Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX)

D3.1 DR Ready Prosumer Requirement & Interface Specification

April 2017

Imprint

Contractual Date of Delivery to the EC: **30 April 2017**
Actual Date of Delivery to the EC: 28 April 2017

Author(s): **Sašo Brus (INEA)**
Participant(s): **Jure Ratej (ETREL), Erik Bubola (Robotina), Zoran Marinšek (INEA)**
Reviewer(s): **Laurynas Šikšnys (AAU)**

Project: Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX)

Work package: **WP3**
Confidentiality: Public
Version: **3.0**

Contact: **Sašo Brus – saso.brus@inea.si**
Website: **www.goflex-community.eu**

Legal disclaimer

The project Generalized Operational FLEXibility for Integrating Renewables in the Distribution Grid (GOFLEX) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731232. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the Innovation and Networks Executive Agency (INEA) or the European Commission (EC). INEA or the EC are not responsible for any use that may be made of the information contained therein.

Copyright

Executive Summary

This document provides a detailed requirements of adaptations needed for upgrading the existing Energy Management Systems (xEMS) for use withing GOFLEX project. There are four complementary EMS systems used in the GOFLEX project: Factory EMS (FEMS), Home EMS (HEMS), Charging EMS (CEMS) and Charging-Discharging EMS. The purpose of this document is to inform the reader about existing functionalities of xEMS systems and provide a roadmap to reach innovative prototypes of those solutions. This report outlines the interaction between xEMS systems and other components of GOFLEX project. This document comprises project deliverable 1 of Work Package 3 (WP3).

Document History

Version	Date	Status	Author	Comment
1.0	21 Dec 2016	Draft	Sašo Brus	First draft
2.1	5 Feb 2017	Draft	Sašo Brus	Added xEMS types
2.2	8 Mar 2017	Draft	Sašo Brus	Full document structure
2.3	14 Mar 2017	Draft	Sašo Brus	FOA-xEMS interface
2.4	21 Mar 2017	Draft	Jure Ratej	Added CEMS GOFLEX requirements
2.5	28 Mar 2017	Draft	Sašo Brus	Added FEMS GOFLEX requirements
2.6	28 Mar 2017	Draft	Sašo Brus	Added performance indicators
2.7	1 Apr 2017	Draft	Sašo Brus	New document structure
2.8	4 Apr 2017	Draft	Sašo Brus	Added FEMS energy reservoirs
2.9	5 Apr 2017	For internal review	Sašo Brus	Added chapter 6.2 from Robotina
3.0	20 Apr 2017	Final	Sašo Brus	Updated, based on the comments from reviewer

Table of Contents

List of Figures

List of Tables

List of Acronyms and Abbreviations

Abbrevia-tion	Definition
EMS	Energy Management System
xEMS	x can be F-factory, H-home, C-charging or CD-charging-discharging EMS
Prosumer	Active energy consumer and/or producer
FOA	Flex-Offer agent
DSM	Demand Side Management

1 Introduction

1.1 Purpose

This document contains functional and non-functional requirements for several types of Enegy Managemnt Systems (xEMS) across GOFLEX demonstration sites. Since xEMS solution prototypes already exist, this document also includes some specifications of those systems in order to efficiently present capabilities that will be used by higher-level systems within GOFLEX.

To give better understanding of processes on prosumer level, this document also depicts some of the typical characteristics of specific loads, devices and processes within each of the 4 xEMS groups.

The most important part of the document is the interface between different EMS systems and Flex Offer Agent (FOA, see also D2.1). Therefore, chapter 5.5, which contains interface specification is the most detailed. This allow different solutions from different vendors to progress individually and follow the implementation plan, defined in chapter 8.

1.2 Related Documents

Main focus of WP3 is utilization of energy reservoirs at prosumers. Therefore the relevant documents for prosumer acquisition and integration are D7.1, D8.1 and D9.1. Uplink to other GOFLEX systems is done trough Flex Offer Agent (FOA), which is the focus of WP2. FOA and other components of trading platform are described in D2.1.

Interaction between all GOFLEX systems is managed within WP6. D6.1 contains also the specifications for interconnection between xEMS and FOA.

1.3 Document Structure

Document is structured into 10 chapters. In chapter 2 we offer a brief description of work package 3. We then proceed to interfaces to and from other work packages in chapter 3 and 4. In chapters 5 and 6 we describe functional and non-functional requirements for WP3. We provide architectural considerations in chapter 7 and describe three levels of prototypes in chapter 8.

2 Work Package Description

The main objectives of WP3 are to develop solutions and prototypes to:

- Augment demand response through Energy storage in processes
- Integrate explicit and virtual energy reservoirs with Energy Management Systems (EMS) and trading interface

- Integrate Optimized and balanced Demand Response Ready EMS
- Integrate grid users from the transport – Charging/discharging EMS

D3.1 identifies operational needs of constituent DR ready prosumer subsystems, their interactions and the characteristics of the data sources in the deployment of the overall system. It identifies and outlines key functionalities of the DR Ready EMS system and its interactions with other subsystems (WP2) and cloud based common service platform (WP5), mapping the required features, capabilities and other characteristics of all the building blocks; designates EV user classes and specific operational requirements; component interplay and interfaces applicable to the different phases in development (prototype, full, final) of the DR Ready prosumer as integrated (WP6) for demonstration in different demonstration cases.

GOFLEX addresses several types of prosumers, which can be in general classified into 2 groups:

- With independent EMS system
- Without EMS system, where prosumer offers load control to the external party

WP3 focuses on prosumers with EMS system. Such an EMS system performs two tasks:

- Optimizes all the processes within the prosumer; this is a primary role of EMS, since it has to follow prosumer's constraints and requirements.
- Trade the flexibility potential (results of the local optimization) with higher level system; this is secondary role, because it directly depends on results from the primary role;

Different types of EMS systems can be defined, based on the use/business case and type of the underlying processes.

We provide a brief overview of different xEMS systems in chapter 7.

3 Provided to other work packages / components

3.1 Functionality

The main focus of WP3 is storing the energy to and capturing the energy from virtual and explicit energy reservoirs at prosumers. These prosumers differ mainly on their business role, but also on devices, loads and processes they utilize. Therefore we describe each xEMS separately in the chapters 5, 6 and 7. Generically, WP3 provides those functionalities (mainly to WP2):

- Predict energy profile for certain interval in the future

In order for FOA to prepare FlexOffer (defined in D2.1), it needs to "see" into the future. Each xEMS, therefore, must be able to predict the future use of energy (baseline). xEMS can utilize statistical models or use static schedules for operation.

- Assess the flexibility potential

  Flexibility potential is the amount of energy consumed or produced (in time series), which can be either increased or decreased with respect to the baseline. xEMS must always follow the comfort and technical constraints, defined by prosumer. We say that xEMS must know the specifics of the loads in order to be able to assess what deviations can be done.

- Execute adaptation according to contract

  The last step in FlexOffer process is the realization of the contract. xEMS plays an active role here, since the "mechanical" trigger for deviation is triggered by xEMS (with respect to all known constraints of certain load or device). xEMS must also constantly monitor the operation, especially during adaptation.

It is vital to realize, that xEMS mainly performs local (isolated) control and optimization. To achieve better economical and other results, using FOA, xEMS is able to expose a certain amount of flexibility at this optimization to higher-level systems.

3.2 Data

WP3 provides the following data to WP2:

- [TIMESERIES] Predictions on load profile for certain prosumer
- [TIMESERIES] Flexibility potential with priority levels
- Other constraints (in energy, power, time,…) for specific loads and devices

All the data is sent to FOA using the interface, defined in chapter 5.5.

4 Depends on other work packages / components

4.1 Functionality

WP3 requires the following functionality from other WPs:

- RESTful API for sending the following data:

    - [TIMESERIES] Predictions on load profile for certain prosumer
    - [TIMESERIES] Flexibility potential with priority levels
    - Other constraints (in energy, power, time,…) for specific loads and devices
- RESTful API for receiving accepted FlexOffer schedules from FOA.
- Cloud storage for consumption data (objects with values and timeseries). We will define API together with WP5, after we get a complete picture about types of data at demo locations (prosumers).
- Cloud service for efficient weather forecasts.

4.2 Data

WP3 requires the following data from other WPs:

- Metering data: in order for xEMS to operate, it needs real-time metering data for overall consumption and for specific loads. Data can be gathered either from the metering chain (WP5), or locally using the sub-meter (WP3).
- Weather forecasts, especially for prosumers with electrical heating, and with PV or wind generation capabilities (WP5).

5 Functional Requirements

Table 1: Functional requirements

Requirement Number	Requirement Description
F3.1	DSM-ready FEMS: updated control algorithm with dynamic interval window, based on FOA
F3.2	DSM-ready FEMS: updated prediction engine, which allows longer prediction periods
F3.3	DSM-ready FEMS: data interface with FOA
F3.4	DSM-ready HEMS: forecasting and control strategies
F3.5	DSM-ready HEMS: HTTP API for communication with FOA
F3.6	DSM-ready HEMS: new GUI screens for demand response
F3.7	DSM-ready CEMS: acquisition of charging preferences from prosumers
F3.8	DSM-ready CEMS: scheduling algorithm with predictions on flexibility
F3.9	DSM-ready CEMS: communications between charger and xEMS, FOA and CEMS, CEMS and xEMS
F3.10	DSM-ready CDEMS
F3.11	xEMS-FOA exchange protocol
F3.12	FEMS Modbus exchange
F3.13	Performance indicator reporting: xEMS systems should provide automatic reporting of relevant KPIs

5.1 DSM-ready FEMS

5.1.1 Peak levelling

The peak leveling is existing functionality of the INEA’s FEMS. Its main task is to maintain the total prosumer’s consumption power below the specified limit and save corresponding costs. The consumption reduction is provided by controlling a certain portfolio of electric loads by exploitation of their thermal or any other energy capacity.

The concept of the peak levelling leveling system is to activate its energy capacity in such way that minimizes peaks. The concept can be seen in the Figure 1.

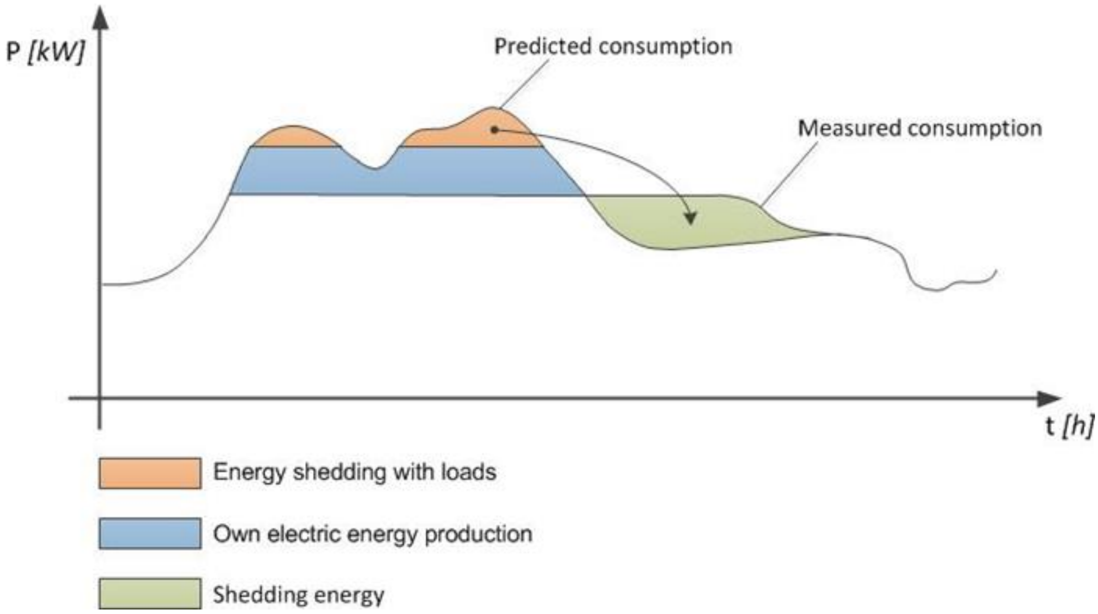

Figure 1: Examples of peaks in consumption

The INEA's FEMS provides short term prediction of the consumption for the next fifteen-minute intervals. If the prediction exceeds energy limit the interventions on the controllable loads are performed.

5.1.2 Necessary modifications of the algorithm:

In order to support the demand response functionality the peak leveling system needs the following adaptations:

- The operation of the algorithm should not be limited to the fixed (15 minute) intervals but should be able to update the adaptation capacity and execute the adaptation demand in the real time.
- Forecasting of maximum electrical energy which can be adapted (energy offer) is extended. Energy offer is calculated for each fifteen-minute interval. In peak leveling the forecasting of available energy for adaptation is only till the end of the fifteen-minute interval. In demand response the energy offer is forecasted for more intervals (defined by FOA).
- The intervention is not triggered only on the internal consumption forecast and limit but also on the external (FOA's) energy demands. Therefore the load control algorithm needs to be open on two different triggers.

- At demand response one has new input “energy demand” in the form of time array which needs to be converted into the load control command. Based on the energy demand the interventions on the corresponding portfolio of loads is performed
- The communication protocol for information exchange with FOA are implemented. For that purpose two memory locations are assigned – one for reception and one for sending the messages.

5.2 DSM-ready HEMS

5.2.1 Existing HEMS functionality

The basis for HEMS will be taken from Robotina’s existing HEMS. Existing HEMS represents energy management system that optimizes onsite electricity consumption for households with a photovoltaic power plant. HEMS measures onsite energy flow from electrical power meters and control the operation of household appliances in a way to maximize self-consumption by the usage of PV generated electric energy within the home.

5.2.2 HEMS functionality adaptation

To actively participate in energy trading platform HEMS needs the following adaptation:

- to specify energy models of typical household devices and systems
- to develop and implement consumption and production forecasting models (on household and device level)
- to extend consumption and production models with respect to flexible and non-flexible devices (sources and consumers)
- Develop HTTP-API protocol for HEMS-FOA communication
- To develop an algorithm for evaluation of energy management strategies
- Improve HEMS architecture to:
    - ensure data and communication security
    - increase local storage and processing capacity
- New electrical diagram, wiring, HW positioning, communication
- Additional implementations:
    - Communication protocols to communicate with selected meters, sensors, devices, automation system…

    - (Re)design control algorithms for providing energy flexibility
- WEB GUI adaptations:
    - Implement new type of prosumers (CDEMS, heat pump, water tank..)
    - Additional user pages for parametrization of energy trading, devices' parameters, alarms and notifications
    - Advanced time plots drawing and task scheduler
    - Configuration pages (locked for users)

5.3 DSM-ready CEMS

5.3.1 Existing CEMS functionality

Currently, the algorithm implemented in the CEMS controls (schedules) the EV charging in the way that the EVs are charged as soon as possible (with maximum power supported by the EV on-board charger), taking into consideration the limits of power available for charging, i.e. the maximum power that can be assigned to EV charging without overload of prosumers' components involved in power supply (grid connection point, internal installation, charging station's elements).

The algorithm considers the future conditions only in the case of optimization of costs for delivery of electrical energy, when it schedules the delivery of as large as possible amount of energy during the periods of low tariffs. To enable such control, the EV user's charging preferences and maximum charging power shall be known in advance (i.e. at least at the beginning of charging session). EV user's charging preferences are described in the form of planned time of departure (disconnection of EV from the charger) and of required energy that shall be delivered to EV batteries till the time of departure. Maximum charging power is the maximum power that can be delivered to individual EV (without consideration of external technical conditions such as power available for charging); it depends on charging cable rated current, and on EV on-board charger characteristics (number of phases, maximum phase current).

If several charge points are installed at the same location (cluster of chargers) and fed from the same grid connection point the algorithm distributes the power available for charging among several EVs that are currently charging. If the power available for charging doesn't allow to charge all connected EVs with the maximum charging power the algorithm uses the data about charging preferences of individual charging sessions to assign to each EV its level of charging priority which is further reflected in its charging schedule.

5.3.2 CEMS functionality adaptation

In order to support the demand response functionality and operation within the GOFLEX system, the CEMS shall be upgraded with the following:

- Acquisition of data about charging preferences: currently, the EV user's charging preferences are estimated based on historical data about individual users' behavior. To enable accurate calculation of flexibility data more precise data about user's preferences shall be known. To achieve this an interface (smartphone app for public charging and web interface for private charging) to enable the users to insert the data about required energy and time of departure;
- Scheduling algorithm: it will be upgraded with additional functions:
  - Determination of time series representing future planned charging load of each session in 15-minutes periods;
  - Calculation of possible increase or reduction of planned charging load (in future 15-minutes periods) without violation of power available for charging and without (excessive) violation of EV users' charging preferences;
  - Determination and consideration of flexible (variable) power available for charging of currently connected EVs: this functionality is applicable in the case of clusters of chargers. The algorithm for load scheduling and determination of flexibility margins will consider the newly connected EV's in the future (and thus a reduced power available for charging of currently connected EVs), estimated by use of historical database of past use of charge points;
- Communication:
  - Interface between charger and xEMS: if one single charge point operates within the prosumer's network, the charger acts as CEMS (see chapter 7.3.2, scenario C) subordinated to xEMS. Communication interface between charger (CEMS) and xEMS shall be developed;
  - Interface between CEMS and xEMS: if several charge points operate within the prosumer's network (see chapter 7.3.2, scenario D) and subordinated to xEMS, the communication interface between CEMS and xEMS shall be developed;

- Interface between CEMS and FOA; if one or several chargers are not subordinated to any prosumer's xEMS (see chapter 7.3.2, scenarios A and B), CEMS communicates directly with FOA and the appropriate interface shall be developed.

5.4 DSM-ready CDEMS

5.4.1 Existing CDEMS functionality

Existing CDEMS is a home energy management system which combines PV plant production, energy storage and load management. It helps the house owner to maximize self-consumption of solar energy and increase the level of energy self-sufficiency.

