. It may also be used to compensate for transformer capacity issues.

4.1.2 Implementation

This builds directly on the functionality described in 3.4 Peak shaving. It can either be run as a fixed set of charge/discharge limits, or a production plan consisting of several demand charge instances having different levels running at different times of day/days of week/seasons.

If a new production plan is received that partly or fully overlaps the previously received plan, the new plan will overwrite the existing from after the end of the current time interval (if ongoing).

This application requires the instantaneously measured power from the meter, normally at the installation connection point.

The regulation will continue until either explicitly stopped, the last interval in a production plan is finished, or a service with higher priority is activated.

4.2 PV self-consumption

4.2.1 Purpose

Increase the local use of PV production. Charge batteries instead of curtailing or feeding-in solar energy generation. Discharge batteries when there is none or little solar energy generation and the local load exceeds the production.

4.2.2 Implementation

The application may be implemented using the functionality described in 3.4 Peak shaving, possibly in addition with or 3.3 Target State of charge. It can either be run as a fixed set of charge/discharge limits plus SoC targets, or a production plan consisting of several peak shaving and optionally target SoC instances having different levels running at different time of day/days of week/seasons.

This application requires the instantaneously measured power from the meter, normally at the installation connection point.

To get to a specific battery SoC, the target SoC service in combination with a schedule may be used. For example, discharging to a certain level during night until sunrise.

The regulation will continue until either explicitly stopped or a service with higher priority is activated.

4.3 Time of use

4.3.1 Purpose

Support loads from battery when electricity rates are high, and charge battery when electricity rates are low.

4.3.2 Implementation

The application may be implemented using the functionality described in 3.2Demand response – power reference, 3.4 Peak shaving and/or 3.3 Target State of charge. It can be run as a production plan consisting of several fixed set of charge/discharge power values, charge/discharge limits and/or SoC targets, having different levels running at different time of day/days of week/seasons.

When using the service 3.4 Peak shaving, this application requires the instantaneously measured power from the meter, normally at the installation connection point.

The regulation will continue until either explicitly stopped, the last interval in a schedule is finished, or a service with higher priority is activated.

5 Example

This chapter gives an example of a system that uses three priority levels and receives an external schedule from an aggregator which is written to the local scheduler.

The service settings as configured in the user interface are displayed in Figure 12, with Demand response as the contingency level, Scheduler in level 2, Peak shaving in level 3, and defaulting to idle.

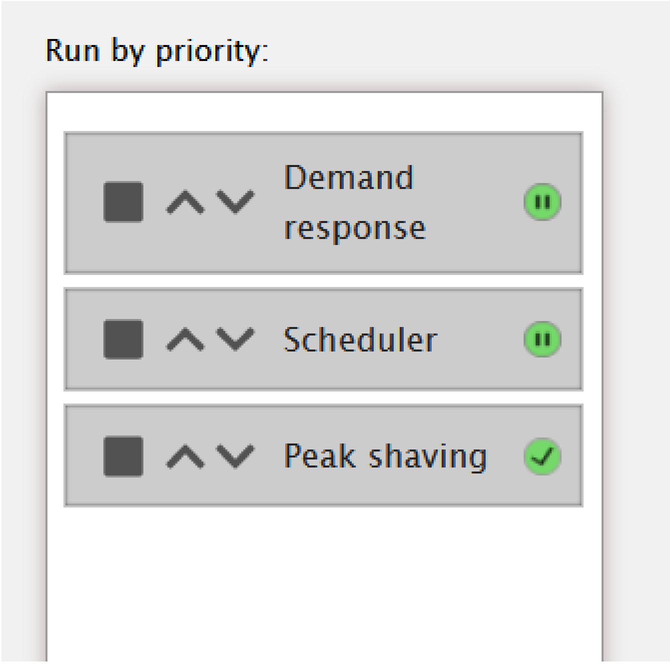
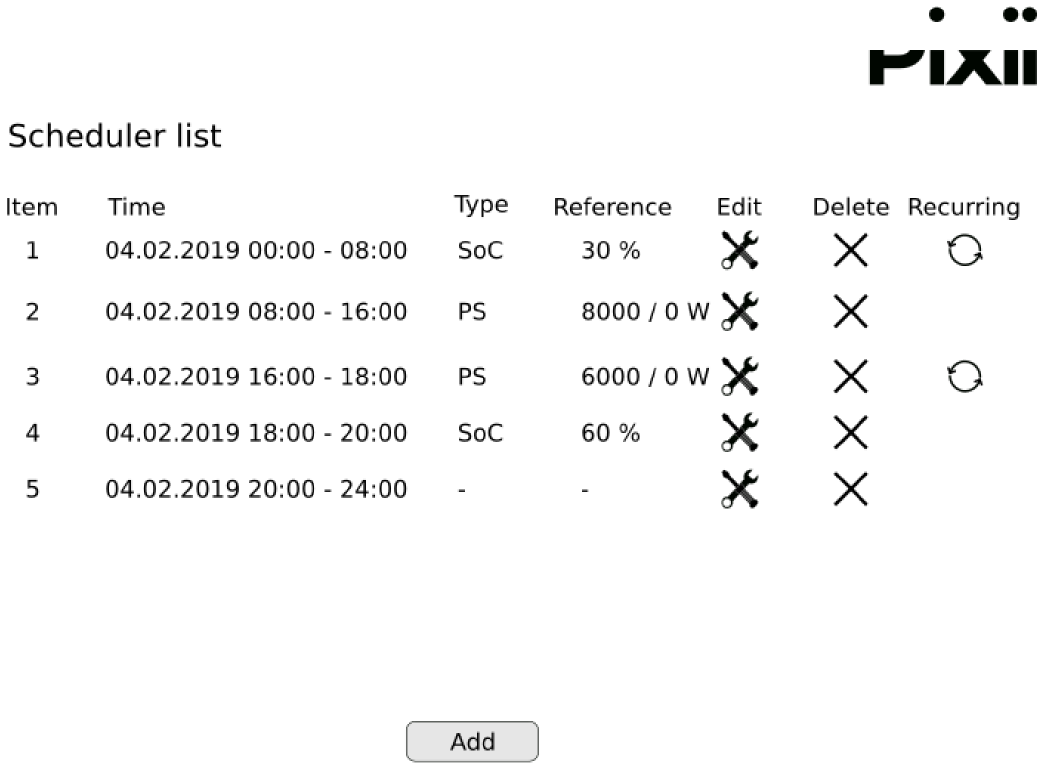