Autonomous operation implements self-consumption maximization, that is: charging the battery with an excess of produced energy during the day and discharging the battery to cover the consumption during the night or cloudy days.

5.4.2 CDEMS functionality adaptation

To demonstrate charging and discharging effect with respect to electric vehicle (EV), CDEMS should be modified significantly. Modified CDEMS functionality will implement EV charge and discharge control with respect to EV energy model. Embedded model will include all relevant EV's parameters, such as nominal energy parameters, hardware limits, owner's preferences, temporal and other constraints or requirements in order to support the generation of flex offer, and others. CDEMS will be able to delegate charging/discharging EV battery according to predefined criteria.

In order to integrate EV charger with CDEMS a standard communication protocol will be chosen and implemented.

5.5 xEMS-FOA exchange protocol

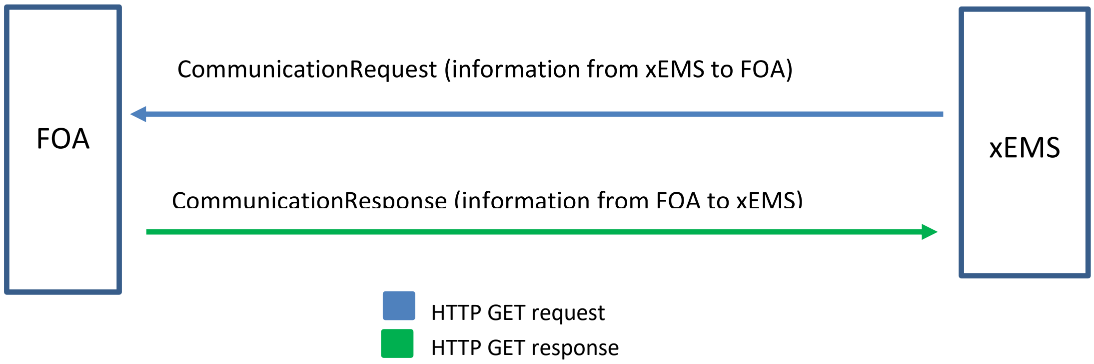

Figure 2: Initiation of the communication between xEMS and FOA

Communication interface consists of HTTP API which resides on FOA, and HTTP client which resides on xEMS. xEMS is the initiator of communication, which periodically, at appropriate intervals, sends CommunicationRequest message in the HTTP Get Request to HTTP API on FOA. The CommunicationRequest message contains the relevant information for the FOA packed as payload body of the Get Request.

In order to get any data from FOA, xEMS first needs to send CommunicationRequest to FOA, and the required information is in the CommunicationResponse message as a packed payload body in the Get Response.

To achieve adequate response times, the [INTERVAL 1] shall be as short as possible.

Each CommunicationRequest can contain the following information packets:

- OperationData
- FlexibilityData
- DemandCancellation

The information packets (if several) are packed into single request sent by xEMS.

Each CommunicationRequest induces a reply which may contain the following information packets:

- Administration control
- Ack/Nack (mandatory)
- ConfigParams
- DemandSchedule/DemandUpdate

- FlexibilityReject

The information packets (if several) are packed into a single response from FOA.

The information exchanged on the xEMS-FOA interface slightly differs from the flex offer interface between FOA and ATP. The main deviation is that there is no price exchanged and the task of FOA is to ceonvert the priority information (see bellow) to the corresponding price when vreating the flex offer from the xEMS flexibility data.

5.5.1 Intervals

[INTERVAL 1] is defined internally on FOA and is defined as minimal response time of FOA-xEMS subsystem. Therefore it is crucial that [INTERVAL 1] is as short as possible. If there are no technical constraints, such as communication lag, [INTERVAL 1] should be somewhere in the range from 1 second to few minutes.

[INTERVAL 2] is global system setting and is closely related to electricity trading interval. Usually trading interval is set to 15 minutes. GOFLEX aims for system response time to be less than that, therefore we aim for [INTERVAL 2] to be around 1-5 minutes. On FOA-xEMS interface this is maximum update time for flexibility predictions.

xEMS is allowed to send updates asynchronously as they become known and doesn't have to wait for [INTERVAL 2] to post updates.

5.5.2 AdministrationControl information

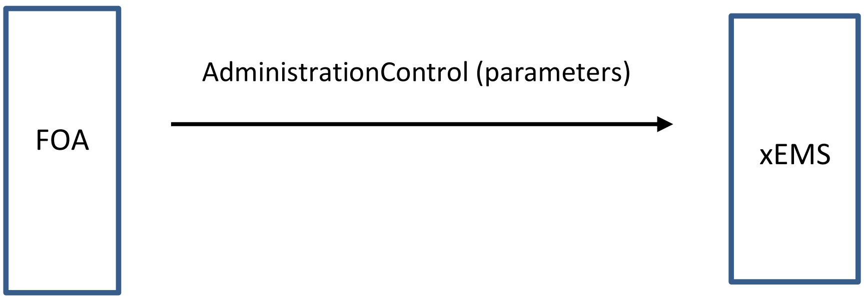

Figure 3: Administration control information

AdministraionControl information packet is sent from FOA to xEMS. It is usually sent at first interaction with xEMS and every time there are changes in configuration parameters. ConfigParams message can contain several settings in the form "Property":"Value". With common message we cover future needs of GOFLEX solutions and we aim for expansion of ConfigParams structure.

Table 2: Administration control packet

Parameter	Description
ScheduleLength	Setting max length of flexibility in seconds. I.e. setting parameter to 3600 means, that xEMS should form the flexibility data for up to 1 hour or less. Setting the value equal to "-1" means that xEMS shall send the maximal length it is capable to. If the information is missing, the last received information is valid for xEMS. If the information has not been exchanged, its default value in xEMS is -1.
TimeSeriesInterval-Length	Duration of the element in the time series expressed in seconds. It defines the operation interval length for adaptation capacity and demand schedule. It also defines the [INTERVAL 2]. Example: If the xEMS sends the adaptation capacity expressed in 5 min times series, while FOA sets this parameter to 15min, then the FOA will aggregate this information to 15 min. Vice versa: If the xEMS sends the adaptation capacity expressed in 15 min times series, while FOA sets this parameter to 5min, then the FOA will split this information to 5 min.
ResendOperation-Power	The command for xEMS to resend the data about past (actual) consumption / production power (OperationPower parameter in OperationData information packet). This happens i.e. in error case when the communication between FOA and xEMS is disabled for a longer time. The additional parameter "From" may be used to send a time series for a longer times.
ResendOperation-Prognoses	The command for xEMS to resend the prognoses of operation schedule (OperationPrognoses parameter in OperationData information packet).
ResendAdapta-tionCapacity	The command for xEMS to resend the adaptation capacity (AdaptationCapacity parameter in FlexibilityData information packet).
EmsCommand	This information element is used to provide specific administration actions on xEMS, if they are supported by xEMS.

5.5.3 OperationData information

OperationData information package is sent constantly by xEMS on [INTERVAL 1]. The information is mandatory. If not present, it may be assumed that xEMS is not available for demand response.

OperationData message also serves as Heartbeat packet – it notifies FOA that xEMS and communication operates properly.

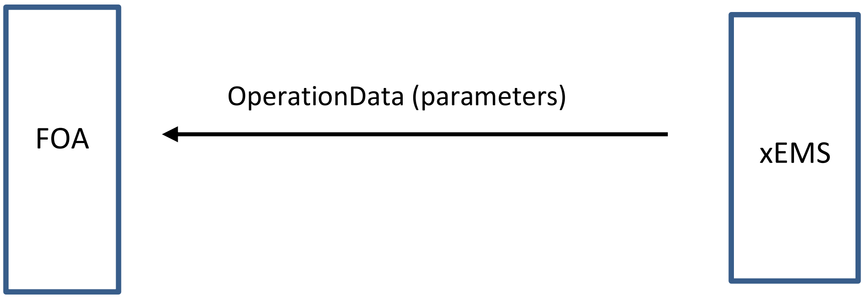

Figure 4: OperationData information

Message may contain the data, described in Table 3.

Table 3: Operation data packet

Parameter	Description
OperationState	Describes the availability for adaptation (“not available”, “available”, “in adaptation”)
OperationPower	Actual consumption or production power. Negative value means consumption, positive values means production. In the case there was communication interruption between FOA and xEMS it may be in the form of the time series.
OperationPrognoses	Time series of the future xEMS operation. Negative values are consumption, positive values are production.

The following values are assumed by FOA if the parameter is not present in the message:

- OperationState – the last value is preserved until timeout parameter in FOA is passed. After that FOA treats the state as »not available«.
- OperationPower – the last value is preserved until timeout parameter in FOA is passed. After that FOA treats the operation power as zero
- OperationPrognoses – it is valid until the time series is passed. After that it is assumed as zero.

5.5.4 Ack/Nack information

Each response from FOA contains also the information about delivery success and data integrity. API uses standard HTTP error codes:

- 200: OK
- 400: Bad request (data was not in correct format, missing)
- 500: Server error (error on FOA)

Error code is sent with each response. xEMS must account for error codes and resend, if necessary, any information not (properly) received by FOA.

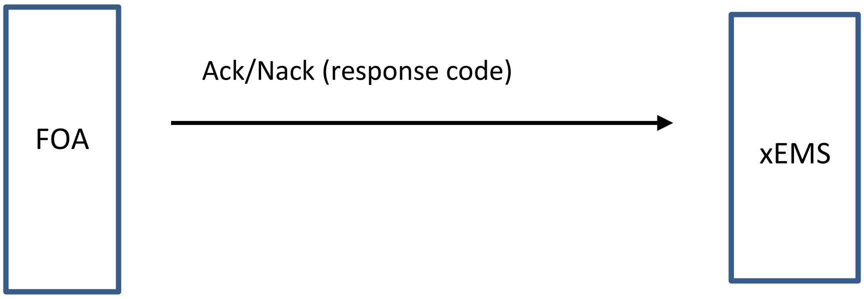

Figure 5: Ack/Nack information

5.5.5 FlexibilityData information

The flexibility data describe the prosumer's adaptation capacity. The information is sent from xEMS (i.e. is included in the CommunicationRequest message) occasionally according to its operation status.

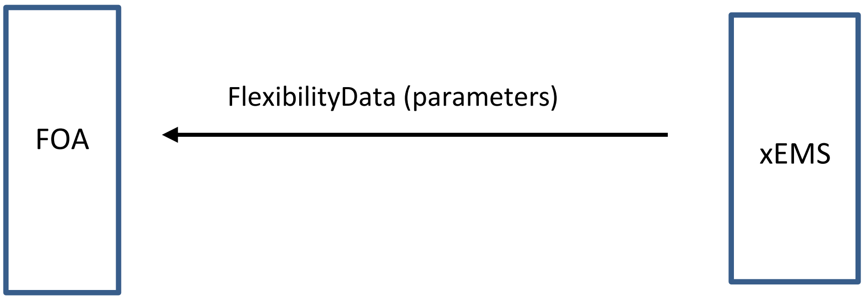

Figure 6: Flexibility data information

Table 4: Flexibility data packet

Parameter		Description	
		Array of parameters:	
		PriorityLevel	Integer value describing the importance of the adaptation. "1" is the lowest priority. Values "0" is reserved for special treatment – the maximal capacity which may be used only in emergency situations in network operation. Only priorities, which are defined in FOA as a parameter are rated properly and converted to price. Other priorities or if the parameter is not present are used in emergency operations only. The actual adaptation capacity for emergency operations is calculated as MAX(Cap(Prio=0), SUM(Cap (Prio<>0)).
		IntervalLength	Length of the interval in seconds. It describes the interval in AdaptationCapacity parameter (time series).
	Energy flexibility parameters	Adaptation Capacity	Time series (of powers or energies) where negative values mean increase of consumption (or reduction of production), positive values mean reduction of consumption (or increase of production) according to the current operation prognoses (which might be represented by sum of earlier / original operation prognoses and last ScheduleChange received from FOA). The array element consists of two values – min and max, between them the flexibility may be used by FOA. If parameter is not present or values are zero, the flexibilities of the particular priority level are assumed as cancelled by xEMS.
		DefaultSchedule	Time series which describes the operation of the adaptive load, if there is no demand for adaptation. If the parameter is not present, it is assumed that the schedule is zero.

		Ener-gyCon-straint	The total energy, which must be produced/consumed according to ScheduleChange (DemandSchedule information packet) in case the flexibility is accepted. It is defined as pair “min, max” and must be achieved until the expiry of EndBefore.
	Time flexibility parameters	StartAfter	The parameter is expressed as Timestamp. It positions the flexibility absolutely in time. It means that the schedule in the ScheduleChange (DemandSchedule information packet) must not start before this time moment. If the parameter is not present, then it is treated as “now” and the flexibility is “floating” in time valid in present moment.
		TimeFlexi-bility	It is expressed in seconds. Together with the “Start after” parameter it defines the time range that the flexibility must be started. If “start after” is not defined, but time flexibility is, then start after is calculated as “now()”. If the value is zero or the parameter is not present, there is no time flexibility.
		EndBefore	Time stamp defining the latest moment when the schedule must finish and the EnergyConstraint must be achieved. If “Start after” is defined then “End before” is ignored.
		MinA-daptation-Time	The parameters define the minimal length of the adaptation capacity time series, which must be realized in the demand schedule. If not present then the minimal length is equal to the adaptation capacity time series length.
		Assign-ment Time	If expressed as Timestamp then it means the time moment when the demand schedule is needed to be received to be executed properly. If expressed as duration (in seconds) it means the minimal time interval that the demand schedule must be received before its execution. If not present, the reception of the demand means also its execution (it is assumed to be zero).

		ExpiryTime	It is expressed as TimeStamp. It defines the moment of adaptation capacity cancellation in the case when no "Start after" parameter is present. If not present, then the parameter in FOA is used.
		Reverse-Operation-Factor	Describes the effect of over consumption when the load is returned from adaptation. I.e. for a heat pump when set to 1 it means that after adaptation the equal amount of energy as it was reduced it will be consumed over the normal operation to recharge the thermal capacity. The parameter is defined as pair "before, after" and "time". The "before" means that the load has a capability to overload the thermal capacity before the adaptation to make it more efficient. The "time" describes the duration of operation in the units of realized adaptation. If the parameter is not present it is assumed as "0".

If the priority level "0" is not present or its capacity is smaller than total, then FOA assumes the total of all available capacities also as "0" priority.

There may be several array elements with the same priority.

If the message contains less priorities than its predecessor then the received priority capacity is updated, and other priority capacities remain unchanged.

The parameters "OperationPrognoses" from OperationData and "DefaultSchedule" from FlexibilityData form the total operation schedule of xEMS in the following way:

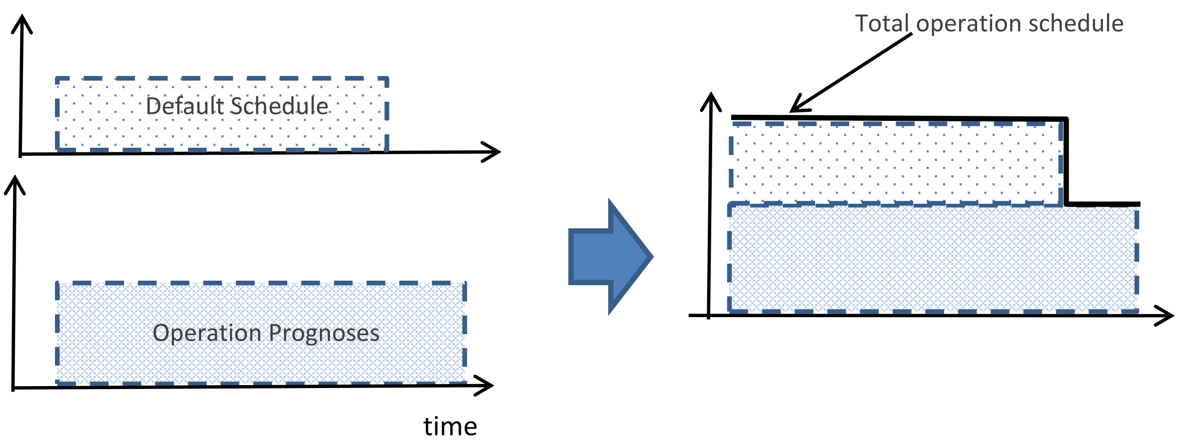

Figure 7: Handling of the default schedule (Total operation schedule = OperationPrognoses + Default schedule)

The total operation schedule is going to be realized if no demand schedule is received from FOA.

5.5.6 DemandSchedule information

DemandSchedule information is sent from FOA to xEMS as a reply to CommunicationRequest message. It is a final step in the flexibility trading process and contains the concrete schedule of deviation from OperationPrognoses previously sent by xEMS to FOA, which the xEMS must follow. The event is connected to previously sent FlexibilityData message, from which FOA created FlexOffer that was accepted by Control Centre.

DemandSchedule message contains schedule, which falls under the constraints, defined in the previously sent FlexibilityData message. Once xEMS receives a DemandSchedule response, it must start realization according to received schedule.

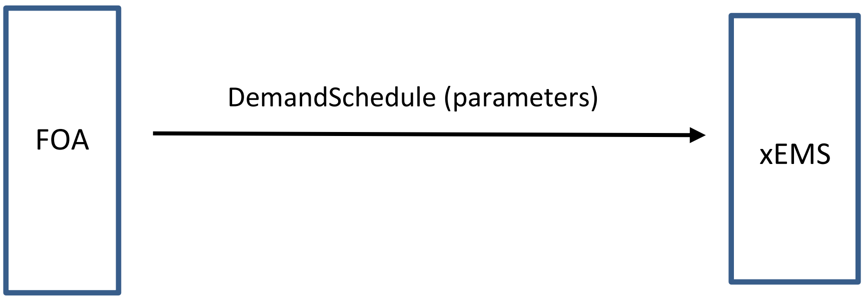

Figure 8: DemandSchedule information

The demand schedule is sent from FOA to xEMS irregularly according to the operation of FOA. It describes the required change of xEMS operation.

Table 5: Demand schedule packet

Parameter	Description
Accepted Priority	The priority of the offered adaptation capacity which is going to be activated. It is expressed as a pair of "min, max".
StartTime	The parameter expressed as Timestamp describes the moment the schedule is going to be executed. The Start Time is in future. If not present, the schedule is executed immediately.
IntervalLength	Length of the interval in seconds. It describes the interval in ScheduleChange parameter (time series).

ScheduleChange	Time series which describes the change of the xEMS's total consumption regarding the operation prognoses. Negative values mean reduction of production or increase of consumption, positive values mean increase of production or decrease of consumption.

The sum of parameters "OperationPrognoses" from Operation Data and "ScheduleChange" from DemandSchedule represents the total operation schedule of xEMS in the following way:

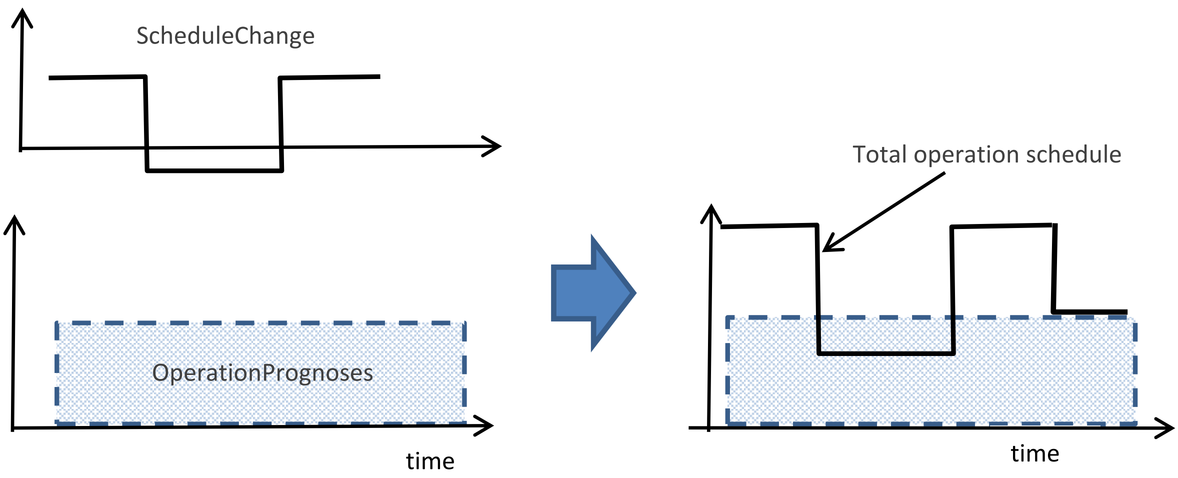

Figure 9: Total operation schedule (Total operation schedule = OperationPrognoses + ScheduleChange)

After the reception of the DemandSchedule, the xEMS updates the OperationPrognoses to the "total operation schedule".

5.5.7 DemandUpdate information

DemandUpdate is sent from FOA to xEMS in the case when adaptation in progress needs to be increased, reduced or stopped.

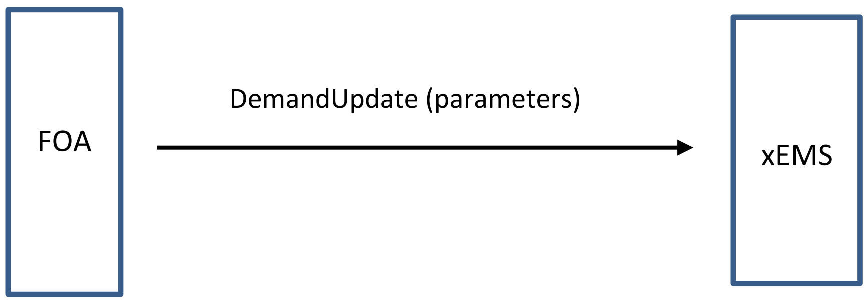

Figure 10: Demand update information

Table 6: Demand update packet

Parameter	Description
Accepted Priority	The priority of the offered adaptation capacity which is going to be activated. It is expressed as a pair of “min, max”.
StartTime	The parameter expressed as Timestamp describes the moment the schedule is going to be executed. The Start Time is in future. If not present, the schedule is executed immediately.
IntervalLength	Length of the interval in seconds. It describes the interval in ScheduleChange time series.
ScheduleChange	Time series which describes the change of the xEMS’s total consumption regarding the operation prognoses, which was updated according to the last demand.

5.5.8 DemandCancelation information

Demand cancelation message is sent when xEMS decide not to start adaptation or abort ongoing adaptation. The information is sent from xEMS to the FOA.

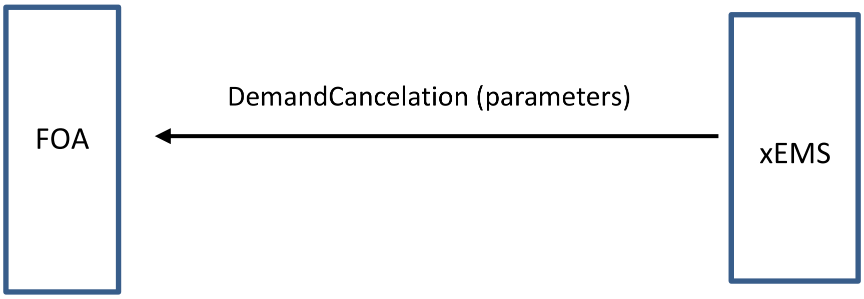

Figure 11: DemandCancellation information

Table 7: Demand cancellation packet

Parameter	Description
Reason	The reason may be “aborted by the user”, “demand not consistent with adaptation capacity”, ….
Operation prognoses	Time series of the future xEMS operation. Negative values are consumption, positive values are production.

	In the case the parameter is not present, the total operation schedule (derived from OperationData/OperationPrognoses and from FlexibilityData/DefaultSchedule) is used by FOA.

5.5.9 FlexibilityRejection information

In the case the FOA cannot convert the received FlexibilityData into the FlexOffer it can return FlexibilityRejection message to xEMS.

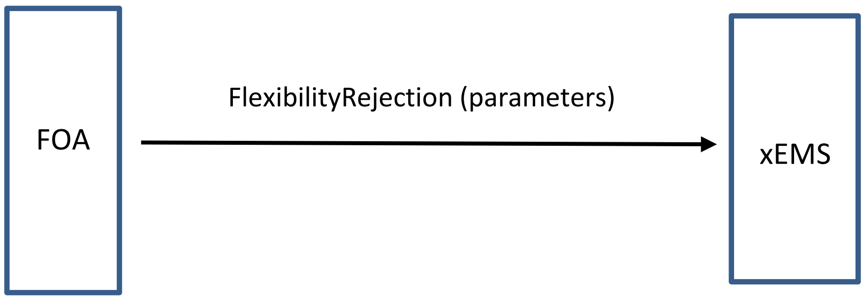

Figure 12: FlexibilityRejection information

Table 8: Flexibility rejection packet

Parameter	Description
Reason	Reason may be “parameter inconsistency”, “control center not in operation”

5.5.10 Examples

Electric vehicle on the charging station (CEMS)

Scenario: Charging of the electric vehicle with defined end of charging time:

12:00 - There is no car on the charging station. The adaptation capacity of the charging station is zero. The operation prognoses is also zero.

12:15 - The charging station sends regular update of the operation data:

- OperationState = available
- OperationPower = (12:15, 0.0 kW)

12:20 - An electric vehicle arrives to the charging station with the following parameters

- Energy required: 43 kWh

- Maximum charging power : 20 kW
- Required end of charging: 17:00

12:20 - The xEMS on charging station forms the following FlexibilityData

- DefaultSchedule:

Start	Length	Power
12:20	4h 40 min	-9.2 kW

- Element of the FlexibilityData:
  - PriorityLevel: 1
  - IntervalLength: 900
  - AdaptationCapacity:

Id	Min power	Max power
1	0,0 kW	-20,0 kW
2	0,0 kW	-20,0 kW
18	0,0 kW	-20,0 kW
19	0,0 kW	-20,0 kW

  - EnergyConstraint: Min=Max=-43.00 kWh
  - EndBefore: 17:00

12:28 The FOA sends The following DemandSchedule

- Accepted priority: 1
- Start Time: 12:30
- ScheduleChange

	Length	Power
1	900	0
2	900	0
…	…	
10	900	-6.0
11	900	-20.0
…	…	-20.0

18	900	-20.0

The DemandSchedule is assigned to start at 12:30. The missing time interval from sending the flexibility data till the starting the demand (from 12:20 till 12:30) is processed as "Default schedule". xEMS sends the Operation data with "OperationState = in adaptation".

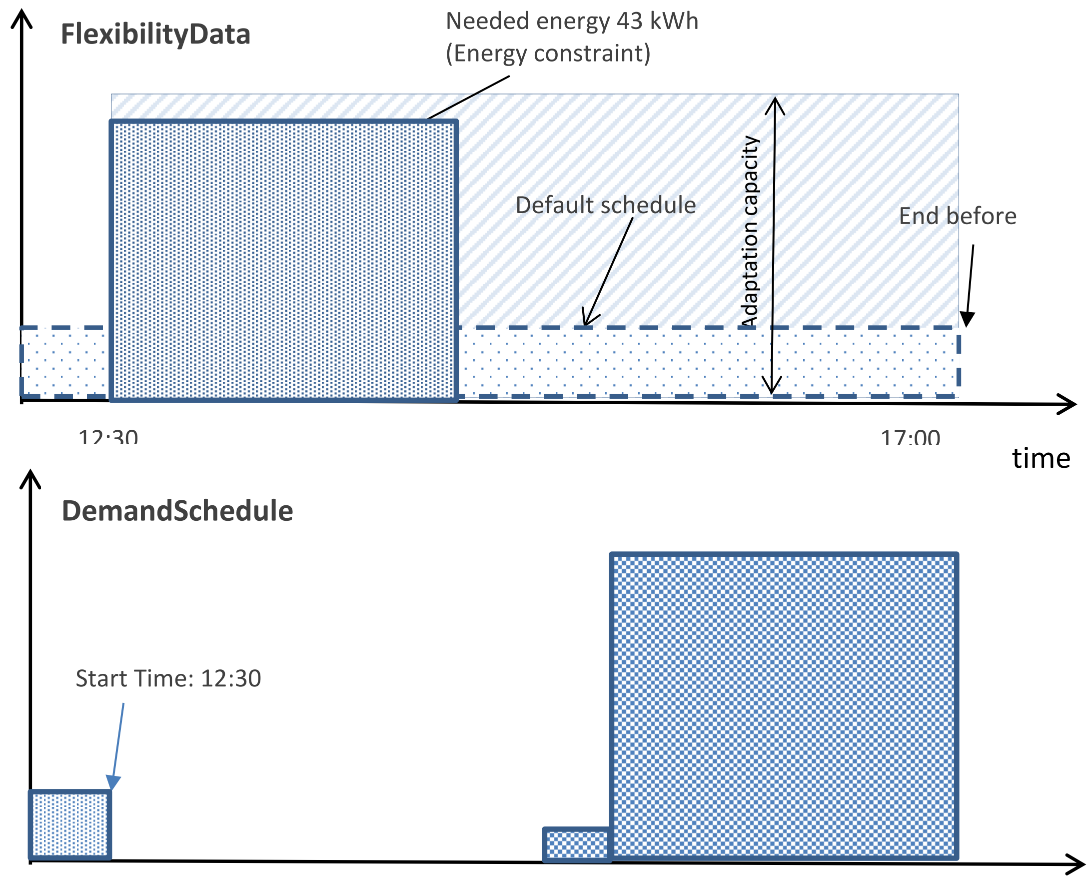

Figure 13: EV example

Battery storage (CDEMS)

Scenario: The battery is put into the network ready to stabilize it if necessary. It is controlled by dedicated xEMS, which is according to past charge/discharge actions capable to determine the available capacity.

Initial status: The battery is installed at a prosumer location, which also has some background (out of xEMS control) consumption. The battery is already charged to the half if its capacity and has the following technical parameters:

- Total capacity: 100 kWh

- Max charging power: 10 kW
- Max discharging power 25 kW

12:20: xEMS Sends regular update of the Operation Data:

- OperationState = available
- OperationPower = (12:20, -3.7 kW) – describes the background operation power
- OperationPrognoses

Start at	Power
12:30	-4 kW
14:00	-5 kW

At 12:20 the xEMS forms the following Flexibility Data

- Element 1 of the Array of Parameters:
  - PriorityLevel: 1

Id	Length	Min power	Max power
1	900sec	0	+25kW
2	900sec	0	+25kW
	…		
16	900sec	0	+25kW

  - Adaptation Capacity:
- Element 2 of the FlexibilityData array:
  - PriorityLevel: 2
  - AdaptationCapacity

Id	Length	Min power	Max power
1	900sec	0	-10kW
2	900sec	0	-10kW
	…		
16	900sec	0	-10kW

  - EnergyConstraint: min= -50kWh, max= +50kWh

12:40 The FOA sends the following demand schedule to xEMS (discharge the battery)

- AcceptedPriority: Min=1, Max = 1
- StartTime: 12:45
- ScheduleChange:

	Length	Power
1	900sec	25kW
2	900	25kW
…	…	25kW
8	900	25kW
9	900	0.0
…	…	0.0
16	900	0.0

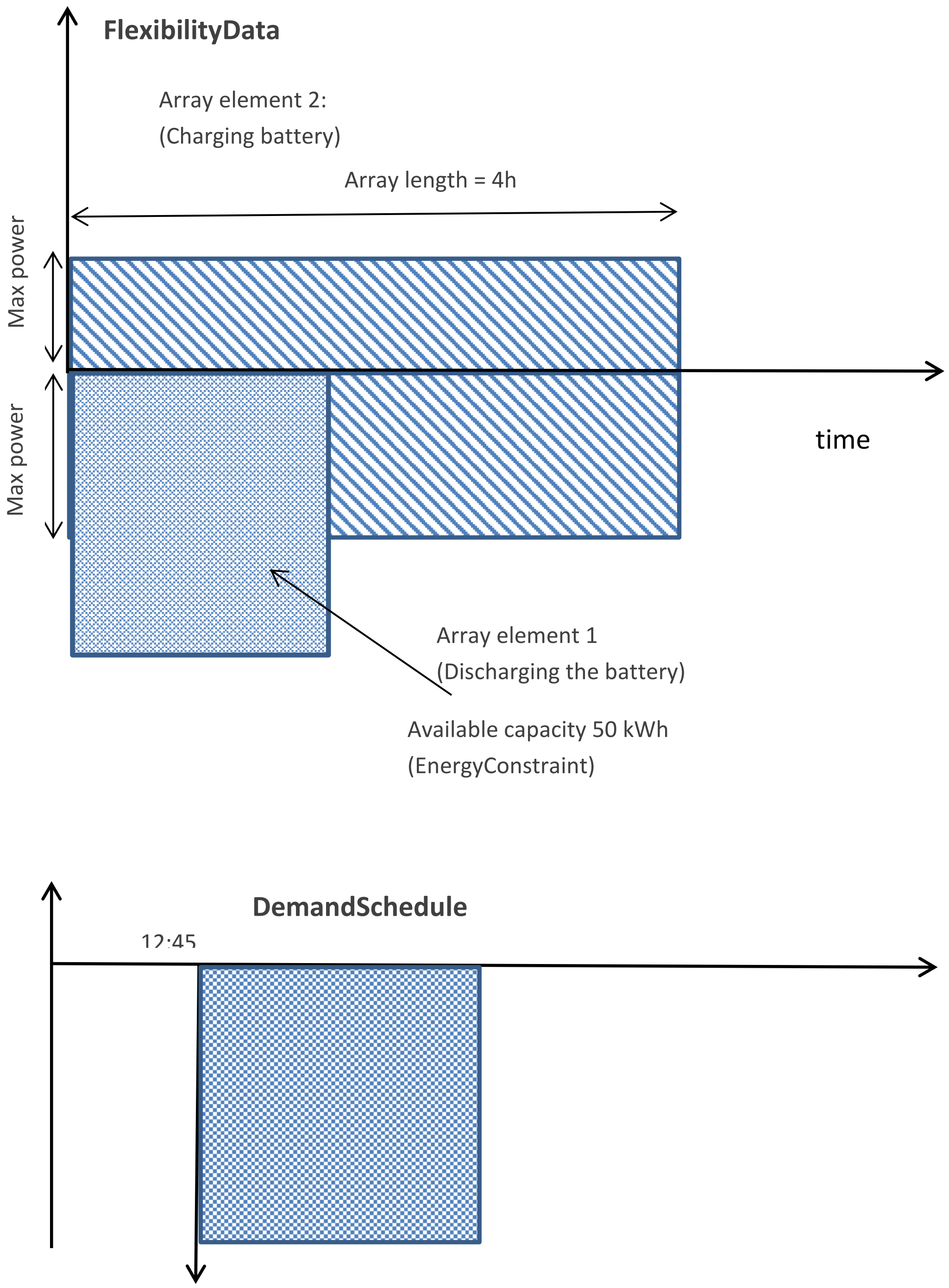

Figure 14: Battery example

Heat pump (HEMS)

Scenario: Heat pump in operation may be switched off for a couple of hours preserving the destination temperature within acceptable limits.

Initial status: Heat pump is in operation with the consumption power = 12 kW.

12:20: xEMS sends regular update of the OperationData

- OperationState = available

- OperationPower = (12:15, -23.7 kW) (background consumption and consumption of the heat pump)
- OperationPrognoses

Start at	Power
12:30	-25kW
14:00	-22kW

12:20: The xEMS forms the following FlexibilityData

- Element 1 of the Array of flexibilities:
  - PriorityLevel: 1
  - AdaptationCapacity:

Id	Length	Min power	Max power
1	900sec	+12kW	+12kW
2	900sec	+12kW	+12kW
	…		
8	900sec	+12kW	+12kW

  - Min Adaptation Time = 15 min.