Figure 12. Example Services list

The scheduler is as shown in Figure 13. It consists of SoC and Peak shaving services. Between 20 – 24, no service is defined. The scheduled task between 18:00 – 20:00 is received from an external aggregator, the rest are configured via the web interface.

The references in the peak shaving slots are discharge and charge thresholds, respectively.



Scheduler list

Item	Time	Type	Reference	Edit	Delete	Recurring
1	04.02.2019 00:00 - 08:00	SoC	30 %			
2	04.02.2019 08:00 - 16:00	PS	8000 / 0 W			
3	04.02.2019 16:00 - 18:00	PS	6000 / 0 W			
4	04.02.2019 18:00 - 20:00	SoC	60 %			
5	04.02.2019 20:00 - 24:00	-	-			

Figure 13. Example internal schedule list

In this example, a Demand response signal is sent at 12:00 with a duration of 30 minutes to discharge 2 kW. This overrides the scheduler.

The resulting timeline of services performed is shown in the "Executed" lane at the bottom of Figure 14.

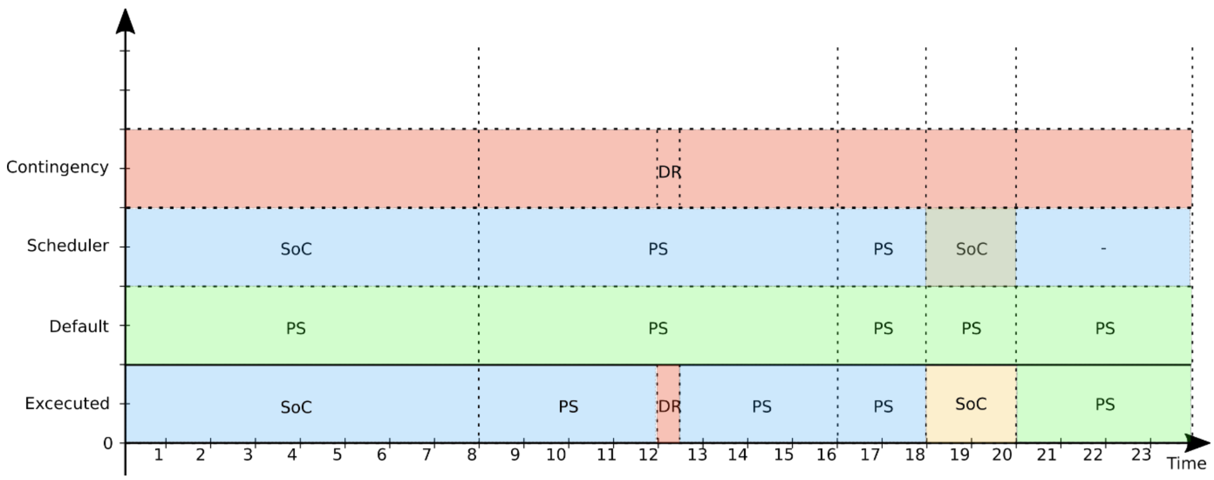


Figure 14. Resulting execution of example