12:50: The FOA sends the following demand schedule

- AcceptedPriority: 1
- ScheduleChange:

	Length	Power
1	900	12 kW
2	900	12 kW
3	900	12 kW

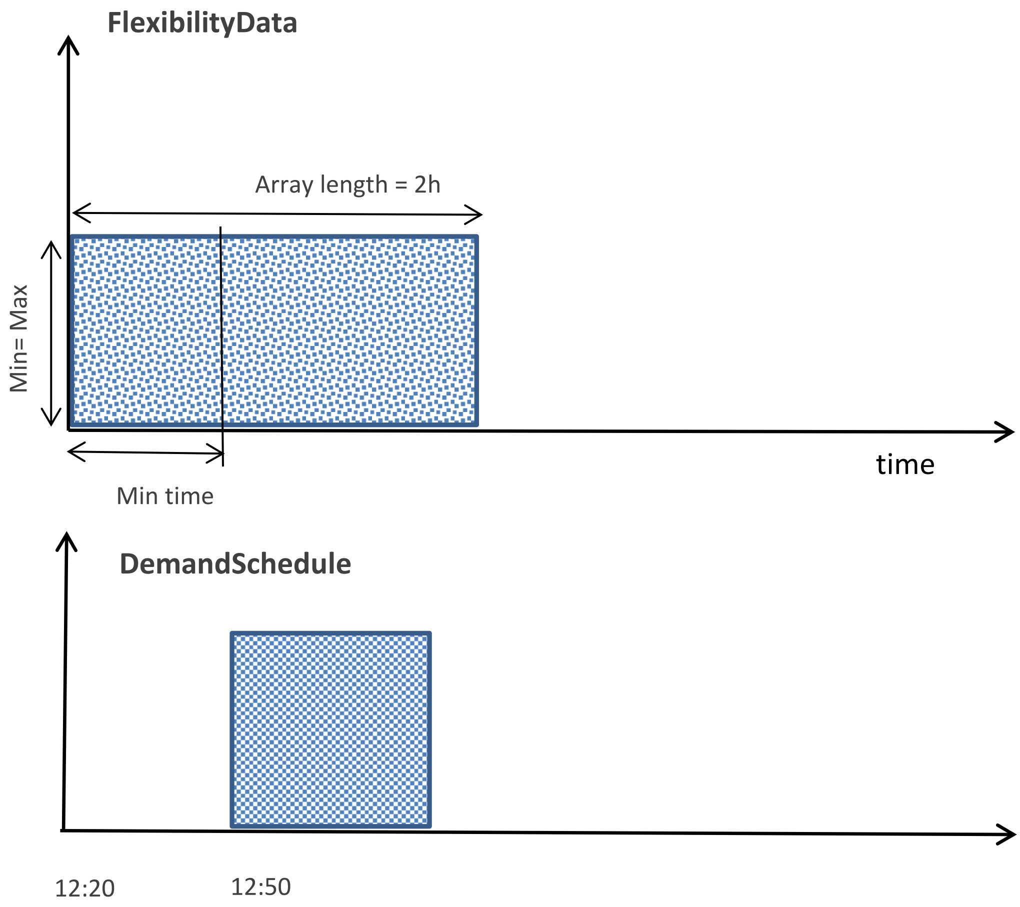

Figure 15: Heat pump example

5.6 FEMS Modbus exchange

The FEMS will use the MODBUS TCP protocol to communicate with the FOA, therefore FOA will need a dedicated Modbus TCP driver to convert HTTP textual messages into the byte coded information understandable to FEMS.

FOA's driver acts as a Modbus master and FEMS has the role of the Modbus slave. The communication is initiated by the master. The FEMS response contain the information for FOA in the binary form.

The message is sent periodically with the period [INTERVAL 1], which needs to be small as possible to achieve fast regular updates from FEMS.

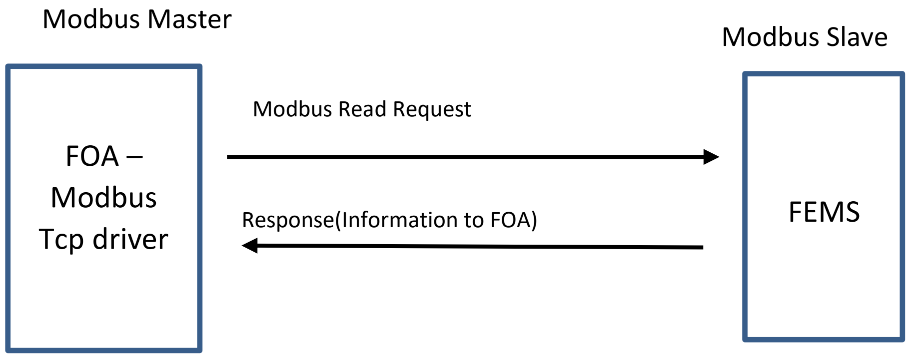

Figure 16: Information from FEMS to FOA

When the FOA needs to send information to FEMS the Modbus Message write message is used.

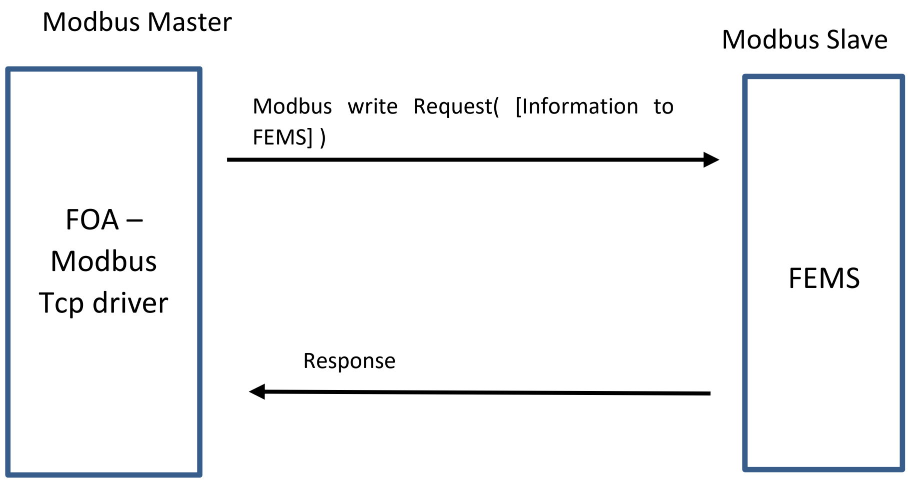

Figure 17: Information from FOA to FEMS

6 Non-functional requirements

Table 9: Non-functional requirements

Requirement Number	Requirement Description
NF3.1	Prosumers relevant for xEMS implementation: loads and devices, that have shifting capacities and control capabilities
NF3.2	Reliability: all xEMS systems should provide reliable operation and automatic recovery in case of errors
NF3.3	Extensibility: xEMS systems should be able to addres all relevant equipment found at prosumers
NF3.4	Interoperability: xEMS systems should be able to communicate with different systems, such as SCADA, PLCs, smart appliances, etc.
NF3.5	Ease of use: xEMS systems are installed at prosumers. Interaction with those systems should be simple and effective in order to achieve sufficient adoption.
NF3.6	Security: each xEMS system should provide security measures, which allow prosumers protection of their private data.

Additionally to functionalities and data, WP3 especially requires relevant prosumers to install xEMS systems. GOFLEX defines numbers and processes / devices / loads needed for efficient demonstration.

Selected prosumers should:

- Have appropriate loads, generation and adaptation capabilities
- Be willing to participate in GOFLEX demonstration
- Be willing to install and support installation of xEMS systems
- Appoint responsible person for operation
- Provide a detailed description and technical specifications of their loads, devices and other systems, to be included into GOFLEX demonstration.

WP3 provides in this chapter some additional info on capturing specific energy reservoirs in different prosumers. It shall be used as a guied on prosumer selection and acquisition.

6.1 Energy reservoirs in FEMS

In the industrial sector there are numerous types of loads suitable for inclusion in the demand response system which adaptation capability is based on the capacity storage (thermal capacity, material storage, …) or internal production (cogeneration units, steam generators, back up diesel generators, …). The first priority at integration of the loads into the demand response processes is minimal impact on the prosumer's production process, therefore the load control must be precisely adapted to the specific of the industrial production process. The next chapter describes some approaches to include various types of loads.

6.1.1 Load types

The load types described in this chapter are met in various industrial branches like foundries, paper industry, metal production, textile and others. The adaptation capacity depends on the specific of their operation which are taken into account at demand response control algorithm.

6.1.1.1 **Load with keeping stock within limits**

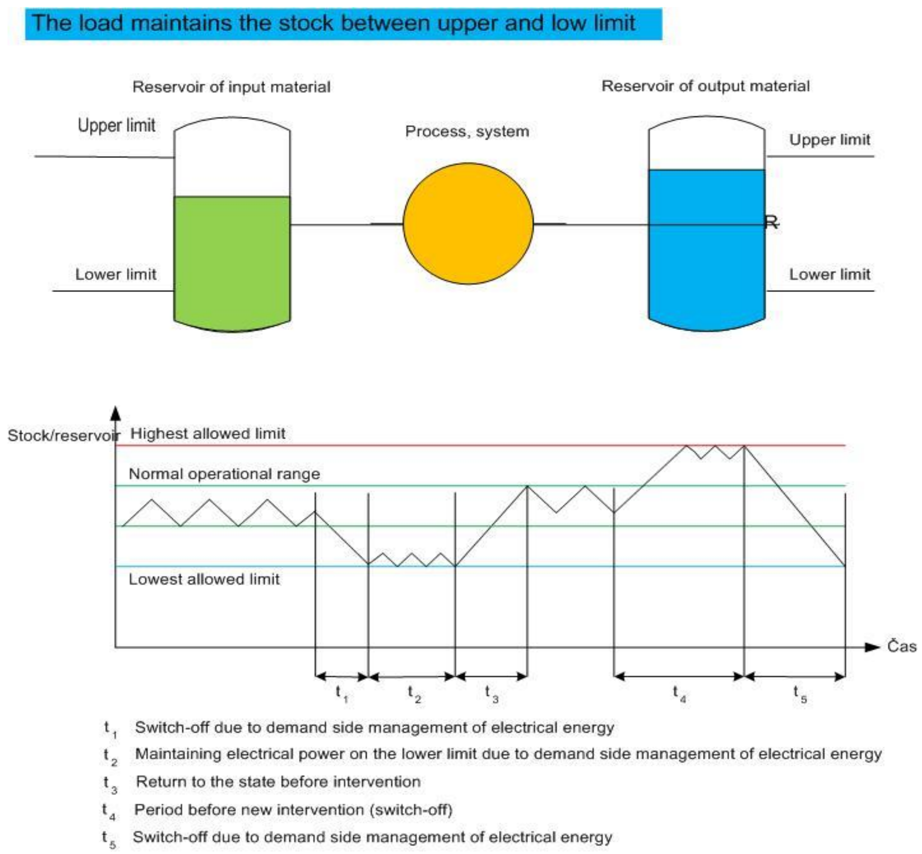

Figure 18: Load type – keeping the stock between limits

This load type is based on the process involving large reservoirs of input and output material. During the intervention the material level is preserved within the limits what does not affect the production process.

The control requires the following parameters

- Maximal intervention time.
- Minimal intervention time.
- On/Off operation ration to keep the required level.

6.1.1.2 On/Off load type

"On/Off" load type operates in one load state. The operation may be either in steady power or variable one. In the second case the power measurement is needed for proper inclusion into the demand response system. The load is ready for the adaptation only when it is in operation. The main control parameter is maximal intervention time.

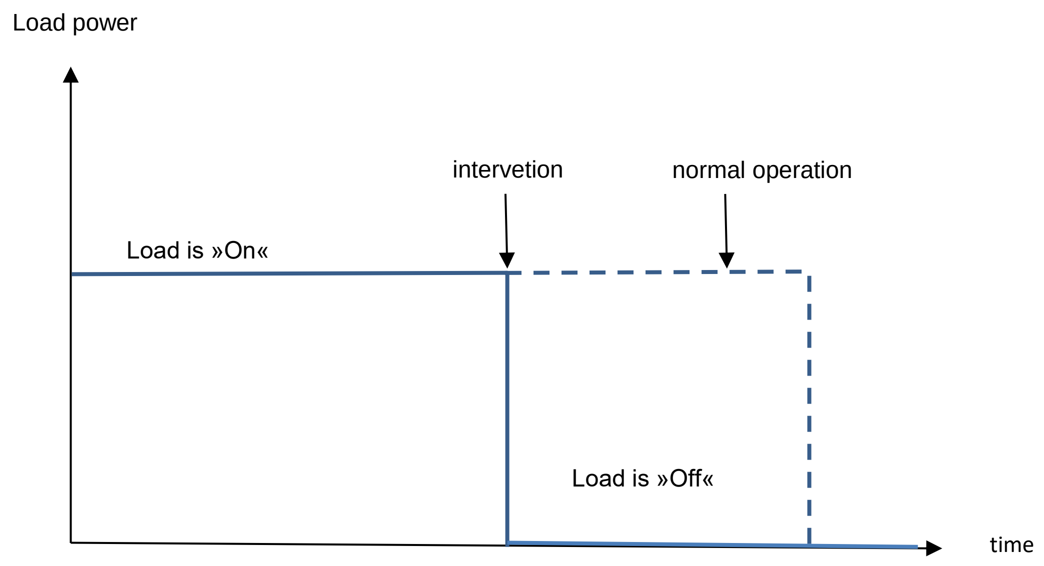

Figure 19: "On/Off" load type operation

6.1.1.3 Load with relief state

Compared to the "On/Off" load the "Load with relief state" requires an additional operation in "relief" mode after it finishes the process operation. Such operation is required due to the operation and technical characteristics of the load or the process it is involved in like

- Frequently turning on and off of the load results operation failures due to the start-up current peaks and material wear.

- The load need a specific time to reach the target operation parameters. Total turn off enlarges the startup time and affects the production performance.

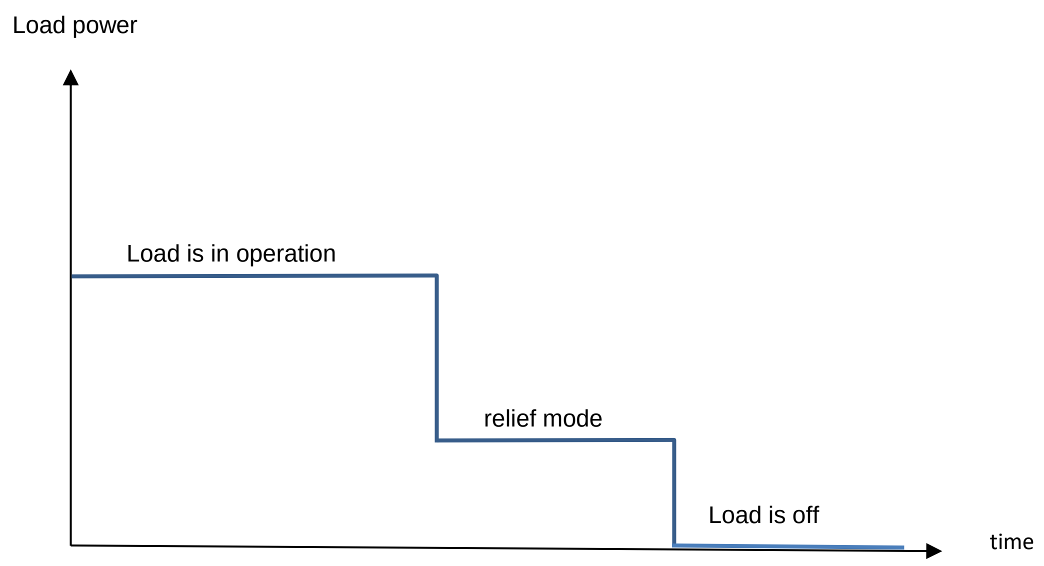

Figure 20: Load with relief mode

6.1.1.4 Multistep load

The multi-step load operates in different states with cascade consumption power. The load intervention may use the operation state change to adapt the consumption according the demand response needs.

The cascade steps are adapted to the load design and construction. The change of operation state due to the intervention depends on the technological procedure of the process. The power change ranges between the actual operation and minimal operation power.

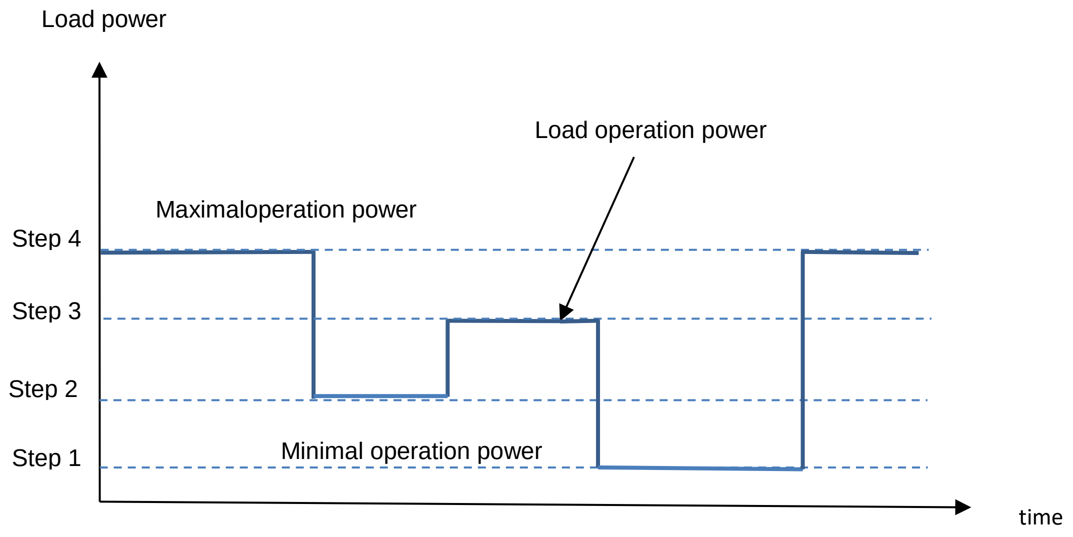

Figure 21: Load with relief mode

6.1.1.5 Adaptation delay load

The load type with the adaptation delay requires a specific time interval to react on the intervention signal and achieve required consumption adaptation. Usually there are two reasons for such behavior

- Specifics of the production process requires a sequence of the operation states to move the process in a proper mode for a discharge.
- Technical design of the load requires gradual power change according to the characteristic power time

The example of the gradual power change load is local power generator, which operation power cannot be changed immediately but must be continuously controlled according to the technical limits.

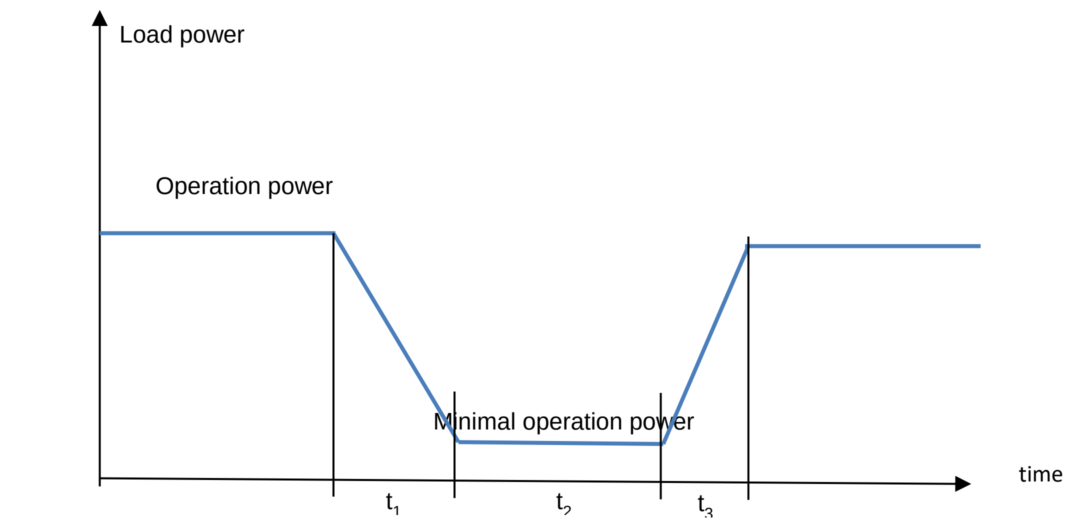

Figure 22: Adaptation delay load operation

Then minimal operation power may be 0. Additional characteristic parameters are duration of power discharge, minimal time of discharge operation, duration of power enlarge.

6.1.1.6 Load with continuous power change

This load type is capable to adapt the consumption to any power within the technological limits. The power change is not limited to the discrete values but may be set to any value between minimal and maximal limit. The main characteristic, which must be taken into the account at control is the power change rate. This one may be different for reduction and enlargement.

An example of the continuous power change load is a steam turbine, which power change capability is defined by the following characteristics

- Steam boiler characteristic limits the change rate of the steam production
- Steam turbine characteristic limits the rate of the electricity power change on the deviations of the steam inflow change.

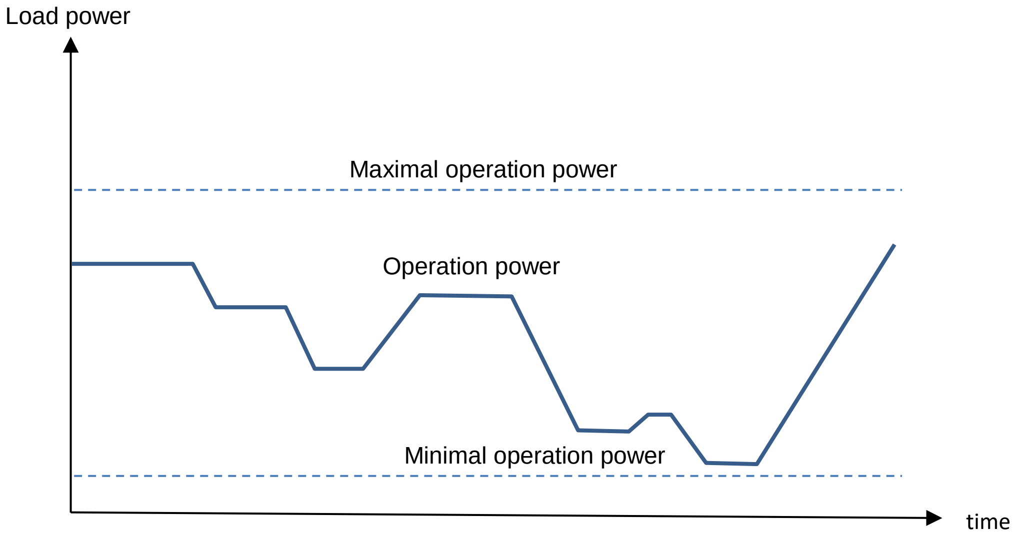

Figure 23: Load with continuous power change

6.1.2 Load control examples

The two concrete examples bellow show the inclusion of the load with the internal capacity and the local energy production load.

6.1.2.1 Induction vacuum melting and casting furnace

A typical vendor of Induction furnaces with several installations is Junker. The input metal material with additives is put into the furnace. The heat for the melting is provided via the induction process, where the input material represents the secondary side of the electricity transformation. The power of the induction furnaces is changed by steps what corresponds to the multistep load type.

The usage of the induction furnaces at intervention is realized by

- Hold operation start
- Slow down the material heating

The first option is actual before the process changes to melting phase, when the operation is delayed for desired time. The second option is realized by charging the load with lower power as at normal process. The power step is adapted to the actual limit of the demand response schedule.

The load is also proper for the enlargement of consumption – the second action is provided with the larger power. All the interventions may be provided automatically. The control may be fine-tuned by additional parameters like minimal intervention time and intervention ratio.

A little bit different is the control of the muffle furnace, which main process is to boil the material within certain temperature limits for the period specified by the technological process. The adaptation may be involved by reduction (or enlargement) of the temperature to the lower (or upper) limit. The temperature is maintained by periodically turning the load on and off. The consequence is a longer interval of the process.

6.1.2.2 **Steam turbine**

A Siemens condensing steam turbine is an example of the load with the continuous power change. It may produce an electricity with up 10MW of active power. The turbine usually provides three consumption points:

- Two unregulated consumption points on 13,5 bar level.
- One regulated consumption point on 3,5 bar level.

Steam turbine power, which value is defined by the consumption of the heat in the production process, may be adapted by regulating the steam flow on the controllable low pressure level.

Part of the steam which is not used by the technological process is directed through the lower pressure level of the turbine where it condensates and part of its energy is transformed into the electricity power. During normal operation the steam flow on low pressure is around 5t/h what in the lower part of the range from 3t/h to 12t/h. That generates around 625kW of electricity power on the lower pressure level only. The flow is usually not enlarged since the process does not need additional steam, while the price electricity production is higher than the one from commercial suppliers.

For the demand response interventions the commercial circumstances are different and adaptations on the steam turbine may become interesting. With the variation of the steam flow one can achieve the change more than 2MW of electricity power in the form of 1.5MW for enlargement and 0.5MW for reduction of the production.

At calculation of the adaptation capacity the control must take into the account the measurement of the steam on the lower pressure level and compare it to the limit values

The control may be implemented automatically. In practice many steam turbine installation come with 24/7 person control in the control room, which may take over the responsibility over the demand response service.

6.2 Energy reservoirs in HEMS

6.2.1 Consumption profile

The first step to improve efficiency of building management system is to construct the consumption profile. It is enough to base home energy management on power flow measurements at grid connection point for simple management application. For implementation of comprehensive management application, additional measured quantities should be taken into account in order to express the consumption cycle and profile patterns. The knowledge about the patterns together with user defined temporal and hardware limitations represent the input for load management in order to identify the load shifting possibilities within HEMS and to support the generation of flex offer based on planning. Planning denotes seeking for the optimized operation schedule of all flexible devices within HEMS with respect to certain criteria and consumption plans of those devices.

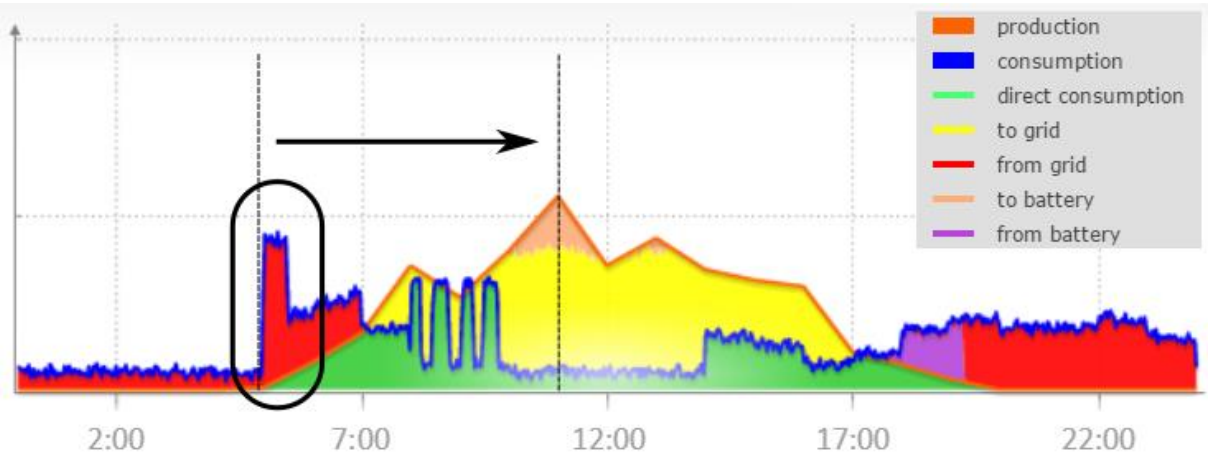

Figure 24: An example of an electric water heater consumption pattern within HEMS.

Figure 24 shows the consumption pattern of electric water heater consumption pattern that is regulated directly with an integrated thermostat. After the drop of water temperature below minimum required temperature, an electric heater starts heating water and consuming electrical energy (pattern within black circle in Figure 24). As indicated with black arrow, HEMS seeks for the better temporal location of electric water heater operation, taking into account the constraints (user-defined, price, device specific, other). In special cases where production/consumption is affected by the weather conditions (i.e. solar radiation), the weather forecast (available on the Cloud service platform) should be taken into account for planning. Besides maximizing self-consumption, weather forecast enables the prediction of several operating parameters of some depicted device within HEMS, an example being heat pump coefficient of performance (COP) that depends heavily of weather conditions, such as outdoor temperature. Taking into account the weather forecast also COP dynamics can be predicted with higher confidence and planning can therefore be more effective.

Figures 25 and 26 showa an example of electric water heater operation without and with HEMS respectively. If there is no planning and management, water heater performs ON/OFF heating regulation with hysteresis between min temp and max temp. On the other hand, with management, HEMS chooses an appropriate time slot and delegates the operation of water heater according to predefined criteria, such as energy price, cycle length and/or user-defined constraints. In Figure 27, HEMS does not respect hysteresis, but delays the heater operation to the latest possible time (marked with "t´" in figure Figure 27) within Flex offer, that is required to generate enough hot water for next predicted hot water consumption.

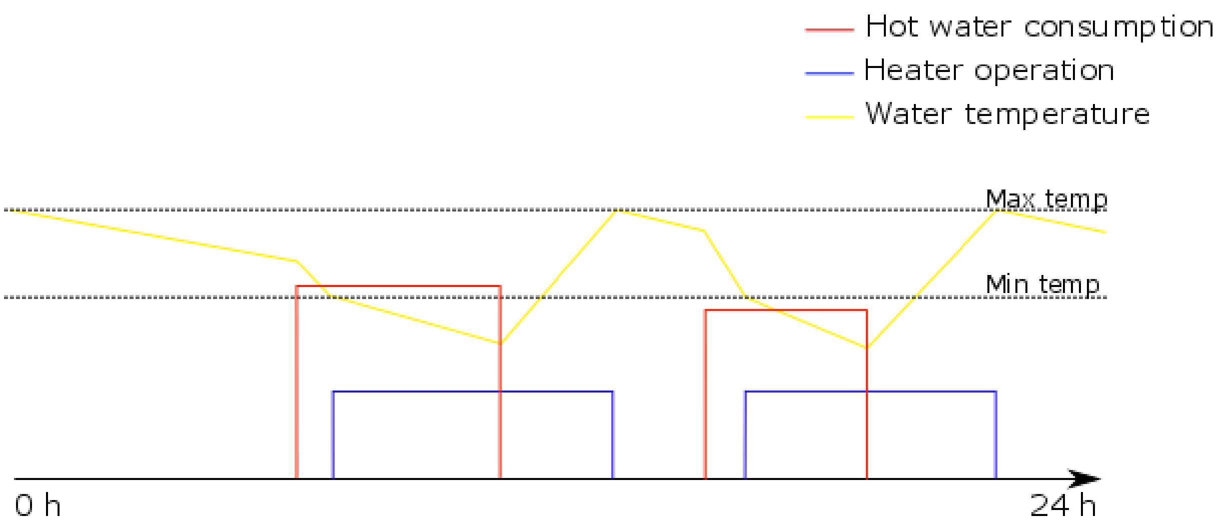

Figure 25: Electrical water heater operation - normal operation

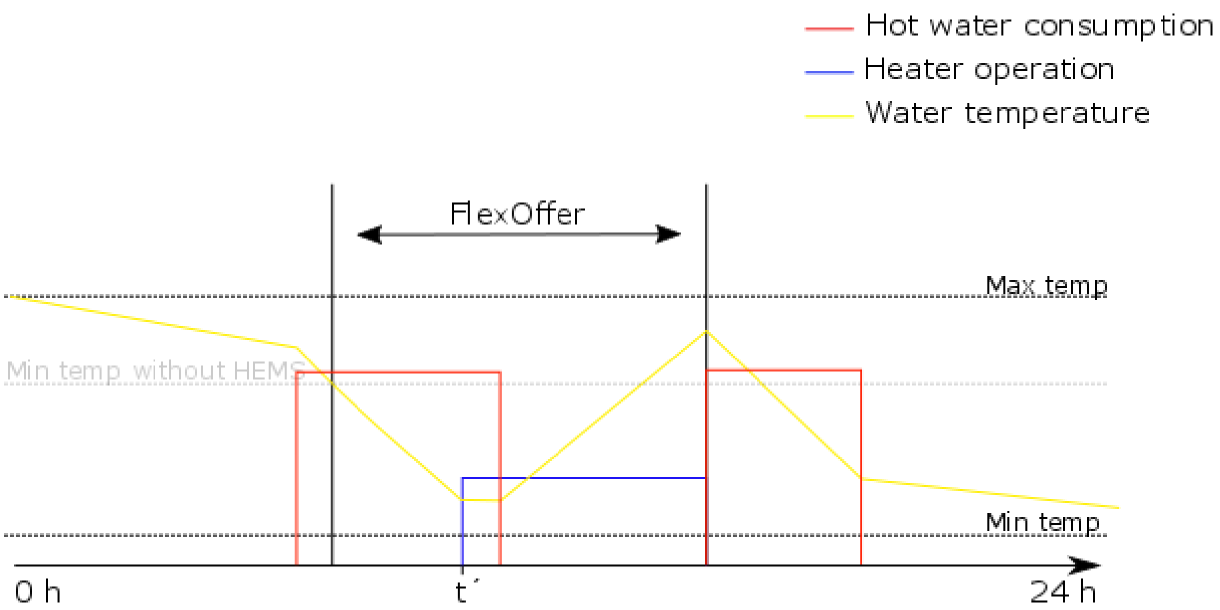

Figure 26: Electrical water heater operation - with HEMS

6.2.2 Device models

Each device model contains a combination of the following data and parameters:

- **General info**: includes general info about the device, such as the producer name, device model, version, support contact, web page address, etc.
- **Instance info**: Includes specific information about the installed device, an example being: location info, and other parameters, that are set during the installation process.
- **Nominal parameters**: Includes nominal parameters, the specification of the producer: nominal capacity, installed peak power, max charging current, etc.
- **Sensors and states**: Include sensors and device states with the corresponding values, i.e.: operation status/mode, state of charge. That group presents an interface to read the dynamic data.
- **Control parameters**: Include control parameters to be passed to device as a set/point or control command, such as charging set-point, heat-pump operation mode, tank hot-water temperature set-point, pause cycle enabled...

Only relevant data and parameters for depicted device model are given. For example: when a device represents a general sensor without control ability, such device does not include control parameters.

According to (electric) energy-management perspective, a device can represent one of the following characteristic:

- **Source or producer** (i.e.: PV power plant, wind power plant) -representing the device, that is able to generate and transmit electric energy.

- **Sink or consumer or load** (i.e.: heat pump, power plug - socket, electric appliance - such as oven, lights) - representing the device, that is able to generate and transmit electric energy.
- **Storage** (i.e.: battery)

6.2.3 User constraints for load management

Active user can help to improve HEMS operation and even increase his role in energy trading exchange. Proper parameters sets assure that all tasks are done in time and with maximal cost reduction. Any current and planned activity will be listed in HEMS graphical user interface (GUI) so that user is always informed with loads' statuses. Users will have the remote access to HEMS GUI through WEB browser so that any change in their daily plan can be remotely updated.

Being aware of the device statuses and changing user-defined constraints enables the user continuously fine tuning and improving the performance of management application of HEMS as a whole and to improve the optimal operation of depicted device within HEMS.

Figure 27 shows an example of load management table. In first row are listed types of controlled devices ("washing machine", "clothes dryer", "electrical heater"). In second row user select between "auto" and "manual" mode ("sun" – auto, "hand" - manual). In "auto" mode HEMS execute task in period calculated from optimization algorithm and user time preference to completed task (third row in figure 27). In "manual" mode has individual task highest priority and is executed immediately. Current task status is shown in fourth row ("play" – in progress, "M" – manual mode, "OK" – task completed). In fifth row are listed estimated operation times to completed separate task.

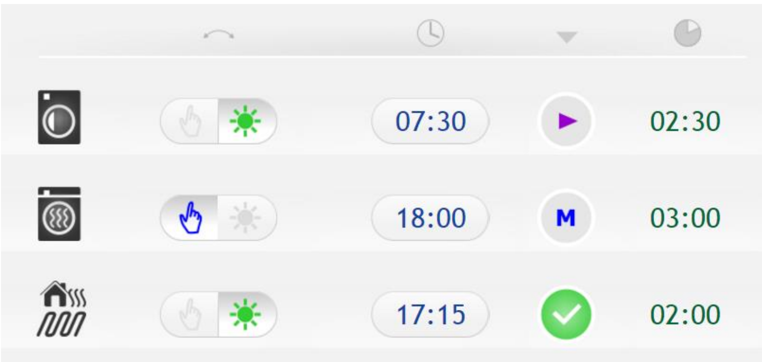

Figure 27: Example of load management table (user view)

6.3 Energy reservoirs in CEMS

6.3.1 General observations

The battery of an electric vehicle (EV) represents an energy reservoir, which can be used for the needs of various actors such as prosumers, (distribution or transmission) system operators, balance responsible parties, or aggregators.

In general, the term “reservoir” means an appliance that can be “filled” with energy, and the energy stored in the reservoir can be “withdrawn from the reservoir” at any time. To enable such operation, the reservoir shall have the capability to be charged (to receive the energy from an external system) and discharged (to return the energy to the same external system). EV charging systems (either on-board, installed in the EV, or off-board, installed outside of EV) currently available on the market do not allow for discharging functionality. A “quasi” discharging functionality of EV charging system can be achieved only when a battery with discharging capability is attached to the EV charging system (and treated as a part of it), as described in Section 7.4.

However, the EV batteries allows the external actor to fill it with different power during the entire charging process. The only preconditions for such operation are:

- the achievable (maximum) charging power is higher than the average one. The average charging power (P_{avg}) is a continuous power that allows for delivery of energy, required by the EV user (W_{tot}), during the time available for charging (t_{tot});
- the minimum allowed or reachable charging power is lower than the average one.

Figure 28 represents three basic scenarios of EV charging (average, forced and postponed) under the following conditions: required energy = 10 kWh; time available for charging = 2 h; maximum charging power = 10 kW; minimum charging power = 0 kW):

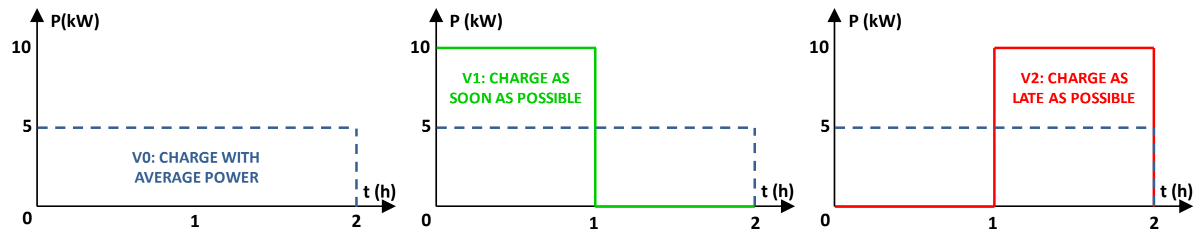

Figure 28: Average (left), forced (middle), and postponed (right) charging

6.3.2 EV battery as a virtual reservoir

If charging with average power (P_{avg}) is considered as a normal (planned) operation, the deviations of charging power (and of delivered energy) from this plan represent, from point of view of an external actor, charging or discharging of a virtual reservoir located in the EV and made available for exploitation of external actor. Under this assumption, the charging of EV battery with a power higher than the average one represents filling the reservoir with energy while charging with a power lower than the average one represents emptying the reservoir. The duration and power of filling and emptying the virtual reservoir are presented in Figure 29 (left – forced charging, middle – postponed charging), where the "+" sign represents filling the reservoir and the "-" sign its emptying.

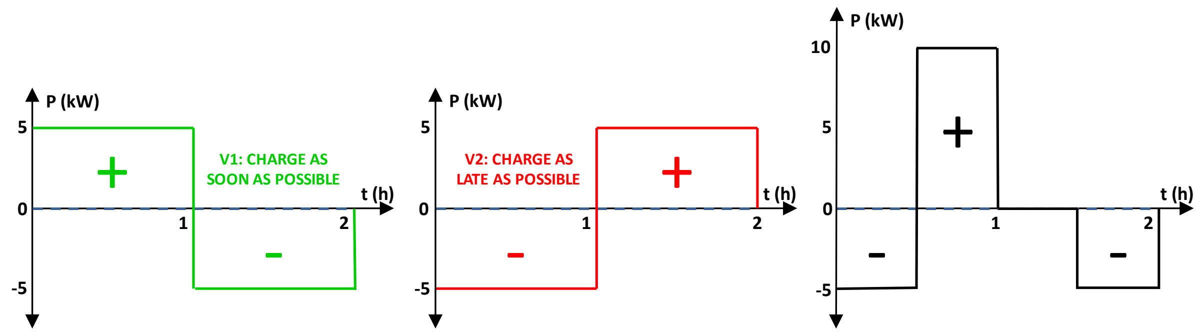

Figure 29: Filling and emptying the reservoir at forced (left), postponed (middle) and mixed (right) charging

In practice, it is not necessary that all "+" periods are concentrated at the beginning of charging (forced charging), or at its end (postponed charging), and that the batteries are charged either with maximum or minimum power. The only precondition in planning the charging session is that the "+" labelled surfaces equal the "-" labelled ones, meaning that the state of the reservoir at the end of time available of charging equals 0 (and consequently the required amount of energy is delivered to the batteries). The charging diagram of filling and emptying the reservoir can be further made more complex if the maximum charging power is increased as shown in Figure 29 (right), where the maximum charging power equals 15 kW (10 kW above the average power) and the charging power per 30 minutes periods equals 0-15-5-0 kW.

6.3.3 Technical characteristics of virtual reservoir

A virtual reservoir can be described by the maximum amount of energy that can be stored in the reservoir and the maximum power of its filling and emptying. The physical values that limit these characteristics are:

- W_{tot}: amount of energy to be delivered to EV battery;
- T_{tot}: time available for charging;
- P_{max}: maximum power that can be delivered to EV batteries. It is limited by minimum of rated powers of components that form the EV battery

charging system (battery charger, charging cable, charge point equipment) and of available power for charging (conditioned by rated power of grid connection point, of cable that supplies the charge point and of consumption of other consumers that are fed via the same grid connection point);

- P_{min}: minimum power that can be delivered to EV batteries. In general, the minimum charging power equals 0 kW (EV batteries not charging). Some charging infrastructure operators control the charge points in the way that every connected EV is charged with at least minimum current (6 A according to IEC 61851 standard, representing 1,4 kW at single phase, and 4,1 at three phase charging).

Maximum power of reservoir filling:

$$\mathbf{P_+} = P_{max} - P_{avg} = \mathbf{P_{max} - (W_{tot} / t_{tot})}$$

Maximum power of reservoir emptying:

$$\mathbf{P_-} = P_{avg} - P_{min} = \mathbf{(W_{tot} / t_{tot}) - P_{min}}$$

Maximum amount of energy that can be stored in the reservoir:

$$\mathbf{W_+ = W_- = t_{tot} * (P_+ * P_-) / (P_+ + P_-)}$$

The theoretical maximum capacity of a reservoir is reached if the maximum power of reservoir filling equals the maximum power of reservoir emptying ($P_+ = P_-$), meaning that the average power P_{avg} is just in the middle between P_{max} and P_{min}. In this case the maximum capacity reaches W_+ (or W_-) = $t_{tot} * P_+ / 2$.

During a charging session, only one of both values (W_+ or W_-) can be reached, and under additional condition that forced or postponed charging scenario, as described in section 6.3.1, is applied:

- forced charging: charging with P_{max} from the beginning of charging. When the reservoir is “filled” with W_+ the charging power is reduced to P_{min} till the end of time available for charging), or
- postponed charging: charging with P_{min} from the beginning of charging. When the reservoir is “emptied” for W_- the charging power increases to P_{max} till the end of time available for charging.

7 Architectural considerations / assumptions

7.1 Factory EMS – FEMS

FEMS is an industrial-grade system, which is designed for optimization of industrial processes in factories and similar entities. Its main characteristics are:

- Robust design, industrial-grade components
- Powerful equipment
- Several levels of hierarchy
- Interfaces between a large number of different systems and devices
- Higher price, but longer time between upgrades/replacements

Figure 30: Example of FEMS control cabinet

FEMS addresses all types of industrial and other loads and production units, which are capable of changing their operation schedule. We call such loads energy reservoirs, since they contain virtual energy storage. Using (sophisticated) FEMS, we can utilize this storage and use it to trade with the higher-level system.

Table 10: FEMS load examples

Load	Nominal power (kW)	Average effective power (%)	Allowed “off” state (%)	Available power decrease (kW)
Melting furnace, Junker	6300	70%	50%	2205

Heat boiler, HVAC, ventilation	70	60%	60%	25
Foundry furnace, P&G furnace	330	60%	20%	40
Drying furnace	240	60%	12%	17
Hardening furnace	43	60%	50%	13
Arc furnace	4000	80%	25%	800
Arc furnace Demag	2000	70%	25%	350
Furnace Junker	2000	70%	25%	350
Induktoterm furnace	2000	70%	25%	350
Foundry machine	230	60%	25%	35
Asea furnace	2500	50%	25%	315
Steam turbine	12000	Production dependant	/	±2000
Vibration equipment	85	50%	50%	21
Pressure and welding equipment	368	40%	40%	58
Extruders	50	80%	8%	3
Furnaces	168	70%	33%	39
Mills	45	50%	66%	15
Cooling aggregate	60	50%	33%	10
Drying furnaces	480	33%	50%	80
HVAC	436	70%	50%	153
Pressure machines	2960	20%	50%	296
HVAC	831	70%	50%	290
Battery charger, Ventilation	250	70%	50%	87
Gas/Diesel aggregate	900			900
Mixers	7910	70%	25%	1384
Various machines	132	70%	25%	23
Various machines	659	70%	0%	0
Pumps, HVAC	148	70%	50%	51
Various machines	311	70%	50%	108
Transport and Mills	97	70%	40%	27
Drying and Transport equipment	104	70%	33%	24
HVAC, Boilers, Pumps	844	70%	33%	196
Drying & winder machine	126	70%	33%	29
HVAC, Pumps	65	70%	50%	23
Boilers	36	25%	100%	9
Various machines	263	60%	50%	79
Various machines	168	50%	33%	28
Pressure equipment	180	25%	50%	22
Foundry furnace	40	60%	8%	2
Various machines	169	60%	50%	51
Various machines	266	70%	33%	62
Boilers	54	25%	100%	13
Compressors	70	50%	33%	12
Mills	100	60%	50%	30
Electrolysers	5200	100%	10%	520
Arc furnace	32000	70%	15%	3360

Ladle furnace	8700	60%	15%	780
Steam turbine with generator	6400	80%	±10%	±510
Steam turbine with generator	16500	75%	±10%	±1250
Grinders	11200	60%	10%	672
Cutting machines	560	60%	33%	112
Blowers	132	70%	33%	30
Arc furnace	15000	70%	15%	1575
Various furnaces	570	70%	25%	99

INEA FEMS consists of the following components:

- Main control and analytics server – can be cloud-based, locally installed (IT server) or supplied within main control cabinet (industrial computer). Inea provides own software, combined with worldwide leading technologies. Server includes the following functionalities:
  - Data acquisition and storage
  - Custom analyses, reports
  - KPI's, comparisons, goal-seek
  - Customizable dashboards, live view of the processes
  - Easy to use web interface
  - Control and parametrization of FEMS subsystems

Figure 31: Example historical view on FEMS WEB interface

- Main control cabinet – contains process equipment, such as PLCs, IO cards, electricity meters, communication equipment. Communication between PLC and main server is standardized and uses modern TCP-based protocols.
- Remote control units – FEMS uses hierarchically nested architecture, which simplifies integration as well as optimizes costs. Each remote control unit is connected to main control cabinet using communication protocols.

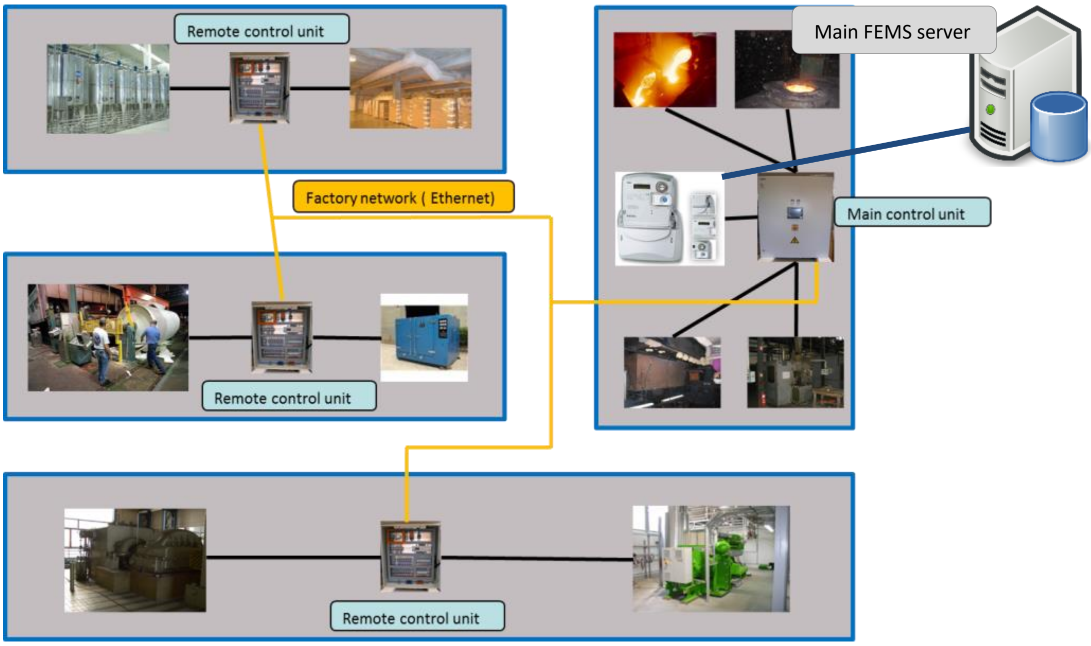

Figure 32: FEMS architecture

Communication protocols between FEMS and loads/processes/devices

INEA FEMS offers several communication options for controlling the loads. System integrator gets access to remote control unit PLC, which allows him to adapt signals for control. Generally, FEMS offers these options:

- IO control – each device is connected to predefined Input/Output signals on PLC.
- Smart control – PLC offers ModbusRTU communication protocol for devices with some local control capabilities. System integrator has to configure correct registers and content, which is device specific.

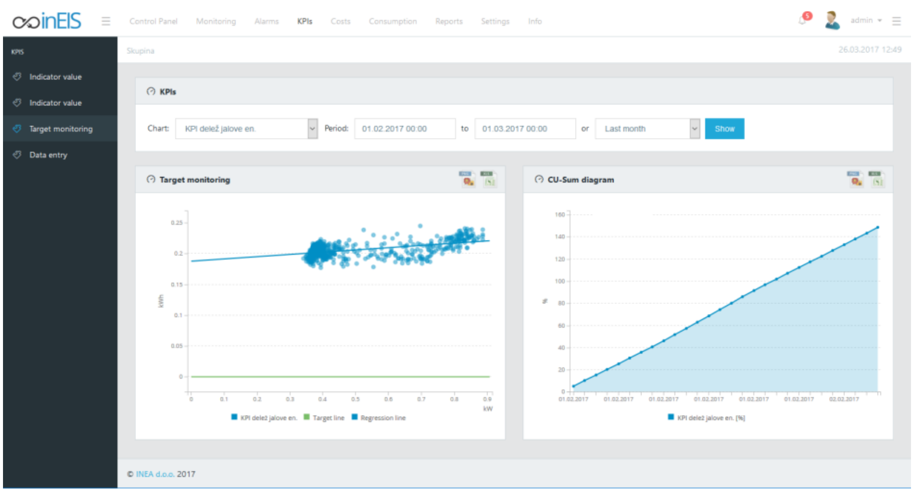

Figure 33: Regression and goal function of FEMS

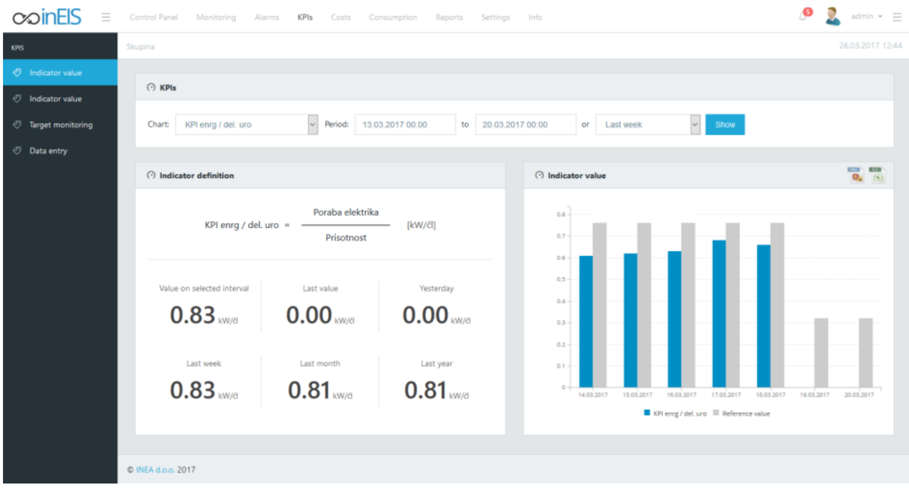

Figure 34: KPI View on FEMS system

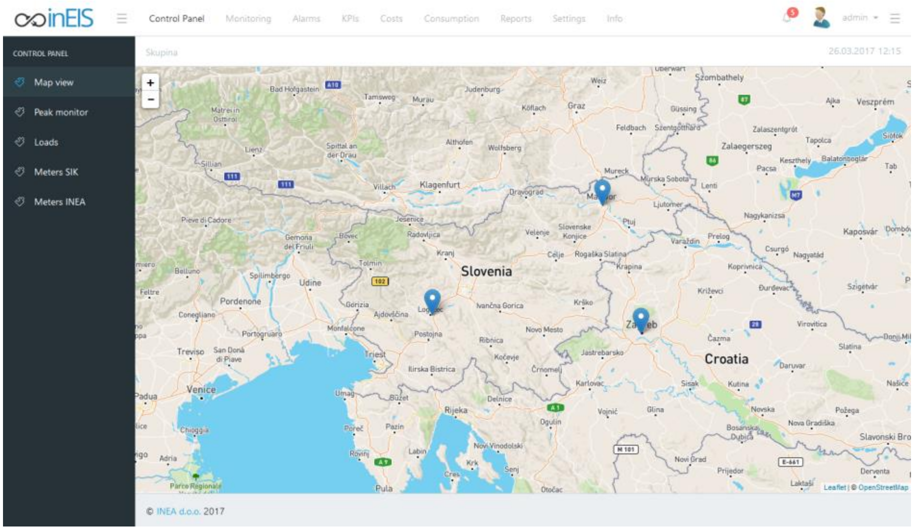

Figure 35: Map overview of distributed FEMS

7.2 Home EMS – HEMS

Home energy management system is fully integrated and adaptive system that transform regular home from passive consumer to pro-active consumer. When HEMS decides and shifts load to some other time, it pro-actively cooperates in energy management. Linked to various devices and equipment, such as electric power meters, sensors and others, HEMS has the priority to use detailed information and environmental measurements about generated and consumed electrical energy, which allow HEMS to delegate the operation periods of devices in terms of energy efficiency, cost efficiency or user comfort efficiency. A device should respect one of the following classifications according to its energy properties: source, sink, or storage.

The basic HEMS kit consists of:

- Intuitive WEB graphical user interface (Figure 36) allows the user to i) configure household devices, operating schedules and trading configuration and ii) to follow the current operational parameters and energy flows and other operational indicators.

Figure 36: Intuitive WEB graphical user interface.

- HEMS connected to electric power meter measuring the energy generated by solar power plant (Figure 37). Optionally - HEMS can exploit the data and information from solar inverter directly.

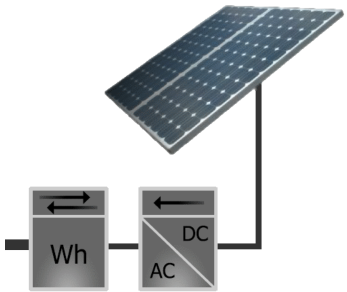

Figure 37: HEMS connected to electric power meter.

- HEMS connected to bidirectional electrical power meter measuring the energy that was bought from and sell to the grid.

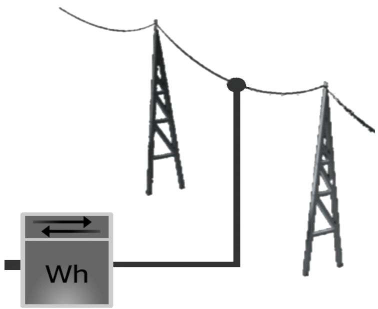

Figure 38: Bidirectional elektric power meter.

- HEMS system is deployed on the top of control system with preinstalled application software, device drivers and connections. It communicates with HEMS devices and coordinates their operation (Figure 39).

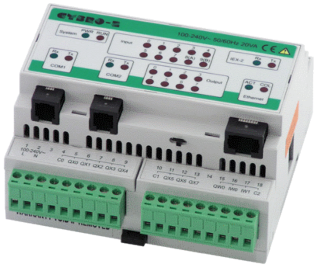

Figure 39: Home control system.

- Specially designed switch (Figure 40) to be installed at the appliance enables triggering the operation mode (MANUAL, AUTO) of each appliance and provide status feedback information (STAND-BY, IN OPERATION, COMPLETED).

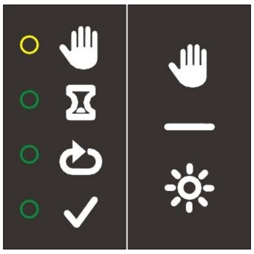

Figure 40: HEMS device switch.

- HEMS controls the battery system (battery and charger with peripherals). It will store the exceeding solar electric energy which cannot be consumed locally. Stored energy can be utilized later, when the price of electricity from the grid is high and there is no electricity production.

7.2.1 Maximizing self-consumption mode

When HEMS besides sinks contain also sources (for example: photovoltaic panels) and storage devices (for example: batteries) then HEMS operation can be divided into two modes:

- Battery as a primary source is shown in Figure 41:
  - This mode is mainly used when the network is stable and reliable.
  - Renewable energy will be primarily feed into grid and stored to battery just when »grid feed limit« will be exceeded – that is, when the generated power is higher than maximum allowed “feed in” power (power to grid).

- Loads are supplied from stored energy as a first priority and from grid only when battery is i) empty or ii) when battery can-not provide enough power as a second priority.
- HEMS will temporally shift significant loads to time periods, when renewable energy is available.

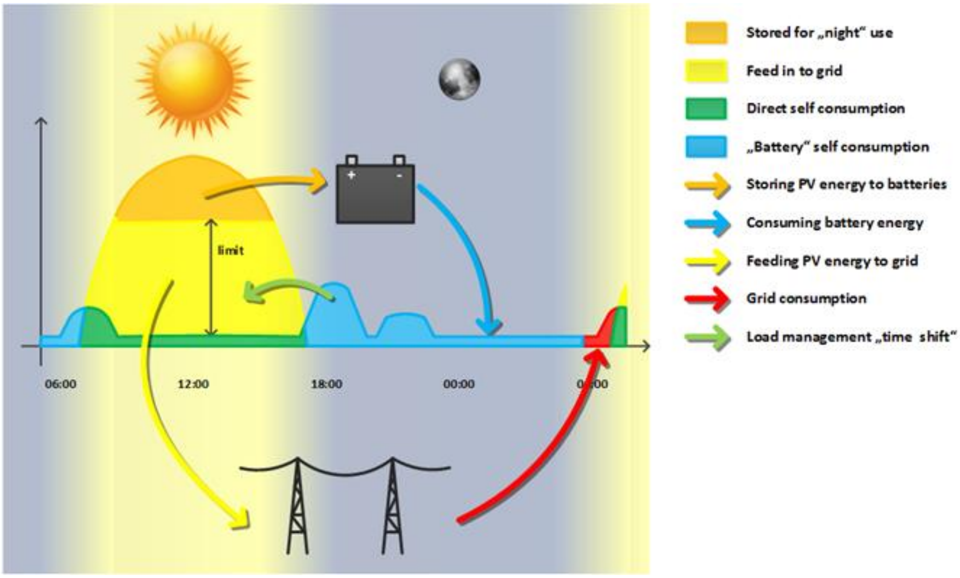

Figure 41: HEMS operation example: battery as primary source.

- Grid as primary source is shown in Figure 42:
  - This mode is mainly used when the network is unstable and un-reliable with the purpose to increase the availability of electrical power supply.
  - Renewable energy will first store to battery and feed into grid just when battery is full.
  - Loads are supplied from grid as first priority and from battery only when there is no grid power as the second priority.
  - HEMS will temporally shift significant loads to be supplied from renewable power directly when battery is full

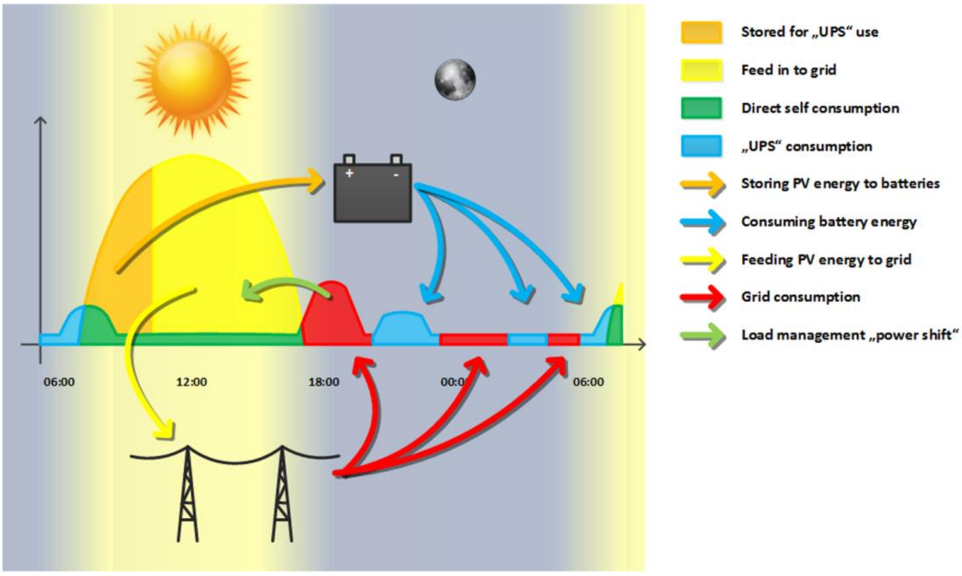

Figure 42: HEMS operation example: grid as primary source.

Loads management in self-consumption mode

Loads wait for the conditions, to begin the operation cycle. There are two conditions to begin the operation cycle of the individual managed load:

- PV energy production threshold: Is there enough energy produced by the PV plant? When the level of production is higher than the demand, the managed load begins the operation cycle. The order of activation is related to the preset start of the cycle in the configuration table.
- Finish time: When is the task required to be finished? HEMS takes care that the individual task is finished at least within the required time specified in the configuration table. The latest time to begin the operation cycle is calculated as the time difference between current time and finish time. When the difference is equal to the cycle time of individual managed load, the load operation cycle begins even if there is not enough energy produced within HEMS. In such circumstances the required energy is taken from grid or battery.

Pause in the operation cycle

The »pause enabled« managed loads will be put on hold when if the electrical production is lower than consumption and the appliance operates longer than the minimum run time setting. Such load will continue the operation cycle when electrical production becomes sufficient again and the minimal pause time is reached.

Finish off the operation cycle

The cycle of individual managed load is finished when the working time exceeds the maximum working time. If the managed load is set for cyclic operation, HEMS will set its status to waiting for conditions to start cycle.

7.2.2 Trading mode

In trading mode the surplus of virtual and produced energy can be sold to third parties. For using this mode selected appliances defined in “Configurator” should be configured accordingly. A configurator is shown in Figure 43.

Appliance

- Description

  Descriptive text of the appliance
- Power demand

  Electric power required for operation of the appliance (in kW)
- Max run time

  The maximum operating time of the appliance (hh:mm, +/-5min)
- Operation type

  Type of household appliance is defined by the nature of its operation:
  - single run
  - After the preset cycle is finished, the state of the appliance changes to 'completed'
  - cycle run
  - After the preset cycle is finished, the state of the appliance changes to 'waiting' and waits for the next start of the cycle

- STOP

  The operation of the household appliance cannot be interrupted
- STOP/RUN

  The operation of the household appliance can be interrupted. The automatic triggering of the appliance is controlled by the following parameters:
  - Min run time (hh:mm, +/-5min)
  - The appliance does not stop automatically before the minimum time of operation runs expires
  - Min pause time (hh:mm, +/-5min)
  - The appliance does not begin automatically before the minimum pause time expires
  - Max pause time (hh:mm, +/-5min)
  - After maximum pause time expires the appliance begins the operation for one cycle.

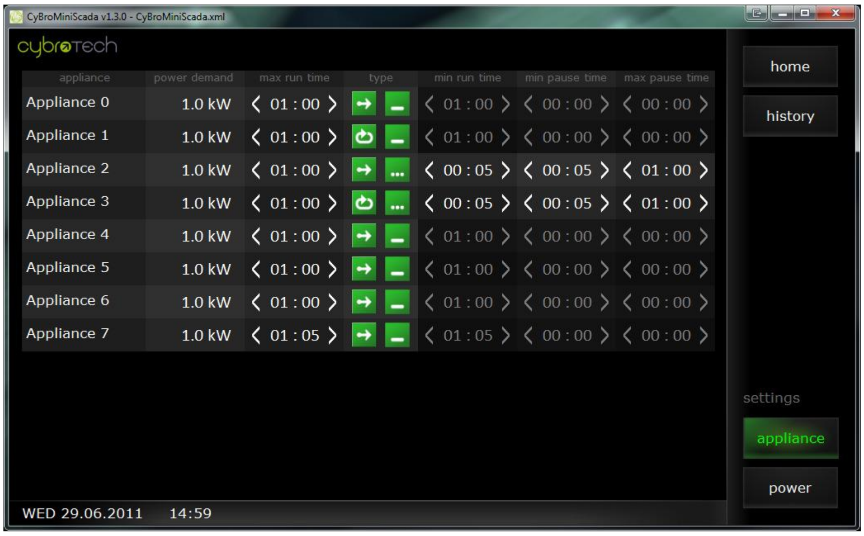

Figure 43: Appliance configurator

7.3 Charging EMS – CEMS

7.3.1 Charge Point Management System

Charging Energy Management System (CEMS) is a part of Charge Point Management System (CPMS) which is used by the Charge Point Operator (CPO) for monitoring, control and management of Electric Vehicle (EV) charging infrastructure. The CPMS consists of the following main modules:

- charge points monitoring and control: acquisition of real-time information about charging sessions (current power, energy delivered) and operation of charging stations (current availability, events, alarms), remote control of charge points (reservations, start/stop charging, unlock connector, load set points, SW reset and update …);
- management of EV user charging authorization: maintenance of local EV users' white lists, communication with external actors for charge point reservation and charging authorization;
- energy management (CEMS): charging infrastructure configuration, acquisition of data about EV user charging preferences and about EV characteristics, calculation of load set points/schedules for individual charging sessions, calculation of load flexibility margins, acquisition of load set points/schedules from external actors;
- billing: billing and tariff configuration supporting multiple pricing schemes and payment options;
- reporting and analysis: overview over charging sessions (energy delivered, parking time, maximum power, charging costs), and over operation of charge points (events, utilization rate, number of charging sessions and energy delivered during selected time frame …);

- asset management and maintenance support: charging station data (locations, equipment installed), work orders (task to be executed, assigned personnel, interventions executed);
- system configuration: charging infrastructure technical characteristics, communication settings within charging system components and towards external actors, assignment of CPMS users' roles and permissions for access to individual functions.

The CPMS can be implemented in two ways:

- as a hosted service in a cloud environment,
- as a licensed SW installed on CPO's servers.

Figure 44: CEMS control system example

The CPMS modules, basic connections between them, and communications to external e-mobility actors (EV user, E-Mobility Service Provider, grid and energy actors) and components (charge points) are shown in the figure below. The modules, actors and communications directly involved in energy management are depicter with red color.

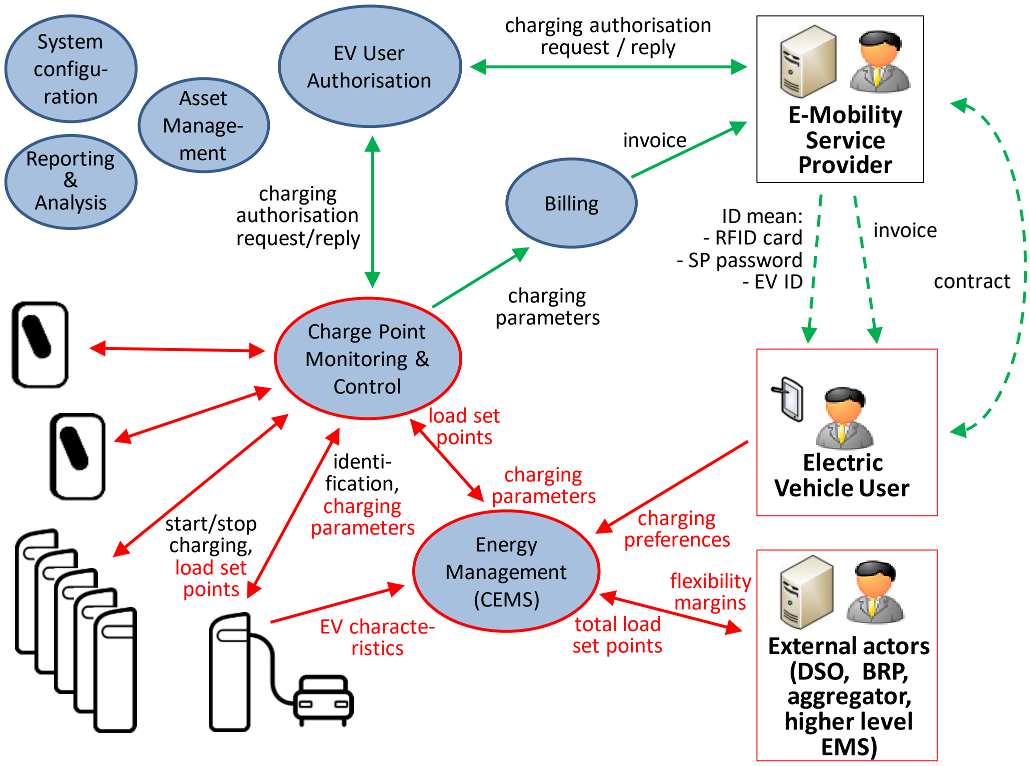

Figure 45: CEMS architecture

7.3.2 Charging Energy Management System

The basic function of Charging Energy Management System (CEMS) is to schedule and control the EV charging load in the way that the user(s) charging preferences (energy to be delivered, time available for charging) are satisfied as far as possible under consideration of external inputs and conditions: technical characteristics of EV(s) and charging infrastructure, and power available for charging.

Figure 46: CEMS GUI example

Despite of the fact that the CPMS (and CEMS) usually manages a large number of charging points erected at different locations, the charging energy management is prosumer oriented: the implemented algorithms consider separately each charging point (or cluster of charging points) installed in the internal network of grid user and fed via the same grid connection point.

The energy management functionality depends on two configuration parameters:

- number of charge points installed in the prosumer's network: in the case at least two charge points (a cluster of charge points) are present, additional algorithms shall be applied for aggregation/disaggregation of charging session data on the prosumer level;
- connection of charge point(s) to public grid: charge point(s) can be connected to the public grid directly, where the grid connection point feeds only the charge point(s), or via the grid user's internal network that comprises also other (controllable) appliances (consumers, or production or storage units). In the latter case the CEMS acts as local control unit subordinated to building's xEMS (HEMS, FEMS).

Combination of these two parameters results in four possible scenarios of charging energy management:

- one single charge point directly connected to public grid: CEMS communicates directly with external actors and executes independently the charging energy management;
- several charge points connected to public grid via the same grid connection point, no other appliances connected to the same internal network: the same as scenario A, additional algorithms are implemented in CEMS for aggregation/disaggregation of charging data from/to several charge points. These algorithms are called "cluster management";
- one single charge point connected to prosumer's internal network: charging station acts as an appliance subordinated to higher level EMS. CEMS is actually represented by the charger itself; some charging energy management functions are executed by higher level EMS;
- several charge points connected to prosumer's internal network: CEMS acts as a remote control unit subordinated to higher level EMS. Cluster management algorithms are implemented in CEMS.

7.3.3 Charging energy management process

The energy management process is executed by CEMS in the following steps:

1. configuration of charging infrastructure: general characteristics of each charge point are inserted into CEMS. In general, these characteristics are: appurtenance to prosumer/grid connection point, grid connection point characteristics (applicable to scenarios A and B), information about charge point(s) supply cable and about interface

to higher control level EMS (applicable to scenario D), rated current of charge point's equipment, wiring of grid phases to charge point phases;
2. acquisition of EV user's charging preferences (energy required, time available for charging) and of EV battery charger's characteristics (number of phases, max/min charging current per phase): the information can be obtained via the EV user's smartphone, or via EV by implementation of ISO/IEC 15118 standard for communication between EV and charging station;
3. determination of power available for charging: in scenarios A and B (one or several charge points directly connected to the grid) the power available for charging is limited by the rated power of grid connection point. In scenario D the power available for charging is communicated to CEMS by higher level EMS;
4. calculation of initial charging schedule(s): CEMS calculates the charging schedules for each charge point (EV) in the way to i) avoid or minimize the violation of EV users' charging preferences;
5. calculation of flexibility margins: CEMS calculates the possible deviations (flexibility margins) from initial charging schedule (aggregated for cluster of charge points if applicable) and communicates the result to higher level EMS (in scenario D) or directly to external actor (in scenarios A and B);
6. acquisition of data about power available for charging: CEMS receives the request for activation of flexibility from higher level EMS or from external actor and reschedules the charging sessions accordingly. If no flexibility activation request is received, the charging loads are controlled according to initial charging schedule(s);
7. CEMS continuously monitors the charging loads: in the case the real load(s) deviate from the scheduled one(s), CEMS reschedules the loads to follow the received flexibility activation request.

7.4 Charging/Discharging EMS – CDEMS

Charging-Discharging energy management system is subordinated to HEMS to actively integrate electric vehicle (EV) as a prosumer in virtual and explicit energy trading.

CDEMS implement communication protocol in order to exchange control and information related data with EV. HEMS can use EV's battery as external battery and extend the storage capacity of HEMS.

CDEMS can either maximize self-consumption or increase trading potential or reduce EV charging costs based on user-selected priorities.

CDEMS can also combine DC photovoltaic system or other generators due to its hybrid design. Such installation contributes to decreasing transformation losses and substantially increase the efficiency of HEMS.

Figure 47: Example of CDEMS (9kWh)

7.4.1 System schematics

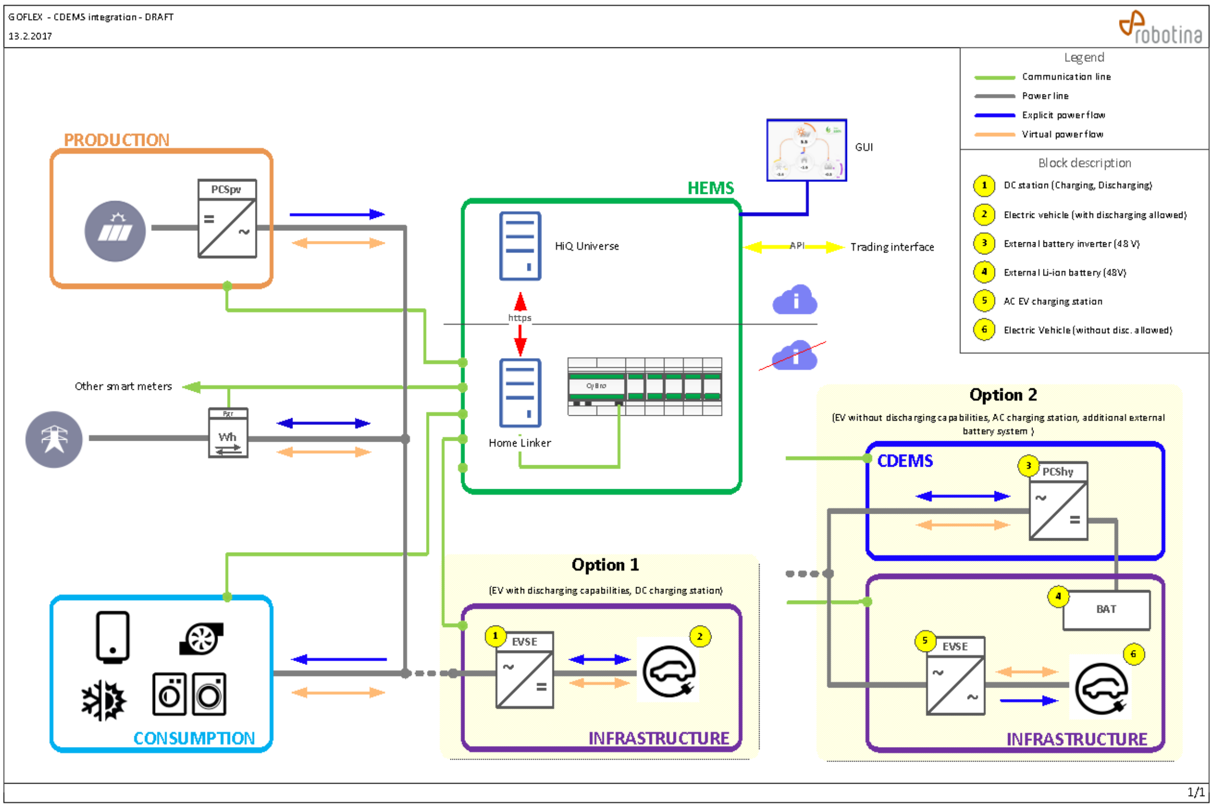

Figure 48: CDEMS architecture

7.4.2 Technical data

Table 11: CDEMS technical specifications

Charging Discharging Management System FEMS	
Grid	
Max Output Power	10 kW
Rated Output Voltage	3N - 400 V
Rated Output Frequency	50 Hz
AC Nominal current	14,5 A/ Phase
Battery	
Structure	Power Cell 19 Ah
Technology	LiFePO4
Cycle life	8.000
Storage capacity	3 kWh - 54 kWh
Photovoltaic	
Max power	14 kW
DC voltage range	320 VDC - 900 VDC
Max current	2 x 18,6 A
String	2

7.5 xEMS – FOA interface architecture

xEMS-FOA protocol is described in the chapter 5.5. It contains data descriptions and required intervals. There are some specifics at each xEMS, which must be separately addressed.

7.5.1 FEMS

Execution part of INEA's FEMS is implemented using Programmable Logical Controller – PLC. Reasoning behind this is mainly because robustness and reliability, but also because of guaranteed response time. PLCs do not offer HTTP protocols, therefore INEA will have to implement translation interface to Modbus TCP, which is described in the chapter 5.6.

Communication between FEMS and FOA is nevertheless the same – IP connection on local Ethernet.

7.5.2 HEMS

Robotina's HEMS consist (at least) of two building blocks: Home linker and cloud-based GUI. We will implement interface to FOA on both levels. Interface will be the same, therefore both Home linker and cloud GUI will have to implement the same functionality.

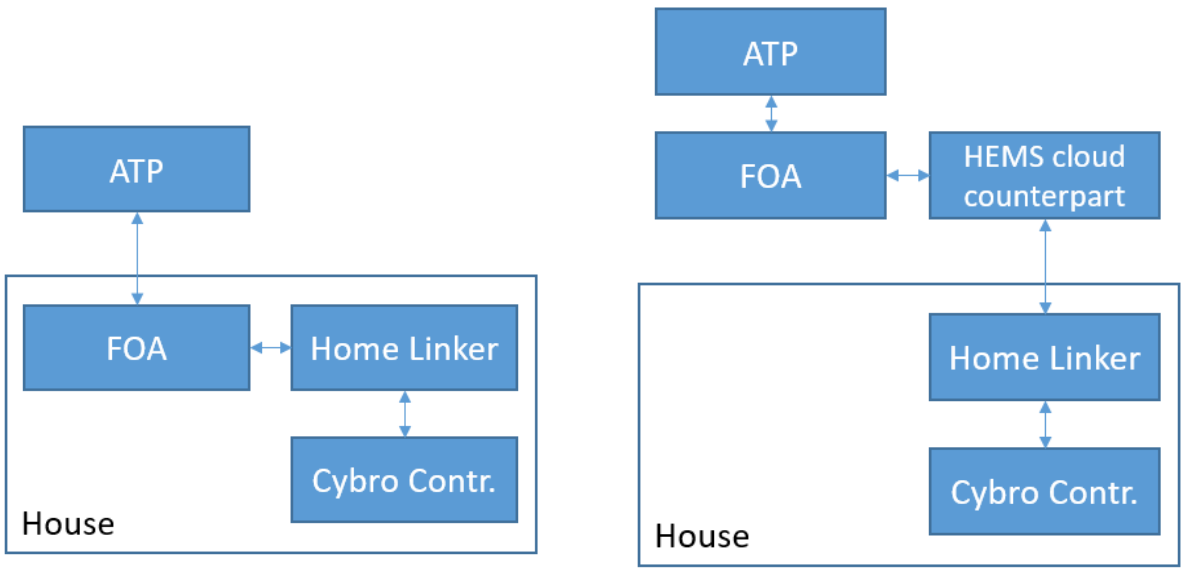

Figure 49: HEMS topology without Robotina cloud (left) and with cloud (right)

In case of interface between FOA and Home Linker, internet connection to ATP (FMAN) is provided by FOA (left). On the right side, internet connection is provided by Home Linker.

7.5.3 CEMS

Connection between charging station(s) and FOA is done via CEMS. CEMS resides on the cloud and uses standard protocols for connection to charging stations. If there will be several charging stations under FEMS or HEMS within the GOFLEX, we will explore the possibility of using

CEMS even in these situations (for local aggregation of consumption and flexibility schedules to be sent to FEMS/HEMS, disaggregation of demand schedules received from FEMS/HEMS, protocol translation and for following physical constraints of charging stations).

7.6 Prosumer topology

WP3 defines prosumer the following way:

- Prosumer = legal entity (pays bills) + connection point (Smart meter).
- Prosumer is at the cross-section between billing and geographical location.
- Each prosumer is equipped with FOA.

If there are several loads (for example charging stations) on same location and under same management (for example parking lot), we can consider this entity as same prosumer with several different loads. Management of those loads is done within xEMS. Example of this would be CEMS, that manages several charging stations on one parking lot.

If prosumers are geographically separated, we consider them separately, even if they can be reached using the same (communication) system or platform.

7.7 Metering data

We assume, that each prosumer will either:

- Be able to provide real-time smart metering data (using metering chain), or
- Be able to install sub-meter(s), according to requirements of each technology provider

Some of the xEMS systems, for example FEMS, may need several sub-meters for operation.

8 Implementation Plan

Requirements will be implemented in a phased project. We note here the prioritization of requirements through the project phases.

8.1 Prototype

WP3 will advance existing technologies per-partes in order to reach common interface to connect with FOA. Therefore implementation of requirements for predictions, capture and utilization of energy reservoirs, observability of the loads and other demo-site specific requirements will be implemented within each prototype:

- F3.1, F3.2, F3.3 – DSM-ready FEMS
- F3.4, F3.5, F3.6 – DSM-ready HEMS
- F3.7, F3.8, F3.9 – DSM-ready CEMS
- F3.10 – DSM-ready CDEMS

Each system will strive towards common interface, that will be implemented on FOA. Prototypes of individual solutions will be available until M12.

8.2 Full Version

Full version of the system will implement the FOA client on each of the xEMS systems – F3.11. Each of the xEMS will be able to send and receive adaptation data to and from FOA. To allow for quick prototyping, we shall implement FOA API earlier, so that each xEMS can utilize that "dummy" API during implementation. FEMS will also implement Modbus translation interface for communication with FOA – F3.12.

Full version will also include all the adaptations that will be collected during site visits and discussions with prosumers and other stakeholders.

8.3 Final Version

xEMS systems aim to be as interoperable as possible. Therefore we do not aim for specific demo-case implementations, rather than provide the common platform, which system integrators on site can expand and integrate with other subsystems.

Final version of xEMS systems will include adaptations, that system integrators will recommend, based on their experience with newly created prototypes.

Technology providers should support system integrators in order for xEMS systems to capture and utilize as much of energy reservoirs as possible. If a system change request arises, that would significantly improve system usability across all three demo sites, technology providers will try to implement that functionalities.

xEMS systems by demo site:

Table 12: Number of xEMS installations

Demo site	FEMS	HEMS	CEMS	CDEMS
Cyprus	1	26	4	1
Switzerland	10	20	10	5
Germany	12	22	5	

8.4 Impact indicators

GOFLEX system will provide semi-automatic analysis of defined impact indicators. In order to capture, calculate and analyse a large number of prosumers, WP3 xEMS systems will provide functionalities for automated measuring of selected KPIs. To do so, we shall define:

- Metric and procedure
- Reference values for benchmarking

There are 3 impact indicators, that are linked to WP3.

8.4.1 Competitive demand response schemes for the benefit of the grid and the consumers

xEMS systems shall provide functionality, that will measure the prosumer involvement. Proposed metric is the following:

Augmented DR = FlexCons / AllCons

FlexCons = SUM[flexible consumption sent to FOA] for each month

AllCons = SUM[consumption for all controllable loads] for each month

Goal value: >= 15%

8.4.2 Emergence of new services provided by storage systems to the distribution grid and the consumers/prosumers at affordable costs, deferral of investments in grid reinforcement

For stable operation of complete GOFLEX virtual power system, it is crucial, we capture enough prosumers with sufficient energy reservoirs (virtual and explicit). Our goals are the following:

- Types of operational DR ready prosumer
  - >= 10 industrial prosumers
  - >= 50 residential prosumers
  - >= 15 charging stations
- Prosumers with implemented virtual energy storage in processes:
  - >= 15 prosumers
- Prosumers with implemented charging/discharging EV battery storage
  (with parked EV)
  - >= 5 prosumers

WP3 will be in charge of equipping those prosumers with systems that will enable utilization of both virtual and explicit energy reservoirs. Sufficient number of prosumers for each category satisfy this indicator, since their reservoirs directly correlate to capacity and reliability of GOFLEX system.

8.4.3 Creation of synergies with transport users (e.g. services to the grid with smart charging) / support the decarbonisation of transport

There are several goals to follow regarding the transport users:

- Flexibility range at average occupancy of charging spot (for CEMS)
    - Proposed metric: % of charging load variation (without violation of user needs) compared to baseline
    - Goal value: +10 / -30 %
    - CEMS shall calculate this value from the ratio between the adaptation capacity values (min, max) and baseline values. The capability of CEMS to effectuate the stated flexibility range will be verified through actual load that should comply with DemandSchedule, received from FOA
    - Value is evaluated on monthly basis
- Flexibility range for varying parking time (for CDEMS)
    - Proposed metric: % of charging load variation (without violation of user needs) compared to baseline
    - Goal value: 2 hours: ±10% 8 hours: ±25%
    - CDEMS shall calculate this value from DemandSchedule messages, received from FOA
    - Value is evaluated on monthly basis
- Charging timing reduction (battery buffer)¸and peak power need reduction (covering peaks from storage) (for CEMS/CDEMS)
    - Proposed metric: % of peak load reduction
    - Goal value: > 15%
    - Value represents the percentage of load, that was shifted from peak hours to non-peak hours
    - Value is evaluated on monthly basis

9 Conclusion

WP3 contains 4 different types of EMS systems by 3 different technology providers. It is vital that all systems communicate through same interface from certain level on. Therefore main focus of WP3 is the definition of standard interface, which serves all 4 types of systems and further down – all types of processes within prosumers.

Each xEMS must separately implement the functionalities needed for upper-level systems to work. The manipulation of processes is different for every type of process and each xEMS must support several. The interaction between demo sites and technology providers is vital for efficient implementation and integration of systems.

This document has at least two functions:

- Structure requirements for xEMS adaptations
- Provide insight into xEMS systems for better understanding and easier acquisition of prosumers on demo sites.

10 References

Gregor Černe and Co. (2012). Kibernet Cosnsumption adaptation message exchange beteeen control center and prosumer, INEA-DP-3/2012, INEA internal documentation, 120.